Scientific Papers. Series A. Agronomy, Vol. LXVI, No. 1, 2023
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

BIOWASTE COMPOST – AN ALTERNATIVE SOURCE OF NUTRIENTS FOR AGRICULTURAL CROPS

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Abstract

Important amounts of biowaste are produced daily both in the rural and urban areas of Romania. Composting is the most sustainable way for their treatment, and compost can be used as fertilizer, including in organic agriculture if it meets specific quality standards. The agronomic value of the compost is given by the macronutrient and organic matter content, and its quality by the absence of phytotoxic compounds (heavy metals and other pollutants), and the absence of pathogens for humans, animals and plants. This paper presents part of the results of a study made to characterize the agronomic value of three types of compost (a. poultry manure + cereal straw; b. poultry manure + vegetable food waste; c. biodegradable household waste). Mixtures of compost and soil were made where the compost was integrated in proportions of 25, 50 and 75% g/g. A test plant, oats (Avena sativa L.), was cultivated in the greenhouse, in pots, on the mixtures made. The intake of macronutrients (N, P, K, Mg, Ca) was analyzed in biomass samples, harvested at the grain filling stage.

Key words: *biowaste, composting, macronutrients, sustainable agriculture, agronomic value.*

INTRODUCTION

Nowadays, humanity is facing a demographic growth that tends to reach 8.5 billion inhabitants in 2030 (United Nations, 2015), wich brings a multitude of social challenges such as poverty, hunger, lack of jobs, lack of hygiene, lack of water, diseases and also economic and financial impact by diminishing natural resources which has a massive impact on the climate, therfore, sustainable development remains the only way to meet the needs of present generations and protect the environment at the same time (United Nations, 2015). In meeting many of the strategic objectives (poverty reduction, food supply, renewable energy production, responsible production, etc.) of the United Nations (UN) 2030 Agenda, agriculture has a key role to play (FAO, 2016), as it is one of the economic areas that can fundamentally integrate the concept of Circular Economy (EC), which has the role of increasing the efficiency of natural resource use, maximizing the added value of products and minimizing environmental and climate impact (Nordin et al., 2022; Velasco-Munoz et al., 2022; Rodríguez-Espinosa et al., 2023). As agriculture needs large quantities of fertilising materials, it may increase the use of organic fertilisers and composts instead of synthetic fertilisers that could contribute to reducing energy consumption, making better use of residual biomass resources, improving the physical, chemical and biological soil properties, increasing the resilience of agroecosystems and reducing climate impact (Chojnacka et al, 2022; De Corato, 2020; Wainaina et al, 2020).
Biowaste such as biodegradable garden and park waste, food and kitchen waste from households, offices, restaurants, wholesale warehouses, canteens, caterers or retail premises and comparable waste from food processing plants (Directive 2081/851/CE, PE) may be recycled through composting which is one of the most sustainable ways to dispose them. Using compost as fertilizing material offers many benefits to agriculture and the environment, directly and indirectly by increasing the natural fertility of the soil, increasing ecosystem services, improving the health of crop plants, improving water quality by reducing pollution caused by the use of synthetic fertilizers,

increasing the quality of agricultural products, etc. (Rashid et Shahzad, 2021; Martinez-Blanco et. al, 2013).

In Romania, increasing the recycling of bio-waste would help to fulfill the objectives of the EU circular economy action plan as well as to reduce the amount of waste. In 2021, 77,148,372 poultry were registered in Romania, which resulted in a large amount of poultry manure, which mostly ended up in landfills.

In 2020, 131 kg/capita/year of food waste was produced in Europe, of which 14 kg from primary food production (agriculture, fisheries and aquaculture), 26 kg from food and beverage manufacturing, 9 kg from retail and distribution, 12 kg from restaurants and catering and 70 kg from households representing 53.43%, the highest share (Eurostat, 2023). Of these, vegetables, fruits and cereals are the food groups that become the largest share of food waste and are generated in the consumption phase, respectively 46%, which means that a large part of household food ends up in the trash (Sanchez et al., 2020). Given the increased consumption of animal products, globally, large quantities of poultry manure are produced every day on farms but also in rural households. The data published in specialized journals on the amount of litter produced by poultry per 1000 heads / day, respectively: chicken for meat – 65kg, geese – 200 kg, ducks – 190kg (Augustyńska-Prejsnar et. al, 2018). Composting of biowaste has many benefits because it helps to reduce the amount of waste in landfills and to produce composts that can replace chemical fertilizers, can improve soil quality and reduce pollution, and, at the same time, contribute to increase of food production which is very important due to the global population that is constantly raising.

The use of poultry manure as fertilizing material has been made since ancient times due to its high nitrogen content (Munch et al., 2022; Rizzo et al., 2022; Rech et al., 2020). However, applying poultry manure directly to the soil is undesirable because fresh poultry manure is phytotoxic and cannot be used as fertilizer (Bargougui et al., 2020). So, composting it with other types of waste, such as food waste or garden waste, is suitable. Zubair et al. (2020) highlighted the importance of using manure of all types, especially for nutrient recovery from these types of waste but concluded that aerobic composting and anaerobic digestion processes can effectively remove and recover nutrients from solid manure and represent a surplus of nutrients used as fertiliser. Numerous studies have revealed the favorable effects of using compost from animal manure on plant production. So, the use of poultry manure compost significantly increased potato tuber production (Minin et al., 2020); composted cattle manure used in cauliflower cultivation increased the total biomass weight (Simarmata, 2016); poultry manure and dry straw compost applied to cereals increased the production of triticale and wheat (Rusakova et al., 2015). Compost has a valuable content of organic matter essential to agriculture. The application of organic matter to the soil has the potential to alter the nitrogen dynamics of an ecosystem (Wang et al, 2022; Rusakova et Eskov, 2015; Hoang et al, 2022). Therefore, it is important to supplement synthetic fertilizers with organic amendments that provide the plants with the nutrients necessary for growth but at the same time help the environment. This paper presents the results of a study regarding the agronomic value, especially macronutrient availability (N, P, K, Mg, Ca) three types of compost obtained from food waste and manure from chickens raised on the ground within individual households in rural areas. The study was conducted in greenhouse with oat plants (*Avena sativa L.*).

MATERIALS AND METHODS

In this study, were used 3 types of compost obtained domestically in a rural locality in Ilfov County, Romania, using composting containers with a capacity of 320L, 65x65x75, namely:

C1_PMWS - poultry manure + dry wheat straw – 3:1 ratio (12 luni);

C2_PMFW – poultry manure + food scraps – 3:1 ratio (12 luni);

C3_HHC – compost from household waste (garden and kitchen scraps, 12 months).

The compost samples were taken to the National Institute of Research and Development for Pedology, Agrochemistry and Environmental Protection, to determine chemical analyses, in November 2021. The soil used for this experiment came from the Didactic Station for Agronomic Research and Development Moara Domnească, in Găneasa commune, Ilfov county.

Table 1. Physico-chemical characteristics of soil and compost used in experiments

Analyzed parameters	Soil	C1_PMWS	C2_PMFW	C3_HHC
pH	5.89	7.14	7.10	8.36
Humidity (%)	19.3	47.21	42.69	44.64
Dry matter (%)	80.7	52.59	56.31	55.36
C_org. (%)	2.02	14.92	13.62	9.71
C:N	9.35	11.39	10.72	9.23
Nt (%)	0.22	1.31	1.27	1.04
N-NO3- (mg kg−1d.m.)	28.67	229	136	910
N-NH4 + (mg kg−1d.m.)	9.12	59.33	53.67	86
P (%)	0.16	1.47	1.62	0.46
K (%)	-	1.23	1.48	1.48

pH is a very important parameter of composting, which depends on the characteristics of the materials that make up the substrate. According to existing studies, a pH range between 6.5 and 9 allows good activity during microbial activity. Both C2_PMFW and C1_PMWS had a pH around 7, resulting in a neutral pH. Similar results have been obtained by other researchers (Tampio et al., 2016; Montovani et Spadon ,2017; Jalili et al., 2019). C3_HHC had a pH of 8.36.

The total nitrogen content was 1.3% in C1_PMWS, compost obtained from poultry manure and wheat straw, and 1.26 for C2_PMFW compost, obtained from poultry manure and plant residues and 1.04 C3_HHC. The results obtained are similar to other experiments where the total nitrogen content of the compost was between 0.9 and 2% (Wilden et al., 2001; Peng et Pivato, 2019; Coelho et al., 2018). The phosphorus (P) content was 1.61% in C2_PMFW, 1,46% in C1_PMWS (Tampio et al., 2016; Peng and Pivato, 2019) and slightly lower in C3_HHC, respectively 0.46%.

The organic carbon content of the composts obtained was 13.62% in C2_PMFW, 14.92% in C1_PMWS and 9.71% in C3_HHC.

The values of nitrates (N-No3) and ammonium (N-NH4) were 136 mg./kg DM N-No3 for C2_PMFW and 229 N-No3 mg/kg DM in C1_PMWS and 54 mg/kg DM N-NH4 in C2_PMFW and 59 mg/kg DM N-NH4 in C1_PMWS. C3_HHC resulted in 910 mg/kg N-No3. Total N normally ranges from less than 1 % to 2,5 % (dry subst.) in finished composts (Wilden et al. ,2001; Peng et Pivato, 2019; Coelho et al., 2018; Jalili et al., 2019).

Table 2 -Content of heavy metals in soil and composts

Treatment	Cd (mg kg $^{-1}$d.m.)	Cr (mg kg $^{-1}$d.m.)	Cu (mg kg $^{-1}$d.m.)	Pb (mg kg $^{-1}$d.m.)	Ni (mg kg $^{-1}$d.m.)	Zn (mg kg $^{-1}$d.m.)	Mn (mg kg $^{-1}$d.m.)
Control - Soil	nd	32.5	26.8	12.3	19.6	661	-
C1_PMWS	nd	183.33	44.1	9.93	19.5	285.67	332
C2_PMFW	nd	126	47.9	19.2	26.83	257.33	439.33
C3_HHC	Nd	34.7	34.5	10.5	19.9	413	-

In Table 2 results on heavy metals content in soil and composts C1_PMWS, C2_PMFW and C3_HHC are presented. No cadmium (Cd) was detected in the three types of compost. In C2_PMFW compost contains 126 mg/kg DM. Cr and C1_PMWS 183.33 mg/kg DM. Cr, noticing a significant difference, a smaller amount having C3_HHC, namely 34.7 mg/kg. In terms of copper (Cu) and zinc (Zn), the results were similar between C1_PMWS and C2_PMFW, with C3_HHC having 351 mg/kg. Higher levels of lead (Pb) and nickel (Ni) have been detected in C2_PMFW, compost produced from poultry manure and plant debris.

Experiment establishment. The experiment was organized in the greenhouse of the University of Agronomic Sciences and Veterinary Medicine Bucharest, in March 2022

(Figure 1). 3 soil-compost mixtures were used, in concentrations of 25%, 50% and 75%. A control variant with a content of 100% soil was used.
V1: 100% soil
V2: 25% soil + 75% C1_PMWS
V3: 50% soil + 50% C1_PMWS
V4: 75% soil + 25% C1_PMWS
V5: 25% soil + 75% C2_PMFW
V6: 50% soil + 50% C2_PMFW
V7: 75% soil + 25% C2_PMFW
V8: 25% soil + 75% C3_HHC
V9: 50% soil + 50% C3_HHC
V10: 75% soil + 25% C3_HHC
After harvesting the plants, they were finely chopped and put in different containers, in order to weigh the production and perform chemical analyzes, carried out at the National Institute for Research and Development for Pedology, Agrochemistry and Environmental Protection Bucharest.

Figure 1. Pre-harvest experiment

RESULTS AND DISCUSSIONS

Compost maturity – Germination index.
The seed germination index (GI) is a widely used indicator of compost maturity and is a mandatory index in many international standards. The newest organic fertilizer standard (NY525–2021) introduced GI as a compost maturity assessment index and added the requirements for the first time, namely GI ≥ 70% (Wang et al., 2022). Tiquia et al (1996) discovered concluded that the GI value greater than 80%, usually means the final product, compost, does not exhibit phytotoxicity.

The determination of germination index (GI) in seeds of Lepidium sativum L. was made according to the method used by Cesaro (2015), namely:

$$GI(\%) = \frac{G1 \times L1}{G2 \times L2} \times 100$$

Where: G1 = no. germinated seeds in contact with the resulting compost solution;
L1= average length of germinated roots;
G2 = No. seeds germinated in contact with distilled water;
L2= average length of germinated roots.
To perform phytotoxicity tests, the compost sample (100 g) was mixed with water to a moisture content of 85%, kept for 2 hours and centrifuged at 6000 rpm for 15 min. Petri dishes were lined with filter paper and moistened with 3 ml of test solution or deionised water, used as a blank. Each plate was seeded with 10 seeds of L. sativum and incubated in the dark at 25 ± 1◦C for 72 hours. Subsequently, the number of germinated seeds was counted and the total length of seedlings was assessed, including both root and shoot. According to UNICHIM (2003), the seed was considered to germinate when the root was over 0.5 mm long.
C2_PMFW had a germination index of 81.44%, while C1_PMWS had an germination index of 91.96%, values according to which composts do not have phytotoxicity, so they can be used for growing green plants.

The content of macronutrients in oat plants.
The N content of oat plants harvested from all composted variants is higher than the control variant containing 100 % soil (Figure 2).

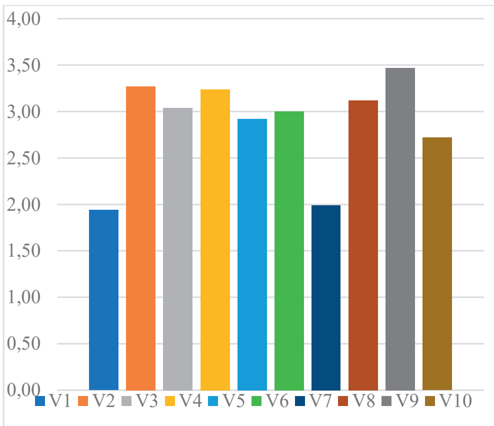

Figure 2. N content of oat plants (%)

Thus, in variants where C1_PMWS was used, the N content was higher by 68.55% in V2 (75% C1_PMWS), 56.7% V3 (50% C1_PMWS) and 67% V4 (25% C1_PMWS). In variants where C2_PMFW was used, the increase was 50.52% V5 (70% C2_PMFW), 54% V6 (50% C2_PMFW) and 2.58% V7 (25% C2_PMFW) and in variants where C3_HHC was used, the value was higher by 60.82% V8 (75% C3_HHC), 78.87% in V9 (50% C3_HHC), also the highest concentration of N, 3.47%) and 40.2% V10 (25% C3_HHC), respectively.
The highest P content was obtained from V3_50%PMWS (P = 0.641%), 6.31% more than the control variant, followed by V4-C1_PMWS and V6-C2_PMFW with a P content 5.32% lower than the control variant. Compared to the control variant, the lowest concentrations of P had plants harvested from the variants where C3_HHC was used, which had lower values by 32.39% in V6 (75% C3_HHC), 40.36% in V7 (50% C3_HHC), respectively 47.34% in V8 (25% C3_HHC), the latter being also the variant with the lowest P content (0.317%), as can be seen in Figure 3.

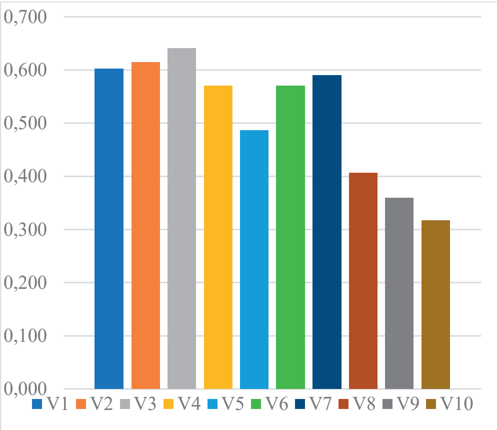

Figure 3. P content of oat plants (%)

The K content had the lowest value in the control, namely 5.69%, all variants that included compost, with concentrations higher than K, with 13.88% (V2 - 75% C1_PMSW), 22.67% (V3 - 50% C1_PMSW), 47.28% (V4 - 25% C1_PMSW). V5 - 75% C2_PMFW had a K content of 5.89%, 3.52% more than the control variant but V6_50% C2_PMFW and V7 - 25%C2_PMFW had a K content higher by more than 20%. The variants where C3_HHC was used had a K content higher by over 37.08% V10 (25% C3_HHC), 42.88% V9 (50% C3_HHC) and over 47.28% V8 (75% C3_HHC). Thus, plants grown in V4 and V8 had a K content about 50% higher than the control variant. See Figure 4.

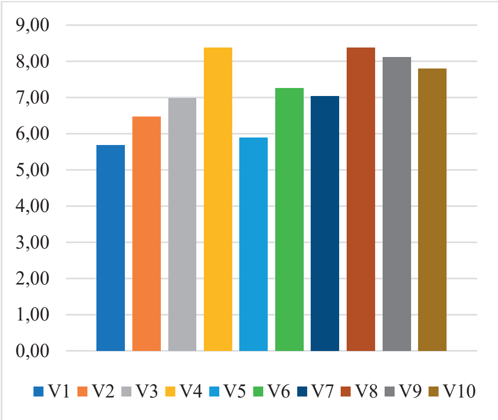

Figure 4. K content of oat plants (%)

The Ca content of oat plants was lower in most compost variants, only plants grown in V6 (50% C2_PMFW) and V10 (25% C3_HHC) had a higher content by 18.64% and 21.19%, respectively, than the control variant and the lowest Ca concentration had V4 (25% C1_PMWS), with 24.86%. However, the smallest amounts of Ca among the variants resulted from V8 (75% C3_HHC) and V9 (50% C3_HHC), as shown in Figure 5.

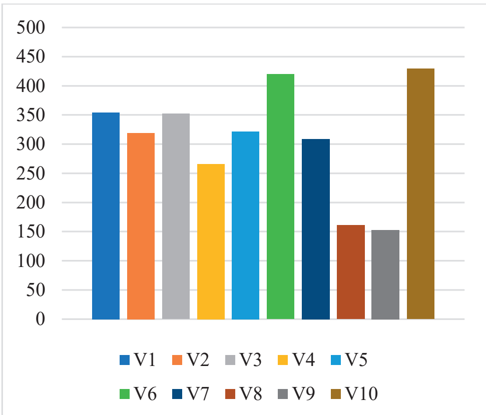

Figure 5. Ca content of oat plants (Mg/kg)

The Mg content of oat plants grown in compost mixtures exceeded in most control variants by 7.8% V3 (50% PMWS), 21.49% V4 (25% PMWS), 10.12% V6 (50% C2_PMFW) and 16.36% V7 (25% C2_PMFW), 11.12% V8 (75% C3_HHC), 27.6% V9 (50% C3_HHC), except V2 (75% C1_PMWS), V5 (75% C2_PMFW) and V10 (25% C3_HHC), having lower Mg concentrations compared to Mt, by 22.67%, 10.12% and 16.36%, respectively (Figure 6).

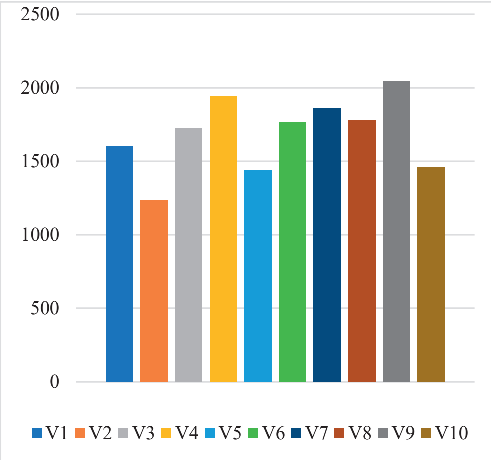

Figure 6. Content of Mg in oat plants (mg/kg)

CONCLUSIONS

Composting requires compliance with a set of rules regarding the types of waste from which to compost. Future studies in this area could lead to the evolution of compost used as fertilising material.

This study was carried out to verify the hypothesis that compost from bio-waste may be an alternative source of nutrients for plants, which is confirmed by the N and K content of oat plants grown from all variants containing compost, regardless of compost type, all of which have higher concentrations of N and K than the control variant where 100% was used.

These results are a first step towards positioning the use of compost as a fertilising material among the healthiest organic waste recycling practices.

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