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# Evaluation of the Compost's Maturity of Different Mixtures of Olive Pomace and Poultry Manure

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## ABSTRACT

The environmental menace presented by olive pomace, a solid residue generated in the course of olive oil production, has been firmly established. Numerous investigations have underscored the efficacy of olive pomace as a soil enhancement. As a result, our examination centres on amplifying its agricultural advantages by means of composting and amalgamating it with other refuse materials. This strategy is designed to alleviate the environmental repercussions of olive pomace and trim down restoration expenses, thereby contributing to the transition toward a circular economy. Combinations for composting, comprising 15% to 50% olive pomace serving as a carbon input and 50% to 85% poultry manure as a nitrogen source, successfully underwent a 120-day composting procedure in barrels. The aim is to juxtapose the physic-chemical and microbiological traits of the composted olive pomace (Gr) and poultry manure (F), along with their amalgamations. This scrutiny endeavours to ascertain which treatment proves more efficacious as a plant fertilizer and soil amendment. The investigation also assesses the feasibility of reusing these two waste substances and gauges the maturity of the resultant compost. Throughout the composting progression, diverse microbiological and physic-chemical parameters like temperature, pH, electrical conductivity (EC), moisture levels, organic matter, and the evolution of the C/N ratio were systematically observed. The initial stages of the treatment disclosed heightened microbial activity in the blends, accompanied by a subsequent reduction in pathogen content towards the culmination of the composting course. The inquiry deduces that employing composts derived from olive pomace and poultry manure as sustainable substitutes for chemical fertilizers exemplifies the viability and potential for ecologically sound agricultural practices.

**Keywords:** composting, olive pomace, poultry manure, physicochemical and microbiological parameters.

## INTRODUCTION

The generation of waste aligns with societal trends, and in Morocco, the production of organic waste, including poultry droppings, has been on a consistent rise. Morocco holds a prominent position as one of the leading chicken-producing countries, with poultry farming being one of the fastest-growing industrial activities. In 2013, Morocco ranked first in northern Africa for broiler breeding, producing 195 million heads, constituting 43.1% of livestock in the Maghrebian region. This surge is attributed to the popularity of chicken, which accounts for 52% of all meat consumed by Moroccans in 2014 [Elasri & Afilal Elamin, 2014]. The national poultry sector has experienced significant growth, with poultry meat production escalating from 510,000 tons in 2010 to 649,000 tons in 2013, effectively meeting 100% of the demand for poultry meat in the Moroccan market [Ministry of Agriculture, 2012]. This robust expansion has led to the substantial production of organic residual waste, specifically more than 519,000 tons of broiler droppings annually.

Astonishingly, over 95% of this waste is directly utilized as fertilizer for agriculture without any pretreatment [Elasri & Afilal Elamin, 2014]. Recent statistics indicate a further increase in poultry droppings production, reaching 8 million tons from 2014 to 2022, underscoring the heightened demand for this consumable meat [Agriculture, Maritime Fisheries, Rural Development, Waters, and Forests Ministry, 2022]. However, the disposal of these organic wastes poses environmental concerns, as they have the potential to contaminate the environment. This contamination may manifest through the production of greenhouse gases and organic pollution in soil and water resources [Elasri & Afilal Elamin, 2014].

The extensive application of chemical fertilizers has harmful consequences on soil quality, leading to the exhaustion of organic matter, a diminished capacity for soil water retention, reduced structural stability, and elevated acidity and alkalinity [Roldan et al., 2005]. Additionally, intensive agricultural practices and erosion contribute further to a decrease in soil organic matter, resulting in reduced fertility. To tackle this soil degradation, a shift towards organic farming has been observed, with an emphasis on utilizing organic matter for soil fertilization. Organic matter serves as a reservoir for nutrients and plays a pivotal role in improving soil physical fertility, aeration, and resilience against degradation and erosion [Girard et al., 2005]. The incorporation of compost in agriculture presents a potential remedy for mitigating soil degradation. Composts are acknowledged for their capacity to preserve organic matter in soils, consequently enhancing physical, chemical, and biological properties, while supplying essential nutrients to crops [Leclerc, 2001]. To address these issues, composting emerges as a logical alternative with the added benefits of waste volume reduction, elimination of pathogenic microorganisms, and the production of an agricultural amendment [Lakhtib et al., 2014]. Composting involves a process of decomposition and synthesis, resulting in a material rich in humic acids, mineral salts, carbohydrates, proteins, and microorganisms. For agricultural applicability, the compost must reach a mature state, exhibiting low microbial activity and stability, as determined by various physicochemical parameters established in numerous studies [Zhang et al., 2013]. Concerning composting technologies, poultry manure presents challenges such as a low C/N ratio leading to substantial ammonia losses and high moisture content [Quiroga et al., 2010]. Moisture levels exceeding 75% hinder a rapid initiation of the composting process [Kelleher et al., 2002]. To produce compost from poultry manure, it is essential to blend this waste with other organic materials to achieve an optimal C/N ratio and moisture content. Consequently, several studies have explored the composting process of poultry manure in combination with other wastes, such as dry barley waste from malt preparation along with chestnut burr/leaf litter [Guerra-Rodríguez et al., 2006], or by-products from the olive oil industry [Walker & Bernal, 2008].

On the other hand, Morocco stands out as one of the leading olive producers, with an annual harvest of 1,414,000 tons. From 2015 to 2019, the country's olive oil output averaged 142,000 tons per year, yielding byproducts in the form of olive husk and olive mill wastewater, sometimes referred to as black water [Agriculture, Maritime Fisheries, Rural Development, Waters, and Forests Ministry, 2022]. These byproducts pose substantial environmental issues, including dangers to aquatic life, disagreeable smells, the formation of impermeable coatings that prevent oxygen transmission, colouring of natural waterways, and toxicity [Yay et al., 2012; El Kafz et al., 2023]. As a consequence of its significant level of organic matter, acidic pH, mineral salts, and presence of phytotoxic compounds, using pomace as an organic supplement in agriculture inhibits plant development [Del Buono et al., 2011]. Composting is a favoured strategy for stabilizing pomace's organic content and maximizing its fertilization potential (Gómez-Muñoz et al., 2012). Nonetheless, Ameziane et al. (2019) found that using raw pomace as a soil additive had no detrimental influence on fertility indices. Another comparable study shows that valorising olive pomace by composting enhances both chemical and physical soil qualities, giving vital nutrients for plant development such as nitrogen, potassium, and phosphorus [Del Buono et al., 2011].

The primary focus of this current study is the development of new composts through various mixtures involving olive pomace as the carbon source and poultry manure. The aim is to mitigate the environmental impact of both poultry waste and olive pomace, reduce waste processing costs, and enhance agricultural productivity by providing an effective fertilizer. Simultaneously, the research seeks to increase the yield of olive pomace compost as a bio-fertilizer.

## MATERIALS & METHODS

### Procedure for sample collection

The pomace used in this investigation is the same as that used by Doughmi et al. (2022), and it was collected in a crusher unit in Tiflet city, Morocco, using a three-phase extraction technology. This city, positioned in the Khemisset province within the Rabat Salé Kénitra region, is geographically situated at 33°53′40″ North latitude, 6°18′23″ West longitude, and an altitude of 340 meters above sea level. Poultry manure, encompassing all substances expelled through the digestive and urinary tract via the poultry cloaca, was procured from a poultry farm in the same city of Tiflet.

### Composting experiment

The composting experiment entails combining olive pomace with another structural agent, specifically poultry manure, in 30-liter perforated barrels [Doughmi et al., 2022]. These barrels are strategically positioned in a sunlit area to ensure optimal conditions for the composting process [Manu et al., 2016]. Mechanical aeration is used at critical phases such as the mesophilic stage commencement, the thermophilic period conclusion, and the cooling stage start [Doughmi et al., 2022]. The piles are regularly turned to facilitate aeration and encourage aerobic fermentation, with constant monitoring and adjustment of humidity levels throughout the process [Doughmi et al., 2022]. The approach relies on mechanical turning and forced aeration, aimed at expediting the composting process [Doughmi et al., 2022]. Choosing a thoroughly mixed and homogenized sample, subsequently placed in barrels, enables the determination of optimal concentrations of fertilizing elements [Manu et al., 2017]. These identified concentrations can then be extrapolated for application in larger quantities. As a result, laboratory-scale results may be extended to full-scale installations by altering forced aeration to match available equipment. Four combinations (GF1, GF2, GF3, and GF4) were made from the two basic materials, pomace (Gr) and chicken manure (F), with percentages ranging from 15% to 50% pomace and 85% to 50% poultry manure. After around 120 days of incubation, the composts were stable and mature (Table 1).

**Table 1.** Percentages of the different mixtures

| Mixtures | Percentages |
|---|---|
| F | 100% poultry manure |
| Gr | 100% olive pomace |
| GF1 | 15% olive pomace + 85% poultry manure |
| GF2 | 25% olive pomace + 75% poultry manure |
| GF3 | 43% olive pomace + 57% poultry manure |
| GF4 | 50% olive pomace + 50% poultry manure |

### Physicochemical characterization

To evaluate the mixes' physicochemical characteristics, taking into account both the initial components and the composts, representative samples underwent a drying process in an oven at temperatures ranging between 40°C and 60°C. Subsequently, to evaluate pH and electrical conductivity (EC) determination, the samples were ground, sieved to 2 mm, and further refined to 0.2 mm to analyse other mineral elements [Doughmi et al., 2022]. A pH meter (Orion Star A111) was used to assess the pH, and a conductivity meter (Orion Star A212) to evaluate the EC. Aqueous extracts were used for pH and EC measurements, using a pH ratio of 2:5 (w/v) [Rodier et al., 2009] and an EC ratio of 1:5 (w/v) [ISO 11265, 1994]. Moisture content was determined by drying samples at 105°C until a consistent mass was obtained [Rodier et al., 2009]. The organic matter content was determined by ignition loss at 525°C for 4 hours [Rodier et al., 2009]. Calcination in an oven at 500°C for 2 to 3 hours produced ashes, which were then dissolved to identify additional mineral elements [Pinta 1979]. Total nitrogen and ammoniacal nitrogen were measured using the Kjeldahl technique [Rodier et al., 2009], and total organic carbon content was assessed using Dabin's method (1970). The macro elements ($CaO$, $Na_2O$, $P_2O_5$, $MgO$, $K_2O$, $Cl^-$…) were analysed at the INRA Rabat laboratory. The Olsen method was utilized for $P_2O_5$ determination [Olsen, 1954]. Meanwhile, the amounts of assimilable potassium ($K_2O$) and sodium ($Na_2O$) were determined by flame spectrometry [Bower et al., 1952]. $MgO$ and $CaO$ were measured by atomic absorption spectrometry [Pinta, 1979]. Nitrate ($NO_3^-$) and orthophosphate ($PO_4^{3-}$) levels were ascertained through molecular absorption spectrometry, whereas sulphate ($SO_4^{2-}$) was obtained using the nephelometric method [Rodier et al., 2009].

### Microbiological characterization

To evaluate the microbiological profile of the various samples, characterization was carried out both at the beginning and end of the composting process. The total aerobic mesophilic flora (FMAT) and thermophilic flora (FT) were quantified by counting colonies on PCA (Plate Count Agar) with incubation temperatures of 30°C and 44°C for 72 hours, respectively [Rodier et al, 2009]. Colony counting for fecal pollution indicators (CT, CF, and *E. coli*) was done using the 3-tube NPP technique [Rodier et al., 2009]. Lactic acid bacteria were counted on MRS agar after 72 hours of incubation at 30°C [Guiraud, 1998]. Fungi had been measured on Sabouraud agar with chloramphenicol at 5 µg/ml (Yeasts and Molds) and incubated at 25°C in the dark for 72 hours [NM 08.0.123., 2004]. The presence of Salmonella was tested by inoculating S-S Agar and watching growth at 37°C for 24 to 48 hours [Rodier et al., 2009]. Table 2 shows the results of physicochemical and microbiological studies on raw materials intended for composting. The values presented are the mean of three replicates.

## RESULTS AND DISCUSSION

### Composts monitoring

*Temperature*

At the conclusion of the composting process, all composts exhibited a uniform dark brown colour and lacked any unpleasant odour. Temperature variations throughout the composting stages

**Table 2.** Characterization, both physical-chemical and microbiological, of the raw supplies employed in the composting experiment (poultry manure and pomace)

| The raw supplies ($T_0$) | Gr | F | GF1 | GF2 | GF3 | GF4 |
|---|---|---|---|---|---|---|
| pH | 5.05 ± 0.53 | 7.52 ± 0.07 | 6.43 ± 0.18 | 7.28 ± 0.15 | 6.68 ± 0.05 | 6.75 ± 0.09 |
| EC mS $cm^{-1}$ | 1.77 ± 0.10 | 3.33 ± 0.19 | 1.53 ± 0.21 | 2.96 ± 0.06 | 2.52 ± 0.08 | 1.75 ± 0.14 |
| Moisture % | 26.52 ± 3.46 | 15.73 ± 0.38 | 78.59 ± 2.41 | 77.92 ± 2.54 | 70.54 ± 2.52 | 70.89 ± 3.08 |
| OM % | 92.35 ± 2.46 | 94.53 ± 1.06 | 88.70 ± 2.03 | 90.74 ± 2.19 | 84.81 ± 4.29 | 92.35 ± 2.20 |
| Ash % | 7.65 ± 2.46 | 5.47 ± 1.06 | 11.30 ± 2.03 | 9.26 ± 2.19 | 15.19 ± 4.29 | 7.65 ± 2.20 |
| TOC % | 53.57 ± 1.43 | 54.83 ± 0.62 | 51.45 ± 1.18 | 52.63 ± 1.27 | 49.20 ± 2.49 | 53.57 ± 1.28 |
| NTK % | 1.27 ± 0.04 | 2.85 ± 0.18 | 1.60 ± 0.03 | 1.43 ± 0.03 | 1.54 ± 0.03 | 1.67 ± 0.02 |
| C/N ratio | 42.23 ± 1.40 | 19.30 ± 1.20 | 32.14 ± 1.41 | 36.76 ± 0.79 | 31.93 ± 1.66 | 32.15 ± 2.26 |
| $PO_4^{3-}$ % | 0.0187 ± 0.0013 | 0.3259 ± 0.0099 | 0.2395 ± 0.0173 | 0.2913 ± 0.0148 | 0.2000± 0.0222 | 0.1876 ± 0.0099 |
| $P_2O_5$ % | 0.007 ± 0.001 | 0.187 ± 0.009 | 0.129 ± 0.007 | 0.170 ± 0.007 | 0.111 ± 0.004 | 0.092 ± 0.007 |
| CaO % | 0.22 ± 0.007 | 0.63 ± 0.050 | 0.61 ± 0.030 | 0.68 ± 0.080 | 0.36 ± 0.060 | 0.11 ± 0.050 |
| MgO % | 0.08 ± 0.005 | 0.23 ± 0.030 | 0.23 ± 0.010 | 0.21 ± 0.030 | 0.18 ± 0.100 | 0.11 ± 0.010 |
| $K_2O$ % | 0.46 ± 0.001 | 1.45 ± 0.087 | 0.90 ± 0.085 | 0.88 ± 0.096 | 1.15 ± 0.009 | 0.55 ± 0.092 |
| $Na_2O$ % | 0.05 ± 0.001 | 0.24 ± 0.034 | 0.21 ± 0.034 | 0.22 ± 0.022 | 0.19 ± 0.017 | 0.14 ± 0.030 |
| $Cl^-$ % | 0.0185 ± 0.001 | 0.0236 ± 0.0004 | 0.0220 ± 0.002 | 0.0254 ± 0.001 | 0.0219 ± 0.002 | 0.0211 ± 0.003 |
| $SO_4^{2-}$ % | 0.0035 ± 0.0006 | 0.0120 ± 0.0085 | 0.0101 ± 0.0010 | 0.0080 ± 0.0007 | 0.0080 ± 0.0007 | 0.0073 ± 0.0008 |
| $NO_3^-$ mg $kg^{-1}$ | 57.55 ± 10.37 | 379.01 ± 76.92 | 375.61 ± 64.73 | 340.28 ± 48.68 | 203.95 ± 47.83 | 162.52 ± 1.31 |
| $NH_4^+$ mg $kg^{-1}$ | 526.01 ± 41.78 | 1116.29 ± 77.37 | 1038.71±120.41 | 982.92 ± 82.90 | 786.99 ± 293.65 | 672.04 ± 82.54 |
| TAMF ($Log_{10}$ CFU $g^{-1}$ of DM) | 10.10 | 7.75 | 8.96 | 9.02 | 8.34 | 8.90 |
| TF ($Log_{10}$ CFU $g^{-1}$ of DM) | 8.80 | 4.63 | 5.73 | 5.99 | 5.04 | 5.98 |
| Fungal microflora ($Log_{10}$ CFU $g^{-1}$ of DM) | 9.82 | 7.29 | 7.57 | 6.98 | 6.30 | 7.39 |
| Lactic acid bacteria ($Log_{10}$ CFU $g^{-1}$ of DM) | 5.79 | 3.01 | 3.68 | 3.86 | 5.10 | 4.30 |
| Fecal coliforms ($Log_{10}$ CF $g^{-1}$ of DM) | 7.95 | 9.20 | 8.41 | 8.42 | 8.55 | 8.54 |
| E.Coli ($Log_{10}$ E.Coli $g^{-1}$ of DM) | 7.20 | 8.20 | 7.66 | 7.92 | 8.25 | 8.13 |

indicated distinct phases. Initially, all mixtures began with nearly identical temperatures (Fig. 1). From the 28th day onwards in this investigation, temperatures steadily rose for all mixtures, peaking on the 84th day. Notably, mixture GF1 reached a high temperature of 60.56°C, while mixture GF3 recorded a minimum of 43.03°C. This temperature increase occurred during the thermophilic period, driven by intense microbiological activity, particularly that of thermophilic microorganisms [Mustin, 1987]. Sustaining temperatures above 60°C for several days contributed to organic matter stabilization and suppression of pathogenic microorganisms [Hachicha et al., 2009]. It's noteworthy that all temperatures in this study remained below 70°C, a critical threshold for the destruction of living microorganisms [Bernal et al., 2009]. Additionally, the thermal energy produced by microbes was discovered to be proportional to the pile's bulk [Godden, 1986]. Following the thermophilic phase, temperatures began to decline, marking the maturation phase. This phase exhibited a gradual decrease in temperature, stabilizing around the outside temperature at the end of the composting cycle [Doughmi et al., 2022].

### *pH*

The pH influences several processes that affect nutrient bioavailability and mineral element solubility in bacteria. Initially, the olive pomace Gr exhibited an acidic pH (5.05 ± 0.31) [Doughmi et al., 2022], whereas poultry manure started with a neutral pH (7.52 ± 0.07), falling within the range between these two values. Throughout the composting process, all mixtures followed a similar pattern, commencing in the acidic phase, transitioning to the alkaline phase, and ultimately stabilizing near a neutral pH by the end. The minimum pH value, observed after 48 days (5.25 ± 0.16), was for the GF3 mixture. Subsequently, the pH of all mixtures increased, reaching a peak on day 112 (8.67 ± 0.11) for the GF1 mixture. As the composting process concluded, pH levels decreased toward neutral, with GF3 recording the lowest (7.21 ± 0.19) and GF1 the highest (8.18 ± 0.10). This indicates the maturity of all composts, making them suitable as soil amendments (Fig. 2). Ameziane et al. (2020) observed that combining olive waste collected from the Fès-Meknès area with chicken manure (7.63 ± 0.12) and

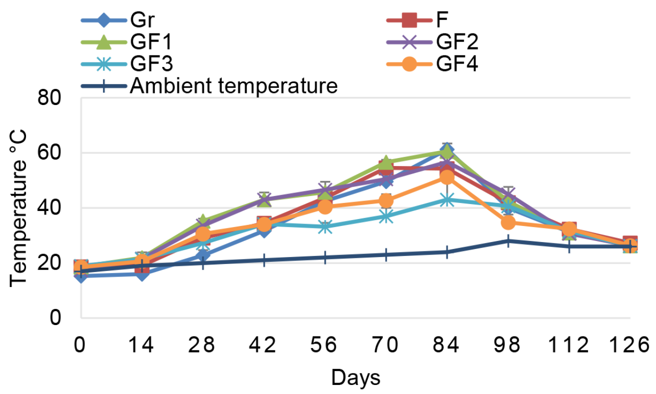


**Figure 1.** Temperature changes throughout the composting process

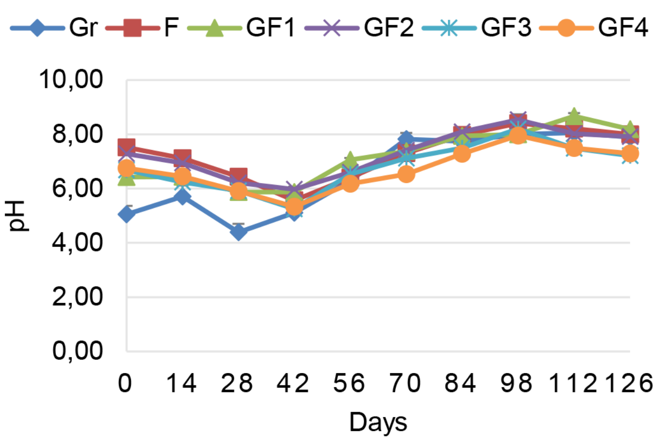


**Figure 2.** Changes in pH over time throughout the composting process

bovine's dung (8.16 ± 0.03) resulted in a comparable pH level after composting. The initial pH of poultry manure (7.52 ± 0.07) was lower than that reported in a Pakistani study (pH = 8.3) [Haroon et al., 2018], but closer to the pH found in a Tunisian study (7.59 ± 0.2) [Bargougui et al., 2020]. Nevertheless, it remained higher than the pH of poultry manure reported in an Israeli study (pH ≈ 6.6) [Raviv et al., 1999].

Numerous studies have found that at the conclusion of the cycle of composting, poultry litter has a pH value that's neutral or leans toward alkalinity, whether used alone or in combination with other wastes. The pH range at the end of the process (7.21 to 8.18) is slightly lower than that reported in a Nigerian study involving compost from poultry manure and kitchen waste (pH = 8.75) [Oguntade et al., 2019]. Similar alkaline pH values were observed in a Tunisian study (8.32 ± 0.01) involving poultry manure mixed with olive mill wastes [Hachicha et al., 2009]. Comparable pH values were also found in a study by Haroon et al. (2018), with poultry manure mixed with privet plant at different percentages (7.25 and 7.65). A Japanese study on composting rice straw with oilseed rape cake and poultry manure reported close alkaline pH values (8 to 8.7) [Abdelhamid et al., 2004].

Despite variations, the alkalinity of the pH towards the end of the composting process results from the release of organic-bound bases and the formation of ammonia from the decomposition of protein amines [Peters et al., 2000]. The compost's somewhat alkaline pH at the final stage of the decomposing cycle improves potassium, phosphorus, and nitrogen absorption that is critical to plant growth [Nefzaoui, 1985]. Furthermore, the growth of bacteria and fungi involved in the breakdown of organic matter is encouraged by a pH balance between 6 and 8 [Mennane et al., 2010]. The pH decreases during the acidic stage as a result of the breakdown of lipids, carbohydrates, and other components, which produces organic acids. $CO_2$ from aerobic decomposition dissolves in water to form carbonic acid, which adds to the acidification of the environment. [Mustin, 1987], encouraging fungal development, cellulose, and lignin decomposition [Paredes et al., 1999].

### *Electrical conductivity*

Electrical conductivity serves as an indicator of compost salinity, gauging its efficacy in phytotoxicity tests and as a plant growth fertilizer [Lin, 2008]. Throughout the composting process, the electrical conductivity of various mixtures experiences fluctuations due to the decomposition of organic matter. The majority of mixtures display a decline in electrical conductivity, except for the GF1 and GF4 mixtures, which exhibit a slight increase (Fig. 3). The lowest conductivity is observed in the GF1 mixture at $T_0$, ranging from 1.53 µS cm$^{-1}$ to 1.74 µS cm$^{-1}$ at $T_f$. This number remained significantly lower than the findings of a Tunisian research on mature compost from poultry manure combined with olive mill sludge (9.21 ± 0.08 µS cm$^{-1}$) [Hachicha et al., 2009], and another compost from poultry droppings and olive mill wastes at $T_f$ (7.5 µS cm$^{-1}$) [Bargougui et al., 2020]. It is closer, from the Tiflet region, however, to the electrical conductivity in poultry droppings mixed with olive pomace (2.06 ± 0.22 µS cm$^{-1}$) [Ameziane et al., 2020]. Furthermore, in this

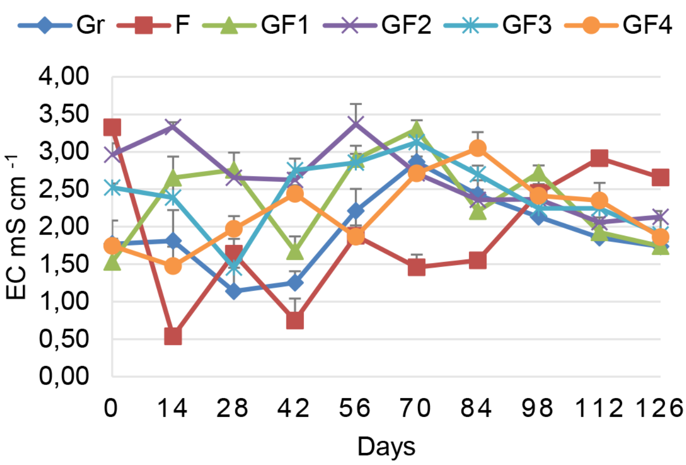


**Figure 3.** Changes in electrical conductivity throughout the composting process

study the electrical conductivity values remain considerably lower than those reported in a Japanese study on composting rice straw with oilseed rape cake and poultry manure (3.62 to 4.29 µS $cm^{-1}$) [Abdelhamid et al., 2004].

Comparing with the study by Lhadi et al. (2004) involving compost from municipal solid wastes and poultry manure (13 to 13.15 µS $cm^{-1}$), this study's electrical conductivities at the outcome of the composting process are lower. However, they are notably higher than those reported in a Pakistani study on compost from poultry manure and privet plant waste (5.2 to 6 µS $cm^{-1}$) [Haroon et al., 2018]. Importantly, the conductivity for the entire final compost does not go over 3 µS $cm^{-1}$ as a limit [Soumaré et al., 2002], showing that its application has no negative impact on plant development. In general, low-conductivity compost may be used directly in the soil, but high-conductivity compost should be mixed thoroughly with other materials like soil or other low-conductivity substances [Chen, 1999].

*Moisture evolution*

According to Chennaoui et al., (2016), moisture plays a crucial role in fostering microbial activity, thereby expediting the composting cycle. In poultry manure, the moisture content experiences a decline from 86.76% at $T_0$ to 32.86% at $T_f$. This reduction becomes particularly pronounced at the end of the treatment, reaching a minimum of 29.42% for GF4 mixture. Entering the thermophilic phase from the 42nd day, there is a notable decrease in the compost's moisture content [Jemali et al., 1996]. Among the composts, GF2 exhibits the greatest moisture loss, with a substantial rate of 61.64% (Figure 4). This loss corresponds to the drainage or evaporation of moisture influenced by elevated temperatures resulting from the activity of microbial organisms when composting [Jemali et al., 1996].

Research by Ameziane et al. (2020), compost consisting of chicken manure and pomace (30 ± 0.3%) and pomace and bovine's dung (30.4 ± 0.14%) produced similar results. A Moroccan study mixing municipal solid wastes with poultry manure in different ratios (3:2) demonstrated a reduction in moisture from 58.2% to 30.02%, and (2:3) from 55.2% to 29.86% [Lhadi et al., 2004]. Water evaporation causes a reduction in moisture content during composting, contributing to the overall reduction [Hayes, 1968].

*Organic matter and ashes changes*

At first, the loss on ignition is continuously greater than 84% in all mixes, with a high of 94.53% in the F mixture (Figure 5). The starting poultry manure value at T0 in the present research (94.53% ± 1.06) exceeds that observed in a Japanese study (87.4%) at $T_0$ [Abdelhamid et al., 2004]. Additionally, the organic matter content rates in all mixtures at $T_0$ are notably higher compared to other composts from municipal solid wastes and poultry manure (76.68% and 71.74%) [Lhadi et al., 2004].

Composting, being the decomposition of organic matter, naturally leads to a reduction in organic matter concentration, a significant outcome observed in all treatments [Ameziane et al., 2020]. Throughout composting, the organic matter content decreases, ranging from 49.96% (GF4) to 37.93% (GF3). Research indicated

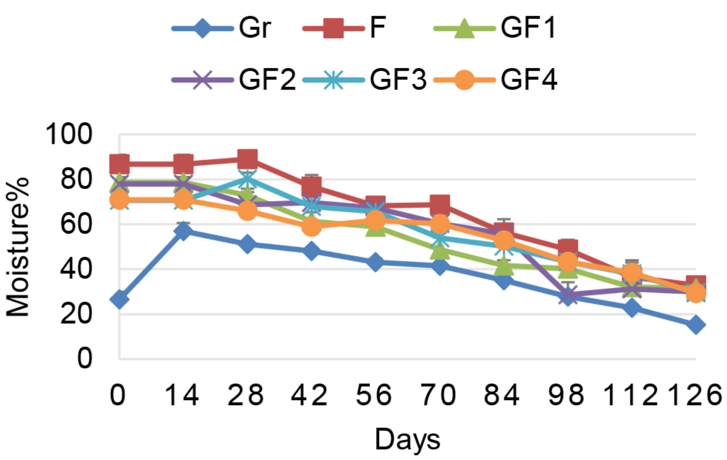


**Figure 4.** Changes in moisture levels throughout the composting process

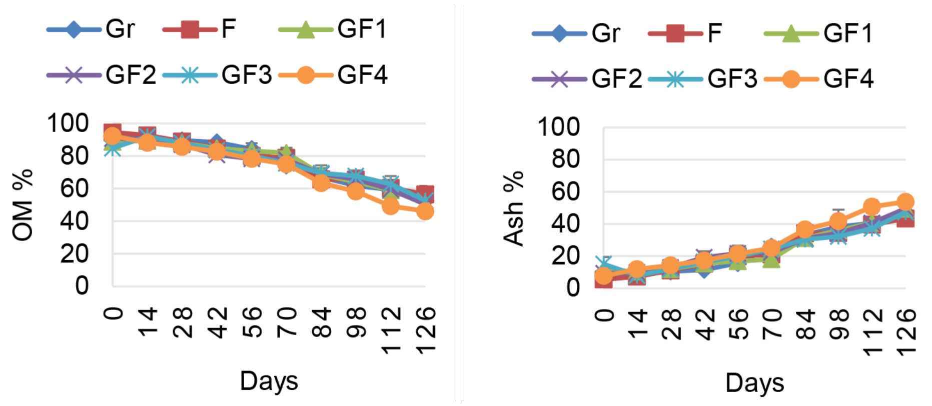


**Figure 5.** Changes in organic matter and ash content over time

that combining pomace from the Fès-Meknès area with chicken manure (43.15 ± 0.15%) and bovines dungs (38.4 ± 0.76%) resulted in similar organic matter content rates at the results of composting [Ameziane et al., 2020]. Comparable results were also reported in a Tunisian study using spent coffee grounds, olive mill wastewater sludge, and poultry manure (49 ± 8) [Hachicha et al., 2012]. In contrast, the amount of mineral component rate rises, with the greatest rate observed in poultry manure (87.38%), attributed to mineralization by microorganisms (Fig. 5). A Tunisian study on olive industry wastes and poultry manure co-composting reported an increase in ash content from 24.13% to 59.2% [Bargougui et al., 2020].

This substantial loss of organic matter is reflected in a reduction in volatile solids and total organic carbon throughout the composting process [Ameziane et al., 2020]. This is likely due to the presence of relatively stable organic compounds such as lipids, polyphenols, lignin, cellulose, hemicellulose, and pectin [Tortosa et al., 2012]. The decline in organic matter level is aided through numerous microbes that interact with temperature and compost quantity variations [Keener et al., 2000]. While germs dominate at the start of decomposition fungi remain active along the entire procedure, becoming especially active when moisture content is less than 35% and less effective when temperatures above 60°C [Bernal et al., 2009]. Additionally, during the maturation phase, highly resistant polymer-degrading actinomycetes become predominant [Bernal et al., 2009].

## Macro-element parameters

### *Total Kjeldahl nitrogen, total organic carbon and C/N ratio*

In this investigation, the C/N ratio decreased across all mixes, which was ascribed to organic matter mineralization. Notably, the GF2 mixture displayed a pronounced decrease, with its C/N ratio dropping from 36.76 initially to 15.85 in the final state (Table 2, Table 3). The reduction in the C/N ratio stems from the decomposition of carbon compounds, primary elements found in molecules that are organic, in addition to nitrogen, which is required by microbes [Chennaoui et al., 2016]. All combinations, except Gr compost, have a C/N ratio less than 20, suggesting mature compost according to the norm [Hirai et al., 1983] (Table 3).

At the final stage of the treatment, composts comprising Fes-Meknes olive pomace mixed with chicken manure (16.72) and bovine's dung (17.16) had nearly matched C/N values [Ameziane et al., 2020]. Similar findings were reported in a Nigerian study, where a relatively high C/N ratio was recorded at the end of the composting process (17.47) [Oguntade et al., 2019]. Numerous studies have indicated a decrease through the C/N ratio when decomposing, transitioning through the initial to the final state. Bargougui et al. (2020) demonstrated a decrease in the C/N ratio in research on composting olive waste with chicken manure in Tunisia (from 29.25 ± 0.2 to 8.15 ± 0.1). Hachicha et al. (2012) also observed a decrease (from 42 ± 5 to 14 ± 2) in a study involving co-composting spent coffee grounds with olive mill wastewater sludge and poultry manure in Tunisia. Abdelhamid et al. (2004) reported final C/N ratios ranging from 13.3 to 8.9 for mixtures of rice straw with oilseed rape cake and poultry manure.

Chicken droppings from Tiflet city had a total organic carbon (TOC) level of 35.85% ± 0.18, which was lower than the chicken manure TOC of 54.83% at the start of the composting procedure [Ameziane et al., 2020]. Furthermore, Tunisia had lower findings (18.08% ± 0.2) [Bargougui et al., 2020]. And in Pakistan (36.82%) [Haroon et al., 2018]. Composting using pomace from Fes-Meknes, chicken droppings from Tiflet city, and bovine's dung resulted in much reduced TOC levels (25.09 ± 0.76% and 22.32 ± 0.89%, respectively) [Ameziane et al., 2020]. Also, low ratings (28.29% and 27.14%) were reported in a Moroccan study on co-composting municipal solid wastes and poultry manure [Lhadi et al., 2004]. However, Abdelhamid et al. (2004) found TOC values higher than those observed in this study, ranging from 35.13% to 36.5%. The total nitrogen and potassium (NTK) content decreased in Gr and GF4 composts, while the other treatments (F, GF1, GF2, and GF3) exhibited an increase during the composting process. The NTK value from the poultry manure in this study (2.26%) was comparable to poultry manure in Pakistan at T0 with a content of 2.61% [Haroon et al., 2018]. Lower values were found in Tunisia (1.46%) [Bargougui et al., 2020] and Morocco (Tiflet city) (1.713% ± 1.78) [Ameziane et al., 2020], and Nigeria (0.32%) [Oguntade et al., 2019]. Composting olive pomace from the Fes-Meknes area with poultry droppings (1.5 ± 2.43%) and bovine's dung (1.3 ± 1.89%) resulted in comparable NTK values [Ameziane et al., 2020]. However, higher findings were reported in Tunisia (2.9% ± 0.04%) [Bargougui et al., 2020] and Japan (from 2.65% to 4.1%) [Abdelhamid et al., 2004].

### *Nitrogen ammonia ($NH_4^+$-N) and nitrates ($NO_3^-$-N)*

The $NO_3^-$ content rose across all mixtures during the composting process. The GF2 mixture exhibited the maximum $NO_3^-$ content at both the beginning (340.28 mg kg$^{-1}$) and the conclusion of the treatment (822.78 mg kg$^{-1}$), despite the GF3 combination had the lowest level at the start (203.95 mg kg$^{-1}$), it increased to about (489.49 mg kg$^{-1}$) by the end (Table 2, Table 3). This rise in nitrate concentration could be attributed to the compost hardening process resulting from increased temperatures, inhibiting the development of nitrifying microorganisms [Chennaoui et al., 2016]. The same results were shown in trials using compost manufactured from pig manure and sawdust, as well as composts made from olive pomace and home organic waste [Doughmi et al., 2022]. Another study on poultry manure composting also demonstrated an increase in nitrate content from 31 mg L$^{-1}$ to 119 mg L$^{-1}$.

High temperatures and excess ammonia were identified as factors inhibiting the activity and growth of thermophilic nitrifying bacteria [Morisaki et al., 1989]. Conversely, $NH_4^+$ content decreased during the composting process for all mixtures, with the GF4 mixture reaching a minimum value of 214.69 mg kg-1. The GF1 mixture, on the other hand, exhibited the maximum $NH_4$+ content at the end of the process, reaching 504.37 mg kg$^{-1}$ (Table 2, Table 3). As indicated by Huang et al. (2004), $NH_4$-N levels in compost heaps increase significantly during composting, attributed to ammonification with rising temperature and pH, and mineralization of organic nitrogen compounds leading to peak values [Mahimairaja et al., 1994]. After an initial increase, $NH_4$-N levels decrease due to volatilization losses and microbial immobilization [Huang et al., 2004]. Similar trends were observed in other studies on composting poultry manure and composts from olive pomace and household organic wastes. Additionally, a study on composting poultry manure with barley wastes or chestnut burr/leaf litter in Spain showed a decrease in ammonium concentration during composting from 13.1 ± 0.2 g kg$^{-1}$ to 7.4 ± 0.5 g kg$^{-1}$ and 10.6 ± 0.5 g kg$^{-1}$ to 9.5 ± 0.5 g kg$^{-1}$ [Guerra-Rodriguez et al., 2006].

According to Chennaoui et al., (2016), the drop in $NH_4^+$ can be due to microbes decomposing nitrogen-containing organic materials and turning it into ammonia. Furthermore, $NH_4^+$ reduction is indicative of a mature composting cycle [Chennaoui et al., 2016]. Good composting and maturation are indicated by the absence or decrease of $NH_4$-N [Hirai et al., 1983]. A maximum $NH_4^+$ content of 400 mg kg$^{-1}$ was suggested by Zucconi and De Bertoldi (1987) for mature enough compost.

### *Assimilable phosphorus ($P_2O_5$) and orthophosphate ($PO_4^{3-}$)*

Phosphorus represents a crucial element generated and originating through the organic matter breakdown. Throughout this investigation, the available phosphorus level witnessed an increase across all mixtures, reaching its maximum in GF2 (0.2606%)

and the minimum in GF4 (0.2038%) by the conclusion of the process (Table 2, Table 3). In the initial stages of the treatment cycle, remarkably low numbers were noted in a compost comprising olive mill sludge and poultry manure in Tunisia (0.007576%) [Hachicha et al., 2009]. Composting using pomace from the Fes-Meknes area, chicken manure (0.3 ± 0.87%), and bovine's dung (0.42 ± 0.86%) resulted in greater $P_2O_5$ concentrations [Ameziane et al., 2020]. Doughmi et al. (2022) demonstrated an increase in assimilable phosphorus during composting in a study involving olive pomace and household organic wastes. However, the P2O5 values remained considerably lower than those uncovered in the present study. Orthophosphate concentrations experienced a rise across all mixtures during composting, with the maximum concentration found in GF2 (0.6122%) and the minimum in GF4 (0.2193%) at the conclusion of the process (Table 2, Table 3).

The escalation in electrical conductivity, attributed to the decomposition of organic substances, can be linked to the release of mineral salts like phosphorus (P) [Gómez-brandon et al., 2008]. Additionally, fluctuations in total P followed the pattern of total N, progressively rising during the composting period as a result of net dry matter loss [Huang et al., 2004]. At the completion of the cycle of composting, a low P value (0.0258%) was found in a compost made from olive industry waste and chicken manure in Tunisia [Bargougui et al., 2019]. Similarly, a compost from kitchen waste and poultry manure in Nigeria exhibited a minimal P value at the conclusion of the process (0.000035%) [Oguntade et al., 2019]. Additionally, a Moroccan study on composting separated municipal solid wastes and poultry manure demonstrated an increase in P during the composting process by mixing different percentages of the raw materials (M1: from 1.97% to 3.73% & M2: from 2.01% to 3.73%) [Lhadi et al., 2004].

### *Sodium ($Na_2O$) and potassium ($K_2O$)*

Sodium ions ($Na^+$) exhibited a noteworthy increase across all mixtures, reaching its peak concentration (0.96%) in the GF2 compost, signifying a rise of 77.08%, while the lowest level was noted in the GF4 compost (0.60%) (Table 2, Table 3). The sodium content in poultry manure at $T_0$ (0.24%) significantly exceeded and was notably higher than that observed in poultry manure from Pakistan at $T_0$ (0.04212%) [Haroon et al., 2018]. In Tunisia, the sodium content in poultry manure (0.000523%) was considerably lower than the initial levels observed in this research at the commencement of the treatment cycle [Bargougui et al., 2020].

Following the cycle of composting, these values were significantly greater compared to those indicated by Bargougui et al. (2019) in a mixture including olive sector waste mixed with poultry manure (0.029%). However, values were more comparable and somewhat higher in a Moroccan study on composting municipal solid wastes and poultry manure (M1: from 0.77% to 1.14% & M2: from 0.8% to 1.15%) [Lhadi et al., 2004]. Similar to $Na^+$ ions, potassium (K) exhibited an increase across all mixtures during composting. Numerous studies have highlighted an augmentation in $K_2O$ content throughout the composting process. The $K_2O$ content in poultry manure (1.45%) was significantly higher than the $K_2O$ content in olive pomace (0.46%) at the outset. This value surpassed the one recorded in poultry manure from Pakistan (0.04692%) [Haroon et al., 2018]. By the conclusion of the composting process, the $K_2O$ content in poultry manure increased to 1.92%, still notably higher than that found in poultry manure in Pakistan (0.05606%) [Haroon et al., 2018].

Among the mixtures, the GF2 mixture displayed the maximum $K_2O$ content of 2.10%, while the GF4 mixture exhibited the minimum content of 1.65% at the process's conclusion (Table 2, Table 3). At the culmination of the composting process, higher $K_2O$ values were observed in composts comprising olive pomace from the Fes-Meknes region mixed with poultry droppings (2.9 ± 1.22%) and mixed with cow manure (2.8 ± 0.36%) [Ameziane et al., 2020]. Conversely, a lower K value was noted in a compost of olive industry waste mixed with poultry manure (0.38%) [Bargougui et al., 2020]. These values at $T_f$ remained considerably lower than those reported by Lhadi et al. (2004) (M1: 4.37% and M2: 4.72%).

### *Calcium (CaO) and Magnesium (MgO)*

The calcium concentrations increased in all mixtures throughout the composting process, has an elevated level in the raw GF2 (0.68%) and a low amount (0.11%) in GF4 observed at the start of composting (Table 2). The poultry manure value at $T_0$ (0.54%) significantly surpassed that found in poultry manure in Pakistan at $T_0$, which was 0.01366% [Haroon et al., 2018]. Concerning the mixtures, the GF2 mixture exhibited the maximum CaO content of 0.80%, while the GF4 mixture had the minimum content of 0.14% at the process's conclusion (Table 3). At the treatment's end, higher CaO values were observed in composts comprising olive mill sludge mixed with poultry droppings (4.23 ± 0.01%) [Hachicha et al., 2009]. Additionally, higher calcium values were noted in composts of municipal solid wastes mixed with poultry manure (5.09% for M1 & 5.3% for M2) [Lhadi et al., 2006].

Excessive $Ca^{2+}$ could impede certain elements (Cu, B, Fe and Mn) absorption [Ben Kheder, 1998]. The entry into the cooling phase can elucidate the increase observed after the second turning [Znaidi, 2002]. The stability of pH during the maturation phase is attributed to the existence of $Ca^{2+}$ ions, which rise during composting due to humification and act as environmental buffers [Morel et al., 1986]. The evolution of magnesium concentrations indicates an increase in all mixtures except Gr during the composting process, with a high concentration in the poultry manure pile characterized by the highest value which was 0.43%, with a lowest value of 0.16% in the GF4 combination at the conclusion of composting. These values remain significantly lower than those found in a compost of municipal solid waste and poultry manure at $T_f$, with 1.1% for M1 and 1.15% for M2 [Lhadi et al., 2004], which are also lower than those in a compost of poultry manure and olive mill sludge in Tunisia at $T_f$ (0.63%) [Hachicha et al., 2009].

### *Chloride ($Cl^-$) and sulphate ($SO_4^{2-}$)*

During the composting process, the sulphate concentration decreased somewhat in all mixes. Poultry manure compost exhibited the maximum sulphate content, with a value of approximately 0.0085%, while the GD3 mixture had the minimum final content of 0.0054% at the conclusion of the composting process (Table 3). These values are somewhat greater than those found in composts made from olive husk and solid waste from households, with a range of 0.0037% to 0.0029% [Doughmi et al., 2022]. Concerning chloride level, it is evident that concentrations increased in the different mixtures during the cycle of composting., with the maximum concentration observed in poultry manure and the GF2 mixture at 0.0291%, and the minimum concentration of 0.0210% in the GF4 mixture at the process's end (Table 2, Table 3). These values stay quite close to those found in composts made from olive pomace and solid organic waste from households, with a maximum of 0.0301% in solid waste from household's compost and a minimum of 0.0235% in the GD3 combination as the process progresses [Doughmi et al., 2022]. The elevation in chloride ions might be ascribed to an increase in electrical conductivity throughout the treatment period [Doughmi et al., 2022].

## Microbiological parameters characteristics

According to Ryckeboer et al. (2003), microorganisms play a crucial role in the composting process. The presence of particular species is indicative of the maturity level of the compost and is a key factor in determining its quality.

### *Thermophilic flora and total aerobic mesophilic flora*

Comparing the initial ($T_0$) and final ($T_f$) concentrations of total aerobic mesophilic flora (TAMF) revealed a decrease in all mixtures.

The initial mesophilic phase exhibited a high bacterial TAMF concentration, ranging from the maximum of $1.26 \cdot 10^{10}$ CFU $g^{-1}$ of DM in olive cake to the minimum of $5.63 \cdot 10^7$ CFU $g^{-1}$ of DM in poultry manure. Among the mixtures, the GF2 mixture displayed a high concentration at the composting process's outset ($1.05 \cdot 10^9$ CFU $g^{-1}$ of DM), while the GF3 mixture showed the minimum concentration ($2.21 \cdot 10^8$ CFU $g^{-1}$ of DM) (Table.2, Table.3). By the ending of the composting cycle ($T_f$), TAMF concentrations decreased and stabilized between $2.54 \cdot 10^6$ CFU $g^{-1}$ of DM in poultry manure and $4.23 \cdot 10^7$ CFU $g^{-1}$ of DM in the GF4 mixture (Table 2, Table 3). Similar to findings by Doughmi et al., (2022), the total aerobic mesophilic flora decreased by the composting process's end, ranging from a maximum of $1.26 \cdot 10^{10}$ CFU $g^{-1}$ of DM in olive husk to a minimum of $2.32 \cdot 10^9$ U CFU FC $g^{-1}$ of DM in solid organic waste from households.

The high TAMF concentrations observed initially in these studies suggest that their storage in contact with soil and air exposed them directly to microbial contaminants [Doughmi et al., 2022]. Moreover, Ojo et al., (2018) noted in their study on compost of cassava peels and poultry manure that, at the initial composting stage, bacterial counts ranged from 8 to $24 \cdot 10^8$ CFU $ml^{-1}$. The 1:2 ratio of poultry manure to cassava peels exhibited the highest bacterial count from the beginning to the end of the composting process, reaching between 22 and $154 \cdot 10^8$ CFU $ml^{-1}$ by the fourth week (end of composting period). These values remained higher than those observed in our study.

A decline in thermophilic flora was evident for all mixtures by the composting process's end. Consequently, there was a minimum concentration in poultry manure, decreasing from $4.30 \cdot 10^4$ CFU $g^{-1}$ of DM ($T_0$) to $3.69 \cdot 10^3$ CFU $g^{-1}$ of DM ($T_f$), and a maximum from $6.32 \cdot 10^8$ CFU $g^{-1}$ of DM to $6.78 \cdot 10^6$ CFU $g^{-1}$ of DM in olive pomace. Regarding mixtures, the GF2 mixture exhibited the highest concentration at both the beginning and end of the composting process, ranging from $9.77 \cdot 10^5$ CFU $g^{-1}$ of DM to $6.31 \cdot 10^5$ CFU $g^{-1}$ of DM. These values remained much lower compared to those seen in composts made from pomace and organic household waste [Doughmi et al., 2022].

### *Fungal microbial community*

The various mixtures exhibit a substantial concentration of fungal microbial community at the commencement of the decomposition cycle. Specifically, GF1 mixture displayed a notable concentration at $T_0$, registering $3.75 \cdot 10^7$ CFU $g^{-1}$ of DM, which later decreased to approximately $1.30 \cdot 10^7$ CFU $g^{-1}$ of DM during the conclusion of the treatment (Table 2, Table 3).

In a study conducted by Ojo et al. (2018), the fungal count during the initial composting stage ranged from 3.3 to $18.3 \cdot 10^8$ CFU $ml^{-1}$. Towards the culmination of the process, the fungal count varied between 11.7 and $22.7 \cdot 10^8$ CFU $ml^{-1}$, with the 1:2 ratio of poultry manure and cassava peels exhibiting the highest value [Ojo et al., 2018]. Upon reaching the final stage, there was a decline in the fungal microflora. This decline can be attributed to the elevated temperatures during the thermophilic period, this produced adverse circumstances for their proliferation, along with a reduction in moisture towards the end of the process [Guene, 2002].

### *Lactic acid bacteria*

Lactic acid bacteria concentrations experienced a slight increase at the composting process ending, while the GF3 combination showed a reduction. With a maximum rate in the GF3 mixture of $1.25 \cdot 10^5$ CFU $g^{-1}$ of DM at $T_0$ and $7.4 \cdot 10^4$ CFU $g^{-1}$ of DM at $T_f$ (Table 2, Table 3). These results are lower than those obtained by Doughmi et al., (2022) using composts produced from the pomace and solid organic waste from households, with a maximum of $2.23 \cdot 10^7$ CFU $g^{-1}$ of DM and a minimum of $2.54 \cdot 10^5$ CFU $g^{-1}$ of DM at the final stage of the cycle of composting. This rise is attributed to their expansion throughout the acidogenic stage of the process of composting [Doughmi et al., 2022].

### *Coliforms and Escherichia coli*

The presence of pathogenic microorganisms in composts may pose a potential contamination risk to plants when applied. Approval of their agricultural effectiveness is a prerequisite for the use of compost in the agricultural sector, emphasizing health and environmental safety aspects [Houot S., et al., 2009]. Fecal coliform concentrations witnessed a decline during the composting process. Initially, the mixtures exhibited a high concentration of fecal coliforms, experiencing a substantial decrease throughout composting. The most notable reduction, observed in the GF2 mixture, reached 39.16%, dropping from $2.65 \cdot 10^8$ CF $g^{-1}$ of DM to $1.33 \cdot 10^5$ CF $g^{-1}$ of DM (Table 2, Table 3). In terms of mixtures, these values remain significantly higher than those reported in composts from olive pomace and organic household wastes, ranging between a maximum of $9.48 \cdot 10^7$ CF $g^{-1}$ of DM and a minimum of $6.33 \cdot 10^1$ CF $g^{-1}$ of DM [Doughmi et al., 2022].

Regarding *Escherichia coli*, all mixtures exhibited a decrease by the end of the composting process. The maximum value, recorded at $T_0$ in the GF3 mixture, was $1.77 \cdot 10^8$ *E. coli* $g^{-1}$ of DM, reducing to $1.34 \cdot 10^5$ *E. coli* $g^{-1}$ of DM at $T_f$. Composts showed a considerable drop, highlighting the efficacy of the process in eliminating pathogenic germs, with the GF4 mixture achieving a high reduction rate of 67.70% (Table 2, Table 3). In terms of mixes, these values remain much higher than those obtained in composts made from olive pomace and organic household waste, ranging from a highest value of $9.48 \cdot 10^7$ *E. coli* $g^{-1}$ of DM to a low of 1.23 *Escherichia coli* $g^{-1}$ of DM [Doughmi et al., 2022]. Ensuring the compost quality for agricultural use necessitates an assessment of its fertilizing and hygienic aspects, particularly concerning pathogenic microorganisms such as *E. coli*, in adherence to organic amendments standards [Houot et al., 2009].

### *Salmonella*

According to Brinton & Droffner (1994) and Hay (1996) the presence of Salmonella and Shigella is seen as a significant and unique concern impacting the sanitary quality of compost. For Salmonella characterization, we conducted a presence/absence test, limiting our study to a qualitative analysis due to the composting being conducted in the winter period. Salmonella was consistently present throughout the composting process, primarily due to the nature of the mixtures (poultry manure), known for its high concentration of pathogenic germs and microorganisms. Salmonella originates from residues of food waste, specifically through meat, chickens, milk, and their byproducts [Hassen et al., 2001]. Additionally, the temperature did not exceed 70°C during composting, especially in the thermophilic period required for the significant or total elimination of Salmonella, a process essential for the destruction of living organisms [Bernal et al., 2009]. None of the mixtures surpassed 60.56°C, the highest temperature recorded on the 84$^{th}$ day of composting (GF1 mixture).

A study by Doughmi et al. (2022) on composting olive pomace with organic household wastes at different percentages revealed that Salmonella persisted during the composting process as long as the mixtures did not reach a sufficiently high temperature to eliminate pathogenic germs. Following microbial requirements, according to the limit level [NF V 08-052:1997], no natural supplement intended for vegetable crops may include any pathogenic agent (Salmonella) per 25 g. This durability may be attributable to the bacteria's widespread nature and high growth rate. The US Environmental Protection Agency (US-EPA) requires a Salmonella rate of less than three bacteria per 4 g dry weight of compost and sludge [Hay, 1996]. Brinton & Droffner (1994) found that certain Salmonella mutant strains may survive high temperatures (42−54 °C) and could contaminate compost windrows while being stored. The summarized results are presented in the Table 3. The values presented are the mean of three replicates.

**Table 3.** Physicochemical and microbiological characteristics of mature composts

| Composts ($T_f$) | Gr | F | GF1 | GF2 | GF3 | GF4 |
|---|---|---|---|---|---|---|
| pH | 7.90 ± 0.29 | 8.00 ± 0.08 | 8.18 ± 0.10 | 7.92 ± 0.08 | 7.21 ± 0.19 | 7.29 ± 0.05 |
| EC mS $cm^{-1}$ | 1.74 ± 0.08 | 2.66 ± 0.13 | 1.74 ± 0.06 | 2.13 ± 0.11 | 1.90 ± 0.07 | 1.86 ± 0.24 |
| Moisture % | 15.22 ± 1.47 | 32.86 ± 1.74 | 31.57 ± 1.38 | 29.89 ± 3.85 | 29.51 ± 3.00 | 29.42 ± 2.95 |
| OM % | 52.62 ± 2.71 | 56.64 ± 5.01 | 50.50 ± 3.22 | 50.40 ± 6.00 | 52.65 ± 5.94 | 46.21 ± 2.71 |
| Ash % | 47.38 ± 2.71 | 43.36 ± 5.01 | 49.50 ± 3.22 | 49.60 ± 6.00 | 47.35 ± 5.94 | 53.79 ± 2.71 |
| TOC % | 30.52 ± 1.57 | 32.85 ± 2.90 | 29.29 ± 1.87 | 29.24 ± 3.48 | 30.54 ± 3.44 | 26.80 ± 1.57 |
| NTK % | 1.06 ± 0.03 | 2.85 ± 0.02 | 1.84 ± 0.04 | 1.91 ± 0.02 | 1.95 ± 0.06 | 1.43 ± 0.01 |
| C/N ratio | 28.90 ± 0.81 | 11.57 ± 0.72 | 16.58 ± 3.36 | 15.85 ± 2.85 | 15.89 ± 1.91 | 18.73 ± 0.27 |
| $PO_4^{3-}$ % | 0.0260 | 0.4518 | 0.3876 | 0.6122 | 0.3234 | 0.2913 |
| $P_2O_5$ % | 0.0088 | 0.2725 | 0.2425 | 0.2606 | 0.2338 | 0.2038 |
| CaO % | 0.38 | 0.63 | 0.74 | 0.80 | 0.47 | 0.14 |
| MgO % | 0.04 | 0.43 | 0.26 | 0.37 | 0.32 | 0.16 |
| $K_2O$ % | 0.40 | 1.92 | 1.95 | 2.10 | 1.98 | 1.65 |
| $Na_2O$ % | 0.19 | 1.02 | 0.92 | 0.96 | 0.71 | 0.60 |
| $Cl^-$ % | 0.0242 | 0.0291 | 0.0290 | 0.0291 | 0.0245 | 0.0210 |
| $SO_4^{2-}$ % | 0.0036 | 0.0085 | 0.0081 | 0.0062 | 0.0070 | 0.0054 |
| $NO_3^-$ mg $kg^{-1}$ | 151.11 ± 14.44 | 779.57 ± 84.48 | 583.76 ± 65.96 | 822.78 ± 153.92 | 489.49 ± 8.10 | 514.02 ± 120.12 |
| $NH_4^+$ mg $kg^{-1}$ | 259.25 ± 19.84 | 586.32 ± 72.00 | 504.37 ± 80.70 | 360.74 ± 257.67 | 300.96 ± 200.64 | 214.69 ± 214.69 |
| TAMF ($Log_{10}$ CFU $g^{-1}$ of DM) | 6.83 | 6.41 | 6.51 | 6.87 | 7.53 | 7.63 |
| TF ($Log_{10}$ CFU $g^{-1}$ of DM) | 6.83 | 3.57 | 5.46 | 5.80 | 4.76 | 5.09 |
| Fungal microflora ($Log_{10}$ CFU $g^{-1}$ of DM) | 6.15 | 5.40 | 7.11 | 6.08 | 6.43 | 5.85 |
| Lactic acid bacteria ($Log_{10}$ CFU $g^{-1}$ of DM) | 7.36 | 3.70 | 3.71 | 4.34 | 4.87 | 4.59 |
| Fecal coliforms ($Log_{10}$ CF $g^{-1}$ of DM) | 5.01 | 6.57 | 5.86 | 5.12 | 6.59 | 5.93 |
| E.Coli ($Log_{10}$ E.coli $g^{-1}$ of DM) | 2.01 | 4.99 | 3.17 | 3.12 | 5.13 | 2.63 |

## CONCLUSIONS

In contrast to the positive aspects of composting, a significant challenge associated with directly using poultry manure in agriculture is the potential contamination risk posed to plants and humans by pathogenic microorganisms. To mitigate these risks, the approach chosen involves blending poultry manure, which possesses high nitrogen concentration and low carbon levels, with olive pomace characterized by a high carbon concentration. This aims to achieve an optimal C/N ratio, thereby reducing organic matter content and mitigating pathogens through the composting process. It can be concluded that continuous monitoring of physicochemical and microbiological parameters offers valuable insights into the condition and progression of compost throughout the composting procedure. The physicochemical and microbiological outcomes pre and post-composting of mixtures containing poultry manure and olive pomace consistently align with the anticipated outcomes from previous studies.

Composting olive pomace and poultry manure has yielded a high-quality product after a successful four-month treatment period. The resulting composts in this study are distinguished by their neutral pH and a C/N ratio below 20. They are also rich in essential mineral fertilizers such as nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg). Despite poultry manure being known for its elevated salinity, the final products did not exceed the acceptable electrical conductivity limit for soil support (3 μS $cm^{-1}$). Additionally, the combinations showed a decrease in pollutant indices. At the conclusion of the composting process, the GF2 mixture displayed the lowest C/N ratio (15.85), with the highest $P_2O_5$ content (0.2606%) and ammoniacal nitrogen content (360.74 mg·$kg^{-1}$) below the specified limit (400 mg·$kg^{-1}$). The achieved results underscore the benefits of composting these organic wastes. Consequently, composting has proven to be an effective method for sanitizing poultry manure and olive pomace, resulting in a stable, organic-rich compost suitable for soil enhancement as an organic fertilizer.

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