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Valorization of cow manures and poultry manure in composting: Comparative studies

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Abstract

A successful use of compost for agronomic value and improvement of physical properties and fertility of soil requires monitoring of compost quality. For this purpose, two types of composts were prepared from cow manures and poultry manures and were analyzed for their physic-chemical characteristics. Reference analyses include the determination of pH, electrical conductivity, temperature, total organic carbon (TOC), total nitrogen (TN), ammonium (NH_4^+), nitrates (NO_3^-), available phosphorus (P_2O_5). The preliminary results of compost analyses have shown a good evolution of the temperature during the process of composting, an alkali pH, a reduction of the TOC and the C/N ratio. Also the NH_4^+composition was less than NO_3^- with NH_4^+/NO_3^- ratio <1 in the final products. It can be concluded that the final products showed acceptable maturity levels and can be used for agricultural applications.

1. Introduction

Livestock and poultry manure represent a good deposit of fermentable biomass in Morocco, with more than 87 million tons per year can be recovered [1]. These biodegradable wastes have to be managed under appropriate disposal practices to avoid a negative impact on the environment (odor and gas emissions, soil and water pollution…) [2, 3].

Composting is a biochemical process converting various components in organic waste into relatively stable humus-like substances called compost that can be used as a soil amendment or organic fertilizer [4]. The main requirement of compost to be safely used in soil is a high degree of maturity, which implies a stable organic matter content and the absence of phytotoxic compounds and plant or animal pathogens [2, 5]. Indeed, immature composts can pose problems during storage, marketing and use. The material may become anaerobic, odorous, and develop toxic compounds. Active decomposition of the material after application to soil can be harmful to plant growth by reducing root-available oxygen, plant-available nitrogen, or through release of phytotoxic compounds into the root zone [6]

The objective of the present study is to characterize the composting process of cow manure and poultry manure, each mixed with wheat straw using physico-chemical parameters to determine the changes in the mixtures during the process and to assess the quality of the final products, in order to guarantee its successful use in agriculture.

2. Material and Methods

2.1. Feedstock composition and composting process

Cattle manure and poultry manure were collected from cattle farm and poultry farm located in Settat, Morocco. Since Wheat straw has a high carbon content, it was used as bulking agent in order to adjust the C/N ratio and to help maintain moisture and ensure more airy structure of the pile which promotes the action of aerobic microorganisms. The mixture was prepared so as to have the optimal parameters for good composting namely 60% humidity and a C/N ratio of around 30. Selected physico-chemical characteristics of the raw materials are listed in Table1.

Table 1: Physico-chemical characteristics of the raw materials

Parameters	Cattle manure	Poultry manure	Wheat Straw
TOC* (%)	8,37	35,1	38,5
TN* (%)	1,05	3,61	0,28
C/N*	7,97	9,72	137,2

* Results expressed in % of dry matter; TN: total nitrogen; TOC: total organic carbon; C/N=TOC/TN

The dimensions of the windrow studied were 1.5 m high, 2m wide and 3m long. Each pile was deposited by alternating raw materials in successive layers from bottom to top. In order to maintain aerobic conditions during the composting process and to keep cool environment if the temperature is too high, the pile was turned manually and was watering every 15 days during a period of four months from March to June. This experimental work was conducted in a farm at 4km from the city of Settat. Samples of each compost were collected from different levels of the pile (middle, surface, core of the heap, sides) and were mixed and homogenized at different stages of the process from raw mixture, after 30, 45, 60, 90 and 105 days. A sample for analyze was sieved through 2mm.

2.2. Physico-chemical analysis

The samples were measured to analyze pH, electrical conductivity (EC), total organic carbon (TOC), total nitrogen (TN), Ammonium (NH_4^+), Nitrates (NO_3^-) and Available phosphorus (P_2O_5).

Temperature was recorded daily in several locations at a depth of 50cm of composting pile. pH and electrical conductivity (EC) were measured in a sample-water suspension 1:10 (w / v). TOC was determined by oxidation to potassium dichromate using the Walkley and Black method [7]. TN was measured according to Kjeldahl method [8]. NH_4^+ was extracted with KCl (1M) and then was dosed by colorimetry with indophenol blue and NO_3^- was determined spectrophotometrically by chromotropic acid [9, 10]. $P_2O_5$was determined by the Olsen method [11]. All samples were analyzed in triplicate.

3. Results and discussion

3.1. Temperature evolution

During the initial stage of composting, the temperature of both mixtures increased rapidly over time to a maximum of 65°C for MB at day 6 and 61°C for MV at day 7 (Figure 1A). The temperature persisted at more than 55°C for 8 and 7 days for MB and MV respectively. These temperatures corresponded to a recommended value for the suppression of pathogenic microorganisms [2]. This phase represent the bio-oxidative phase that result from self-heating of organic matter due to the microbial respiration [12]. Therefore these conditions indicate that there's an adequate supply of carbon source [13].

The temperature of the two mixtures decreased gradually to reach the ambient temperature of 25°C at the end of composting that can indicate the maturation phase (Figure 1A).

3.2. Evolution of pH

The average pH value at the start of composting was 6.4 for MB and 6.98 for MV (Figure 1B). The slight acidity is typically due to anaerobic conditions established before the start of composting process and resulting from the formation of organic acids [12]. The pH increased thereafter to 8.11 and 8.64 for MB and MV respectively.

Several studies found a similar increasing in pH values, during composting of fruit and vegetable wastes from 7.3 to 8.6 [14], and from 6.8 to 7.8 [15] of sewage sludge mixed with green waste.

The rising of pH value during composting is a result of organic acids degradation [16], and of the mineralization of proteins, amino acids and peptides that induce the release of ammonium or volatile ammonia [12].

3.3. Evolution of electrical conductivity

Electrical conductivity reflects the degree of salinity in the composting product indicating its possible phytotoxic/phyto-inhibitory effects on the growth of plants, if applied to the soil. During the composting process, results showed a decrease from the initial conductivity of 5 to 3mmohs/cm in (MB), in the same way, it dropped from 7 to 2.75mmohs/cm in (MV) (Figure 1C). Similar decreases have been reported and were related to the volatilization of ammonia and the precipitation of mineral salts [13; 17]. EC did not exceed the limit value of 3mS/cm recommended by V.L.A.C.O [18], which indicated that EC would not adversely affect the plant growth.

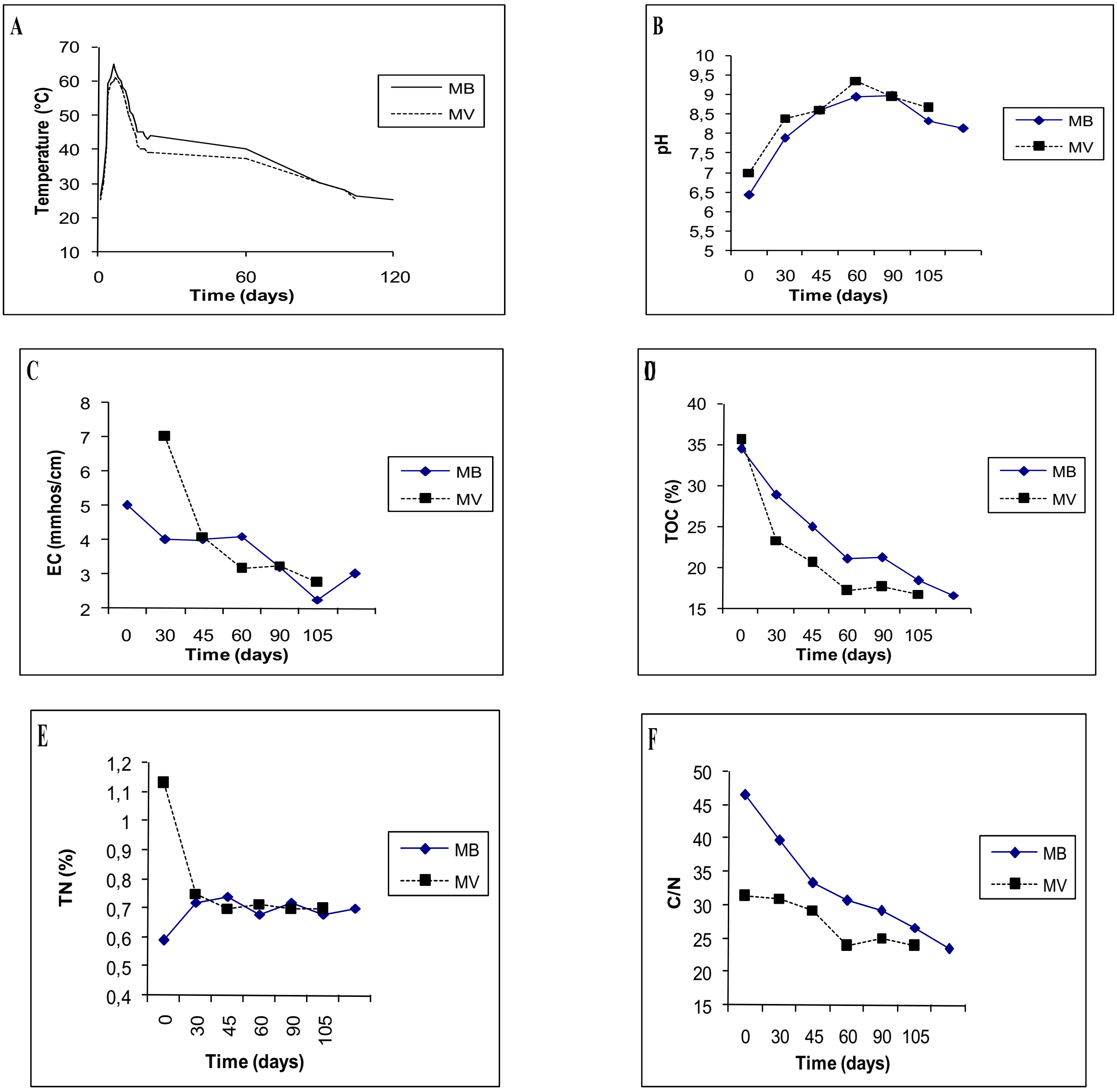

Figure 1: Evolution of temperature (1A), pH (1B), electrical conductivity (1C), total organique carbone (1D), total nitrogen (1E) and C/N ratio (1F) of the two mixtures MB and MV.

3.4. Evolution of carbon and nitrogen ratio

The average percentages of total organic carbon (TOC), measured from the two mixtures, has the same tendency to decrease during composting from 34.38 to 16.56% of dry matter for MB and from 35.48 to 16.67% of dry matter for MV, at the end of the process, after 120 days (Figure 1D).These trends were not linear and presented two distinct periods; The first one was between 0 to 60 days where the carbon decreased rapidly and the second phase was between 60 and 120 days, showing stabilization of carbon. Carbon reductions during composting has often been reported in other studies and it was assimilated to the mineralization of organic matter by microorganisms, that induce a weight lose of the pile and a decrease in the C/N ratio [2, 19].

Total nitrogen shows an increase between 0 and 30 days with 0.59 and 0.72% of dry matter for cattle manure (Figure 1E). This effect is due to a concentration caused by the strong degradation of carbon compounds which reduced the weight of composting mass [2, 20]. Poultry Manure showed a decrease in TN from 1.13 to 0.69% of the dry matter. This fall was explained by Bernal and al. [2] as a consequence of the high initial ammonium concentration and the presence of easily mineralisable compounds, such as uric acid in poultry manure and slurry, in addition, leaching and volatilization of ammonia (NH3) can lead to nitrogen loss through composting.
The C/N ratio shows that both mixtures follow a similar drop. At the end of the composting, C/N ratios were 23.45 and 23.88 for MB and MV respectively (Figure 1F). Similarly to several studies [21; 16], the decrease of C/N is related to the degree of maturity. Huang and al. [22] reported that C/N changes reflect the decomposition and stabilization of organic matter. Moreover, the C/N has the same tendency as the TOC with two distinct phases. The first 60 days are characterized by a progressive decrease in the C/N ratio from 46.5 to 30.65 for MB and from 31.4 to 23.92 for MV, reflecting a sustained decomposition of organic matter. The process is later distinguished by a stabilization phase, reflecting a slowdown in mineralization and indicating the beginning of the maturation phase.
The C/N values found in our results are higher than those found by Kalamdhad and Kazmi [13] where the C/N ratio was12 for the cattle manure and 11 for the poultry manure. However, Baffi and al. [23] reported that the C/N ratio of mixtures of organic matter, municipal solid waste, lingocellulosic waste and newspaper fluctuated between 24 and 32. For Mathur and al. [24], a value of 20 is commonly accepted for this ratio, but various studies have concluded that it is underestimated. The California Compost Quality Council (CCQC) [6] considers compost with C/N>25 is immature. It requires performing other stability tests (CO_2 evolution rate, self-heating test ...) and other maturity tests (NH_4^+, NH_4^+/NO_3^-, germination index...) to confirm the maturity of the compost. According to Chang et al. [25], since the nature of the inputs strongly influences the C/N ratio, this parameter alone can not be considered as an index of absolute maturity.

3.5. Evolution of ammonium and nitrate
Average levels of NH_4^+ decrease severely during composting, from 2.58 to 1.17 mg/g of dry matter for MB, and from 3.95 to 0.71 mg/g of dry matter for MV (Figure 2A). However, NO_3^- ions progress over time from composting from an average of 0.26 to 1.38 mg/g of dry matter for MB, and from 0.38 to 1.84 mg/g of dry matter for MV (Figure 2B). NH_4^+ contents correlate negatively with those of NO_3^- (r = -0.81), this phenomenon can be explained by the presence of favorable conditions for the development of microorganisms responsible for nitrification when temperature is below 40 °C and aeration is adequate [2; 26].
NH_4^+ and NO_3^- contents of MV are higher than those of MB, this can be explained by the nature of poultry manure which is known to be very rich of nitrogen [15, 27].
The respective values of NH_4^+/NO_3^- ratio related to MV and MB of the final products, being 0.85 and 0.39 lower than 1. According to Garcia and al. [28], this value is indicating the maturity of the final compost. Furthermore CCQC [6] gives a range between 0.5 and 3 to qualify a maturity of compost. However they also recommended a concentration of NH_4^+ between 0.075 and 0.5 mg/g. These concentrations are below the amounts found in our study (Figure 2A). As a matter of fact, numerous studies revealed a large heterogeneity of standards for compost quality [2, 29].

3.5. Evolution of available phosphorus
The evolution of the P_2O_5 mean content of MB during the composting process shows a slight decrease from 2.87 to 2.43 mg/g of dry matter, while that of MV reveals a net increase from 1.71 to 4.21 mg/g of the dry matter and decline to 2.52 mg/g of the dry matter at the end of the process (Figure 2C). This variation may be due to the mineralization of the organic material thus releasing P_2O_5 [30]. Also, P_2O_5 of these composts can increase phosphore availability on soil supply rate and crop's needs. Indeed, Quaye and al. [31] found a significant effect of biosolid compost amendments on soil P supply rate and on foliar nutrient concentrations.

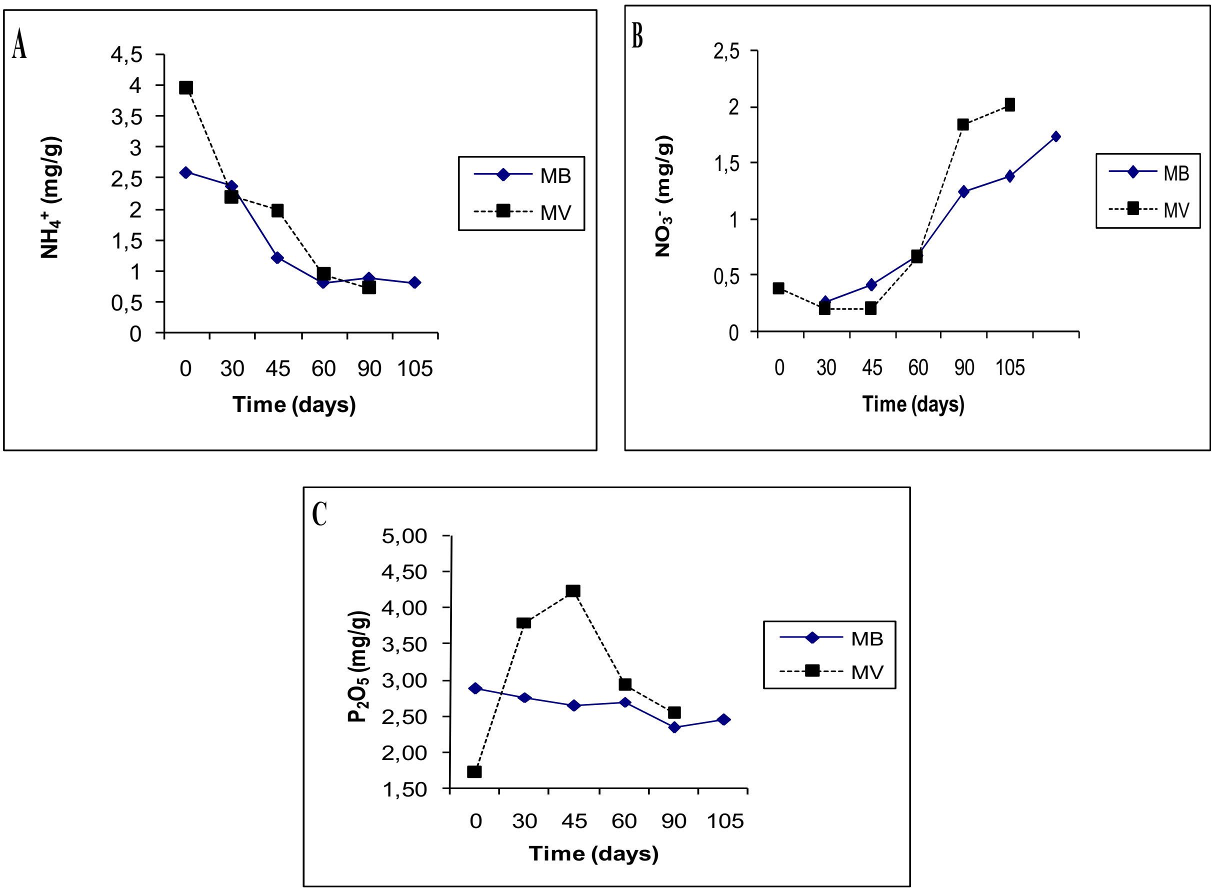

Figure 2: Evolution of ammonium (2A), nitrate (2B) and available phosphorus (2C) of the two mixtures MB and MV.

Conclusion

The mixture's evolution of cattle manure-straw and poultry manure-straw during composting and after 120 days, leads to significant changes in their composition. Indeed, two classical phases of composting have been identified; biodegradation phase and maturation phase which result from the microbiological activity of composting and therefore from the high mineralization of organic matter.

The composition difference of the inputs of the two mixtures MV and MB has an influence on the composting conduct and on the contents of the characterized elements.

Also, the NH_4^+/NO_3^- and C/N maturity indices have been shown to be conform with CCQC recommendations [6] and Garcia and al. [27]. As well, composts provided available nutrients (NO_3^-, P_2O_5) that can supply soil fertility.

Therefore, composting of cattle and poultry manure mixed with wheat straw is an effective method for managing wastes and producing acceptable end-products to use in agriculture with respect of optimum conditions that involve adequate initial substrate, humidity, aeration supply and also temperature monitoring. While, it can be concluded that a single parameter is not sufficient to evaluate the compost quality.

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