Physicochemical Characterization of Compost Mixtures Enriched with Agroindustrial Waste

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ABSTRACT

In order to counteract the abuse of agrochemicals, techniques agriculture has been implemented, including the use of organic fertilizers; such is the case of the use of compounds enriched with agroindustrial waste that allows generating an added value to these residues that contaminate the environment. The present research aimed to design and evaluate composites using agroindustrial residues. The experiment was developed with a duration of 60 days for which three treatments were designed, a control treatment (CC) a treatment with molasses (CM) and a treatment with whey milk (CMW); Each treatment was established with cow manure, lamb manure, mango peel, banana peel, leaf litter and peanut husk, however two of the treatments were enriched with 10 L of the corresponding agroindustrial waste. A physical-chemical characterization of the agroindustrial residues was performed, without forgetting the microbiological analysis according to the technique of plaque count of total coliforms. According to the evaluated treatments, the lowest loss of 1.6% of nitrogen (N) corresponding to the whey enriched beds (CMW) was reported, unlike the control treatment (CC) that reported large losses of this macronutrient, without. However, during the 60 days of evaluation, an increase in the levels of organic carbon and organic matter in mixes enriched with molasses (CM) was identified. In addition, this composite mixture was located in a thermophilic stage that allowed the elimination of pathogenic microorganisms with a concentration of 909 MPN/g of Escherichia coli, necessary to qualify the compost as a mixture of quality and useful in food crops.

Keywords: *Agroindustrial waste, Molasses, Milk whey, Compost.*

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1. INTRODUCTION

Conventional agriculture now plays an important role in the food demand of a growing human population, which has also led to a progressive chemical dependence on the supply of fertilizers and pesticides. Chemical fertilizers are substances composed of known amounts of nitrogen, phosphorus and potassium; these are industrially handled, and their exploitation causes pollution of the air and groundwater; to counteract such effects has been sought to produce organic fertilizers that regenerate the soil and are environmentally friendly [1]. The main function of biofertilizers is to maintain the soil rich in all kinds of micro and macro nutrients through the fixation of nitrogen, phosphate and potassium, solubilization and mineralization, favoring the growth of plants, regulatory substances, production of antibiotics and the biodegradation of organic matter in the soil [2].

Sáez, et al. [3] defined composting as a biological aerobic decomposition process of organic solid substrates, which are finally converted into a product called "fertilizer, biofertilizer or compost"; Said process is carried out by means of the microbial action. This technique is generally used as a means of treating organic waste including agro-industrial waste, agricultural waste and domestic waste. During composting, organic matter is subjected to partial mineralization and transformation into substances such as humus. So the final product can be used directly in agriculture as an organic fertilizer that will improve soil fertility, in addition to generating added value by using waste that pollutes the environment Arias, et al. [4]. Based on the aforementioned reasons the waste of the agroindustrial processes are an important element that can alter the environmental balance and jeopardize the quality of life of human beings if they are not treated or exploited efficiently [5]. For this purpose currently are produced two agroindustrial waste that generated environmental problems and detonates on the health of people these are : molasses from the sugar industry and the whey generated by the dairy industry, the waste resulting from a process of agroindustrial processing has high concentrations of biomolecules needed to enrich balanced a mixture such as water, carbohydrates, fats, proteins, vitamins and minerals, so it is thought that by enriching a mixture of compost with these residues are sufficient for the plants grow healthy and productive.

For this purpose the present research work had as objective to design and to evaluate the physicochemical characteristics of mixtures of compost from agroindustrial waste. The study consisted in monitoring through the physicochemical and microbiological analyzes the process of decomposition of mixtures of compost enriched with molasses and whey in order to evaluate their quality and obtain a solid compost biofertilizer.

2. MATERIALS AND METHODS

2.1. Establishment of the Experiments

The experiment was established in the Universidad Politécnica de Chiapas, located in the city of Tuxtla Gutiérrez, Chiapas, México. The geographic location is latitude 16° 45' 11" North and longitude 93° 06' 56", corresponding to tropical regions, with more than 1100 mm annual rainfall. The manure and the vegetable wastes were collected in the municipality of Ocozocoautla de Espinoza, Chiapas the geographic location is latitude 16 ° 45' north and longitude 93 ° 22'.

2.2. Experimental Design

The experimental lasted for a total of 60 days, after which three composts beds per treatments, was used. The different treatments were as follows (Table 1). The treatments are designed in the following way: 5.40 kg of cow manure (22.37%), 7.43 kg of lamb manure (30.79%), 1.80 kg of peanut shell (7, 45%), 1 kg of banana husk (4.14%), 1.30 kg of litter (5.38%) and 7.2 kg (29.83%) of peanut husk, enriched with agroindustrial wastes (molasses and milk whey), ten liters of agroindustrial waste per bed were added according to the treatment to be evaluated. Each treatment was evaluated with a total of three composts beds by triplicate (evaluating a total of nine composts beds per treatment) during 1st–60th day; as shown below:

Treatment 1: Basal composition. Compost control (CC), during 1st–60th day

Treatment 2: Basal composition. Compost + Molasses (CM), during 1st–60th day

Treatment 3: Basal composition. Compost + Milk whey (CMW), during 1st–60th day

While the residues were collected, 9 pits were dug, which represented the basis of the composting beds, the dimensions used were: 1 x 1 x 0.40 meters (length, width and depth respectively). Once the pits were ready, the organic material was collected and the beds were prepared. The beds were placed in the following order: in the first layer the peanut husk was placed, in the second layer the litter was deposited , For the third layer was added the manure of lamb, in the fourth layer was deposited cow manure and in the last layer were deposited the shells of banana and mango.

2.3. Physicochemical Characterization of Treatments

In preparation of samples for chemical analysis proximal, the moisture of the treatments was assessed by drying at 105 °C for 24 h and Carbon (C), Organic matter (OM) and Organic carbon (OC) were determined by a muffle furnace at 550 °C [6-8]. Total nitrogen (N) was analysed by Kjeldahl method [9, 10]. Thus the potential of hydrogen (pH) with the use of a potentiometer (HANNA HI 2211-01) was also determined. According to Konca, et al. [11] and NMX-FF-109-SCFI-2007.

2.4. Physicochemical Characterization of the Agroindustrial Waste

For characterization of agroindustrial wastes reducing sugars concentration it was determined from the reduction of the acid 3-5 dinitrosalicylic DNS (yellow) by reducing sugars, the acid 3- amino -5- salicylic nitro (brick red) detected at 540 nm using a spectrophotometer (ZUZI 4255/50), according to Chranioti, et al. [12]. Finally the total soluble solids (TSS) using a refractometer (RHC-200ATC) was determined according to the established by Chavan, et al. [13] and Skoog, et al. [14] (Table 2).

2.5. Microbiological Evaluation

At the end of the study, i.e. at the 60th day, a random sample was taken taking 20g of sample per bed of compost (totally 3 beds per treatment); the compost content was placed on agar plates for analysis. These samples were also used to determinate bacterial growth by the most probable number (MPN) method. Collection tubes were weighted, wrapped in aluminum sheet and autoclaved for 10 min. The culture mediums were prepared and 24 h before collection samples were poured into petri dishes, Eosin methylene blue (EMB,1.01347.0500) was used to culture Escherichia coli, according to Espina, et al. [15] and Gronewold and Wolpert [16].

2.6. Statistical Analysis

The study was conducted based on a completely randomized design (CRD) with four treatments and ten replicates per treatment. Data were analyzed by InfoStat statistical program using the generalized linear model (GLM) procedure. The statistical comparison was made by Tukey test at the 95% probability level.

3. RESULTS

3.1. Establishment of the Experiments

Table 1 presents the basic materials used in the preparation of compost mixtures, as well as the percentage fraction corresponding to each material.

Table-1. Materials composing the compost mixtures and their physicochemical characterization evaluated for 60 days

Components of the mixtures	Weight (Kg)	Percentage fraction (%)	Moisture (%)	Ash (%)	OC (%)	OM (%)	N (%)	C/N
Cow manure	5.4	22.37	15.7± 0.11	26.4± 0.11	42.6± 0.04	73.6± 0.11	0.07± 0.01	73.5± 0.08
Sheep manure	7.4	30.79	94.4± 0.01*	5.5± 0.01	54.8± 0.01	94.5± 0.12	13.1± 0.11	2.4± 0.05
Peanut shell	7.2	29.83	6.6± 0.21	6.7± 0.12	54.1± 0.12	93.3± 0.07	0	0
Litter	1.3	5.38	82.6± 0.13	17.3± 0.08	47.9± 0.13	82.7± 0.09	0.1± 0.12	59.1± 0.04
Banana peel	1.0	4.14	72.1± 0.11	64.5± 0.06	20.5± 0.12	35.5± 0.08	0.7± 0.08	29.3± 0.02
Mango shell	1.8	7.45	85.4± 0.12	74.4± 0.04	14.8± 0.11	25.6± 0.07	0.5± 0.08	26.4± 0.03

OC= Organic carbon; OM= Organic material; N= nitrogen; C/N= Nitrogen carbon ratio

* Means (±standard error) within each column of dietary treatments with no common superscript differ significantly at P <0.05.

Once the compost mixtures were established, temperatures were recorded for 60 days in order to identify the decomposition stages of the compost. Figure 2 shows the variation of the temperature with respect to the time of each of the evaluated mixtures. For the control mixture the temperatures were always in the range of 23 to 35 ° C and the mixture enriched with whey shows temperatures From 20 ° C to 40 ° C although this compost presented higher temperatures both are located in the mesophyll phase and even did not reach the ideal temperature of this phase, this could be caused by many factors such as the depth of the beds of (Very hot days up to 37 °C, days with heavy rain up to 23 ° C and very cold days with temperatures up to 17 °C). However, the mixture enriched with molasses reached temperatures of up to 57 °C whereby it was positioned in the thermophilic stage.

3.2. Physicochemical Characterization of the Agroindustrial Waste

Before the composting process was carried out, the physical chemical characterization of the agroindustrial waste was carried out. In the molasses, pH, reducing sugars and proteins were evaluated, obtaining 4.8, 0.5 mg / mL and 0.06%, respectively. Thus, whey was also evaluated by determining pH, reducing sugars and proteins, obtaining 4.6, 0.3 mg / mL and 32% respectively (Table 2).

Table-2. Physicochemical characterization of agro-industrial waste

Agro-industrial waste	pH	Acidity (mL of lactic acid equivalent)	Protein (%)	Reducing sugars (mg/mL)
Molasses	$4.8^a \pm 0.10$	$2.7^a \pm 0.02$*	$0.06^a \pm 0.11$	$0.5^a \pm 0.07$
Milk whey	$4.6^a \pm 0.12$	$2.3^a \pm 0.04$	$32.1^b \pm 0.13$	$2.4^b \pm 0.13$

* Means (±standard error) within each column of dietary treatments with no common superscript differ significantly at P <0.05.

3.3. Physicochemical Characterization of Treatments

Before the composting process was carried out, the different mixtures were evaluated through a physical chemical characterization of each of the constituent materials. The tests were moisture, ash, organic carbon (CO), organic matter (MO), nitrogen (N) and carbon nitrogen (C/N) ratio. On average, the materials had 59.5% of humidity, 32.4% of ash, 39.1% of CO, 67.5% of MO, 2.4% of N and a nitrogen carbon ratio of 31.7%, as shown in Table 3.

Table-3. Physicochemical evaluation of the different compost mixtures in a period of 60 days of evaluation

Days	Treatments	Moisture (%)	Ash (%)	OC (%)	OM (%)	N (%)	C/N (%)
15	**CC**	$65^{a} \pm 0.01$	$13.7^{a} \pm 0.08$	$50.1^{a} \pm 0.09$	$86.2^{a} \pm 0.07$	$28^{a} \pm 0.12$	$17.3^{a} \pm 0.13$
	CM	$75.3^{a} \pm 0.02$*	$31.7^{a} \pm 0.06$	$39.6^{a} \pm 0.08$	$68.2^{a} \pm 0.13$	$0.7^{a} \pm 0.11$	$53.7^{a} \pm 0.11$
	CMW	$80^{a} \pm 0.00$	$8.7^{a} \pm 0.09$	$31.8^{a} \pm 0.12$	$87.2^{a} \pm 0.23$	$17.7^{a} \pm 0.21$	$11.2^{a} \pm 0.12$
45	**C**	$7.6^{b} \pm 0.04$	$8.2^{b} \pm 0.07$	$29.9^{b} \pm 0.13$	$51.6^{b} \pm 0.02$	$0.02^{b} \pm 0.01$	$33.8^{b} \pm 0.13$
	CM	$11.8^{b} \pm 0.07$	$16.1^{b} \pm 0.02$	$48.6^{b} \pm 0.01$	$83.8^{b} \pm 0.11$	$0.68^{b} \pm 0.08$	$43.8^{b} \pm 0.014$
	CMW	$18.3^{b} \pm 0.01$	$8.5^{a} \pm 0.02$	$49.9^{b} \pm 0.04$	$85.5^{a} \pm 0.12$	$17.4^{a} \pm 0.12$	$10.8^{a} \pm 0.012$
60	**C**	$7.1^{b} \pm 0.04$	$8.0^{b} \pm 0.07$	$29.6^{b} \pm 0.13$	$51.5^{b} \pm 0.02$	$0.02^{b} \pm 0.01$	$33.2^{b} \pm 0.13$
	CM	$10.8^{b} \pm 0.07$	$15.5^{b} \pm 0.02$	$48.4^{b} \pm 0.01$	$83.6^{b} \pm 0.11$	$0.68^{b} \pm 0.08$	$43.1^{b} \pm 0.014$
	CMW	$17.9^{b} \pm 0.01$	$8.0^{a} \pm 0.02$	$49.0^{b} \pm 0.04$	$84.9^{a} \pm 0.12$	$17.0^{a} \pm 0.12$	$10.3^{a} \pm 0.012$
C		88.3	40.1	40.6	40.1	99.9	95.3
CM		84.3	49.2	22.7	22.8	2.8	18.4
CMW		77.1	2.2	56.9	1.9	1.6	3.5

* Means (±standard error) within each column of dietary treatments with no common superscript differ significantly at P <0.05; ( ) Percentage decrease; ( ) Percentage increase.
C: Compost Control; CM: Compost + Molasses; CMW: Compost + Milk whey; OC= Organic carbon; OM= Organic matter; N= nitrogen; C/N= Nitrogen carbon ratio

Thus, during the 60 days of evaluation, pH, CO, MO, N and carbon nitrogen ratio were evaluated every 15 days to determine how different stages of degradation affect the concentration of the compounds. So that the 45 and 60 days a significant loss of nitrogen was observed in 99.9% for the control mixture, 2% for the mixture enriched with molasses and a loss of 1% in the mixture enriched with whey, but an increase of MO and CO in 22.7 and 22.8% respectively in the mixture enriched with molasses and only a 56.9% increase in CO in the mixture enriched with milk of whey, as can be seen in Table 3.

3.4. Microbiological Evaluation

To evaluate the microbiological quality of composite beds, total coliforms were determined in NMP/g units (Table 4).

Table-4. Evaluation of the concentration of *Escherichia coli* through the most probable number method (MPN)

Treatments	MPN/g
CC	$1400^{a} \pm 0.19$
CM	$909^{b} \pm 0.11$*
CMW	$1314^{a} \pm 002$

* Means (±standard error) within the column of dietary treatments with no common superscript differ significantly at P <0.05.
CC= Compost Control; CM= Compost + Molasses; CMW= Compost + Milk Whey

By applying NOM-004-SEMARNAT-2002 which describes the specifications and maximum permissible limits of contaminants for the use and disposal of sludge and biosolids, the control mixture and the mixture enriched with whey present elevated levels of total coliforms not permissible by the NOM-004-SEMARNAT-2002, the mixture enriched of molasses with 909 NMP/g which, according to the standard, affects the class B considered as "Good quality", related to the maximum temperature reached by this mixture (57 °C) eliminating pathogenic microorganisms and thus improving the quality of compost.

4. DISCUSSION

4.1. Establishment of the Experiments

The temperature behavior (Figure 1) shows that in all treatments the cooling and maturation stage was not present, therefore the final product, obtained in a period of 60 days for the control mixture and the mixture enriched with whey remained in the mesophilic phase, this may be due to the excess moisture present in the mixtures during the degradation process, this prevents the release of CO_2 resulting from the degradation of organic carbon, because in parallel need to remove water by evaporation, as well also these high concentrations of water allow the release of NH_3 to the environment, generating mixtures poor in nitrogen [17]. In the same way Vázquez, et al. [18] mentions that the quality of compost depends of the hydric balance of the composting process.

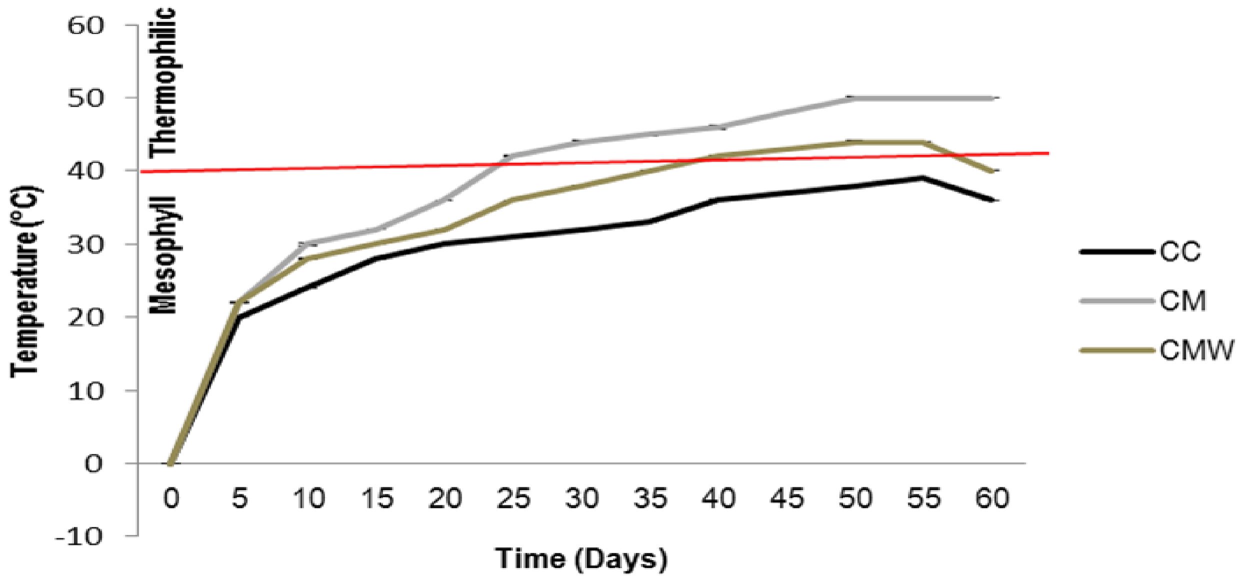

Fig-1. Temperature monitoring during 60 days for the evaluation of the decomposition processes of the different mixtures analyzed. Means (±standard error) within each column of dietary treatments with no common superscript differ significantly at P <0.05. C: Compost Control; CM: Compost + Molasses; CMW: Compost + Milk Whey.

On the other hand, the mixture enriched with molasses reached temperatures of up to 57 °C whereby it was positioned in the thermophilic stage benefiting the degradation of pathogenic bacteria such as *Eschericha coli* and *Salmonella* spp, Sürücü [19]. The hight temperature reached in the mixture enriched with molasses had to be due to the high concentration of carbohydrates and to the correct equilibrium of the humidity present in the mixture, which caused the microorganisms to fully develop and could decompose organic matter such as Chatellard, et al. [20] defines moisture and energy requirements as key parameters for the degradation of organic matter due to the activation of degrading microorganisms.

4.2. Physicochemical Characterization of Treatments

Table 3 shows the significant loss of nitrogen and the increase of M.O during the 45 and 60 days of composting, according with the last, De la Cruz-Barrón, et al. [21] and Paetsch, et al. [22] establishes that an increase of MO incorporated to the soil benefits in terms of bioremediation, improvement in the structure and consistency of the same, in order to reach better levels of absorption by the roots that will be developed in soils with high MO characteristics. Although the different compounds that the plant uses as oxygen (O), carbon (C), hydrogen (H) and macro elements such as nitrogen (N), phosphorus (P) and potassium (K) play a very important role For the development of the plant, therefore a deficiency in nitrogen would impair the nutritional status of the plant as demonstrated by Yang, et al. [23]. So the mixtures developed in the present experiment using agroindustrial waste incorporate nitrogen to the compost mixtures, since in the control mixture a nitrogen loss of 99.9% was observed.

4.3. Microbiological Evaluation

Microbiological analyzes are an important aspect to determine the sanitary quality of compost. Taking as reference the NOM-004-SEMARNAT-2002, which marks as limit <1000 MPN/g for total coliforms in a compost, comparing the result obtained by the mixture enriched with molasses (909 MPN/g) is classified as Of good quality since it is below the limits established by the aforementioned norm, thus, too, Storino, et al. [24] showed that the quality of a compost is evaluated through its microbiological load, especially *E. coli*, guaranteeing a phytosanitary quality with a concentration lower than 1000MPN/g, emphasizing that the decrease of the microbiological load is closely related to the temperature that can reach the compost.

It is important to emphasize that the control compost and the mixture enriched with whey according to NOM-004-SEMARNAT-2002 cannot be used directly to food crops, however it is recommended to take this compost indirectly for forest use or for the improvement of soils due to its high content of organic matter.

5. CONCLUSION

Mixtures of composites of 24.13 kg formed by manure, peanut shell and agroindustrial waste were designed and established.

In the physicochemical evaluation of the mixtures designed enriched by agroindustrial waste a loss of nitrogen of up to 2% and an increase of C.O. Of up to 56% and of M.O an increase of up to 22% over the course of 60 days.

According to the microbiological analysis of compost enriched with molasses it proved to be of good quality which can be used as a biofertilizer in any food crop, since it is below the limits established by NOM-004-SEMARNAT-2002, which does not represents a risk to human health.

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