IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
December 2021 Vol.:20, Issue:2

Solubilization of Togo Rock Phosphate During Vermicomposting of Brewery By-Products and Cow Dung

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Submitted: 23 November 2021
Accepted: 28 November 2021
Published: 30 December 2021

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Vermicompost, Natural Phosphate, Spent Grains, Phosphorus.

ABSTRACT

Phosphorus is fundamental to guarantee the assimilation and root growth of a plant. Studies on the use of Natural Phosphates (NP) for agricultural intensification have shown its limited effectiveness due to its low solubility in soil. This is why we have undertaken this work which has as general objective the valorization of agro-industrial waste (spent grains from the BB Lomé Brewery) and cow dung by vermicomposting with natural phosphate input for soil fertilization. During the work four (04) treatments were carried out, including the absolute control which did not receive NP. The bins were filled with constant quantities of material (1kg of cow dung) and Eudriluseugeniae worms (500g) except the NP which was added in quantities of 10g in bins two (02), three (03), and 50g in bin four (04) and 50g of spent grains in bin three (03). Regular watering and turning over were the maintenance operations. The vermicompost after 3 months of monitoring is analyzed. In comparison with the characteristics of the control bin, we noted at the end a decrease in the contents of total organic matter, total carbon, to the doses of NP provided. On the other hand, the assimilable phosphorus content of tanks 1 and 2 is constant. These values are higher than those of bin 4 and slightly lower than those of bin 3 due to the presence of spent grain. This finding shows that the organic matter/natural phosphate ratios of our study did not produce enough acid for the solubilization of the added phosphate, but the contribution of the spent grain contributed to an increase in assimilable phosphorus.

INTRODUCTION

Growing populations and rapid urbanization followed by changing consumption patterns have led in recent years to an explosion in the amount of waste. According to a World Bank report What to Waste 2.0, the world produces 2.01 billion tons of municipal solid waste per year, of which at least 33% is not properly treated and according to the World Bank report of September 20, 2018, global waste generation will increase by 70% by 2050 [1].. Today, the management of this waste represents socio-economic and environmental challenges for countries. To do so, several methodologies have been put in place until the publication of the European Directive2008/98/EC, which has allowed us to prioritize the 5 modes of waste management which are: prevention, reuse, recycling, recovery, and finally disposal.

Indeed, the waste resulting from food processing activities (brewery dregs, etc.) represents considerable volumes that must be dealt with to reduce environmental damage and preserve public health. The majority of this waste is eliminated by incinerators or stored in landfills. Tropical and subtropical soils are generally acidic and often extremely deficient in phosphorus with high phosphorus fixation capacities [2]. Therefore, substantial phosphorus inputs are required for optimal growth and adequate food production [2]. Appropriate use of rock phosphate (NP) as a source of P can contribute to sustainable agricultural intensification, especially in developing countries with NP resources. But the direct use of rock phosphate in agriculture has limited effectiveness due to its low solubility in soil. Certain processes such as partial acidulation, the addition of sulfur, or its use in conjunction with organic matter can improve its efficiency. To respond to this agronomic, ecological, and economic problem, it is necessary to develop a method of recycling organic waste by transforming it into an organic phosphate amendment to reduce the rate of agri-food waste and to contribute to the solubilization of natural phosphate. It is within the framework of the valorization of the waste of the Lomé brewery, cow dung, and natural phosphate of Togo that this study falls.

MATERIALS AND METHODS

Materials

Agro-industrial waste (brewery dregs from the BB Lomé brewery) and cow dung pre-composted for two weeks were used to avoid the thermophilic phase that would hinder the survival of the earthworms. Cardboard was also added to help maintain humidity.

- **Phosphate ore**

The phosphate ore used in our study is that mined at Hahotoé-Kpogamé (Figure 3). The characteristics of this ore are described below (Table 1). The samples were taken from the merchantable ore, which is the product of raw ore processing.

Table 1: Chemical composition of Hahotoé-Kpogamé ore [3].

Parameters	Raw material	Washed material
CaO (%)	35,80	55,60
P_2O_5 (%)	28,20	38,30
SiO_2(%)	12,50	2,10
Fe_2O_3 (%)	7,20	0,03
AL_2O_3 (%)	5,60	0,01
MgO (%)	3,80	0,01
K_2O (%)	2,60	0,02
Na_2O (%)	2,80	0,01
CO_3^{2-} (%)	0,75	0,68
F^- (%)	0,15	0,40
Cd (ppm)	49,00	58,00
Mn (ppm)	74,00	86,00
Zn (ppm)	35,00	3,50
Cu (ppm)	45,00	2,70

- **Earthworms**

The earthworms used are of the species *Eudriluseugeniae*. They come from West Africa and were collected in the marshy areas of the ZIO of MAYAKOPE in Lomé (Figures 1 and 2).

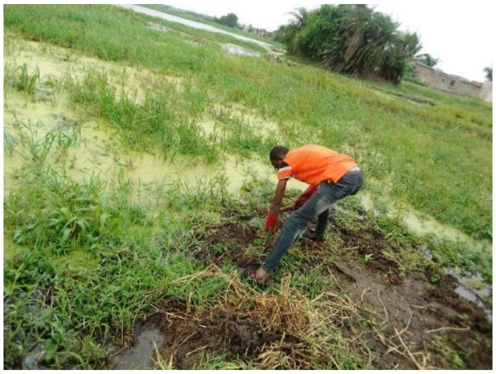

Figure 1: Worm harvesting in Mayakopé

Figure 2: Worms used in worm composting (***Eudriluseugeniae***)

- **Material in the laboratory**

As laboratory equipment, we used a balance, a centrifuge, a pH meter, an oven, a heating plate, a nitrogen distiller, an atomic absorption spectrophotometer, glassware.

- **Drums**

Brewers' grains are the solid, non-soluble organic residues from the processing of germinated and dried cereal grains (malt) for the production of beer and other products (malt vinegar or malt extracts). Spent grain is generally derived from cereals such as barley, maize, rice, wheat, sorghum. Table 2 inspired by [4], shows the chemical composition of brewers' grains studied by some authors.

Table 2: Chemical composition of spent grain from some authors [4]

Components (%MS)	(Kanauchi *et al.*, 2001)[5]	(Pedro Silva *et al.*, 2004)[6]	(Mussatto& Roberto, 2008)[7]	(Adeniran *et al.*, 2010) [8]	(Khidzir *et al.*, 2010) [9]
Cellulose	25,40	25,30	16,80±0,80	-	-
Hemicellulose E	-	41,90	28,40±2,00	-	-
Lignin	11,90	16,90	27,80±0,30	-	-
Protein	24	-	-	2,40±0,20	6,40±0,30
Ashes	2,40	4,60	4,60±0,20	7,90±0,10	2,30±0,80
Fiber	-	-	-	3,30±0,10	-
Moisture content	-	-	-	6,40 ±0,20	-
Carbohydrates	-	-	-	79,90±0,60	-
Lipids	10,80	-	-	-	2,50±0,10
Total carbon	-	-	-	-	35,5±0.30
Total nitrogen	-	-	-	-	1,025 ± 0.05

Figure 3: Rock phosphates

Figure 4: Cow dung

Figure 5: Lomé Brewery's grain mill

- **Cow dung**

Dung is the product of digestion ingested by bovids[10]. Cow dung can be defined as the waste of bovine species. The percentage of mineral elements constituting cow dung varies according to the type of feeding of the bovine: 16.42% nitrogen; 13.72% phosphorus; 19.12% potassium; 16.21% calcium; 16.63% magnesium; 17.87% sodium and contains 80 to 90% water and 20% ash. Its mineralization rate is 1.03% per day [11].

Composting methods

Agro-industrial waste (brewery draff) and cow dung are composted for two weeks in static piles aerated by turning. The bin method was used for vermicomposting. Four treatments were applied with 10 g, 10 g, and 50 g of NP in bins 2, 3, and 4, mixed with 1 kg of cow dung, 500 g of worm compost, and cardboard, except bin 1, which received no NP and was, therefore, an absolute control. In bin 3 we added 50 g of spent grain in addition to the cow dung, compost worms and cardboard. The waste in the bins was covered with cardboard (very high absorbency) to keep the moisture in and protect the earthworms from light. The compositions of the bins are described in Table 3.

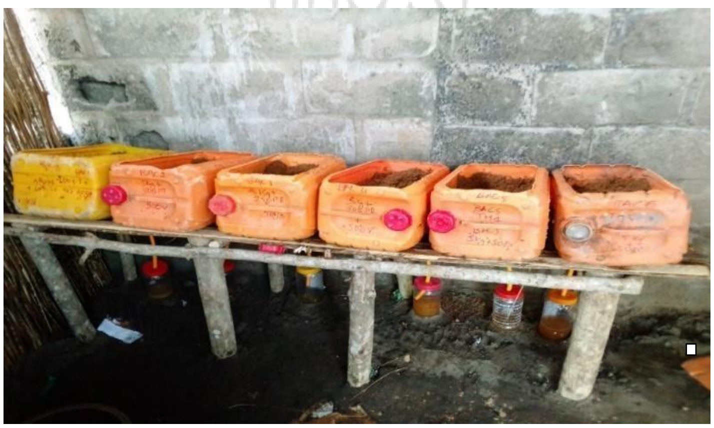

Figure 6: Vermicomposting Bins

The bins are watered sufficiently on the first day until the excess water runs off. At the end, the vermicomposts were sieved to 4 mm and then analyzed at the GestionTraitement et Valorisation des Déchets (GTVD) and Laboratoired'Hydrologie Appliqué et Environnement (LHAE) of the

University of Lomé.The vermicomposting bins are made of plastic and measure 47 cm x 22 cm x 25 cm. These bins are equipped with a leachate collection device.

Table 3: Composition of each vermicompost bin

	Content
Bac 1	1kg of dung +500g of worms +Carton
Bac 2	1kg of dung +500g of worms +10g of NP +Carton
Bac 3	1kg of dung +500g of worms + 50g of dregs+ 10 of NP+ Cardboard
Bac 4	1kg of dung +50g of PN+ Carton +500g of worms

Determination of the different elements

At the end of the vermicomposting process, samples were collected, dried in the shade, and packaged for chemical analysis in the laboratory. Analyses included temperature, moisture content, pH, total organic matter, total organic carbon, total nitrogen, total phosphorus, and available phosphorus.

RESULTS AND DISCUSSION

Temperature evolution (T°C) :

The temperature was recorded every day during the first month (the first 30 days) and thereafter every second day. During the thermophilic phase, we recorded maximum temperatures of 50°C for the spent grain and 35°C for the cow dung. During the vermicomposting phase, we obtained optimal temperatures for our bins 1, 2, 3, and 4 of 27.6°C; 27.9°C; 29.8°C; and 27.8°C, respectively. According to [12], the preferable temperature for *Eudriluseugeniae* would be between 15.7°C and 23.2°C; however, the *Eudriluseugeniae* species used in the vermicomposting process can tolerate up to 35°C. We conclude that in our case, the temperatures recorded in bins 1, 2, 3, and 4 are favorable for the vermicomposting process.

Moisture content (%H)

The moisture content (%H) during the vermicomposting process averaged 61; 58; 53; and 51% for bins1, 2, 3, and 4 respectively. Since worms breathe through their skin, moisture content below 50% in the bedding is dangerous [13]. Thus, the moisture content during our process is normal for the survival of worms (*Eudriluseugeniae*).

pH of vermicomposts

The pH measurement was performed on the raw materials and on the vermicompost samples. Several measurements were taken from the beginning to the end of the vermicomposting process. The results are shown in the table 4 below:

Table 4: Changes in pH of vermicompost's

Age of vermicompost in days	Bac1	Bac 2	Bac 3	Bac 4
0	8.80	8.40	8.50	8.50
15	8.40	8.20	8.50	8.50
30	8.30	8.10	7.90	8.20
45	8.20	7.70	7.70	7.80
60	7.90	7.80	7.70	7.90
75	7.80	7.50	7.60	7.60
90	7.92	7.98	8.16	8.20

For Bouche, composting and vermicomposting have a pH close to neutral. The vermicomposts obtained in our work have a slightly basic pH, which is due to the cow dung, which is a basic material.

Total Organic Carbon TOC, Organic Matter OM, and total nitrogen

These three parameters were determined on vermicompost samples after a 90-day period using the protocols described above. The results are as follows (Table 5):

Table 5: Results of TOC, OM, and NTK determination of the different vermicompost's

	OM	TOC	N	C/N
Bac 1	62.00	31.00	6.93	4.47
Bac 2	53.44	26.72	6.96	3.84
Bac 3	48 .00	24.00	7.72	3.10
Bac 4	44.27	22.40	7.40	2.99

Evolution of TOC and OM

OM generally decreases during the composting process as a result of the mineralization of organic matter. Therefore, the presence of organic matter resistant to degradation contributes to the increase in OM. The organic matter obtained for vermicompost's 1, 2, 3, and 4 is respectively: 62.00%; 53.44%; 48.00% and 44.27%). It can be seen that the OM content is slightly higher in the control vermicompost. This result may be because the presence of rock phosphate favored the mineralization of the organic matter in the other bins.

Evolution of total nitrogen

The results show a higher nitrogen content in the vermicompost 3 sample at the end of vermicomposting. According to Mustin, the increase in the percentage of total nitrogen during the composting process is due to the degradation of proteins in the starting materials by heat and microorganisms. The result obtained is therefore consistent with the fact that spent grain is rich in protein.

Evolution of the C/N ratio

The previous table revealed that the C/N ratio was low in all 4 bins. The statistical analysis did not reveal a significant difference between the different treatments. According to several authors, the final C/N ratio should be between 10:1 and 15:1. During the composting process, the C/N ratio decreases due to the release of carbon in the form of CO_2.During our trial we had values 4 .47; 3.84; 3.10; 2.99 for bins 1,2, 3 and 4 respectively. Due to the very high Nitrogen rate that we recorded in our tanks. Given the low C/N values of our vermicomposts, we cannot conclude on the maturity of our vermicompost.

Determination of total phosphorus in raw materials in % P_2O_5

The results of the assays are shown in the following table 6:

Table 6. Determination of total phosphorus in raw materials in % P_2O_5

Raw material	Total phosphorus content in %P_2O_5
Natural phosphate of hahotoè-Kpogamé	34,59
Brewery Dairy	7,66
Cow dung	3,02

The analysis of table 6 shows that the brewery dregs from BB Lomé are richer in phosphorus than cow dung. This observation explains the increase in the assimilable phosphorus content of tank 3 compared to tank 1 (control tank), whereas the other tanks containing rock phosphate that did not receive the dregs had a low assimilable phosphorus content compared to the control tank.

Assimilable phosphorus content of vermicompost's and leachates

The results of the assimilable phosphorus determination performed at the GTVD laboratory and confirmed by ITRA on vermicompost's and leachates are shown in the following table 7:

Table 7. Assay results for available phosphorus in different vermicompost's and leachates

Bin	**Assimilable phosphorus content in mg P_2O_5/Kg**	**Assimilable phosphorus content of leachate in mg P_2O_5/L**
01	156,82	169.80
02	156,13	131.10
03	166,8	166.25
04	150,66	162.82

The analysis of the table shows that the addition of rock phosphate during vermicomposting did not have a positive effect because the available phosphorus content of the control tank was higher than the available phosphorus content of tank 4, which received 50 g of NP. However, the addition of spent grain in tank 3 had a positive effect by increasing the assimilable phosphorus content of this tank compared to the control tank. The same observation regarding available phosphorus was made by Lompo, 1993 in composting. He justified this by the rapid mineralization of organic phosphorus contained in the organic matter by the microorganisms [14]. These results also confirm those obtained by the FAO in 2004 which says that it is difficult to dissolve completely certain natural phosphates because they are cemented by silica or blocked-in iron and aluminum oxides [14]. It appears from our test that the organic matter / NP ratio used did not produce enough acid for the solubilization of NP.

Table 8: Agronomic values of different vermicompost and leachate at the end of vermicomposting.

No.	Parameters/Samples	Bac 1	Bac 2	Bac3	Bac 4
01	Leachate pH	7.75	7.77	7.33	7.10
02	pH of vermicompost	7.92±0.03	7.98±0.11	8.16±0.17	8.2±0.02
03	Moisture content (%)	61	58	53	51
04	Leachate conductivity (µS/cm)	6710	5260	5910	5390
05	Vermicompost conductivity (mS/cm)	2.34±0.09	2.31±0.08	2.24±0.19	2.05±0.28
06	BOD5 (mgO2 /L)	200	200	125	150
07	COD (mgO2 /L)	2400	800	1200	1800
08	BOD5/COD ratio	0.08	0.25	0.104	0.08
10	MO in %.	62.00	53.44	48 .00	44.27
11	TOC in %.	31.00	26.72	24.00	22.40
12	NTK g N/100g	6.93	6.96	7.72	7.40
13	C/N ratio	4.47	3.84	3.10	2.99
14	Available phosphorus in vermicompost in mgP_2O_5	156,82	156,13	166,8	150,66
15	Assimilable phosphorus in leachate in mgP2O 5/L	169.80	131.10	166.25	162.82

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CONCLUSION

The general objective of our study was the valorization of agro-industrial waste (brewery dregs BB Lomé) and cow dung by vermicomposting with the contribution of natural phosphate for the fertilization of our grounds. The results showed that the contribution of the dregs showed a positive effect on the nitrogen contents of the vermicompost, we recorded a value higher than that of the vermicompost in bins 1, 2, 4. On the other hand, the levels of available phosphorus remained low compared to the absolute control. This suggests that the amount of organic matter added does not appear to have created a sufficiently acidic environment for greater phosphate solubilization.

ACKNOWLEDGEMENTS

The authors would like to thank International Development Research Centre (IDRC) for support through the project FGéPro (Training in Industrial Process Engineering for Treatment and Valorization of Agricultural/Agro-industrial Waste in High Added Value Products).

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Conflict of Interest	No
Funding Information	Laboratory research
Authors' Contribution	all authors contributed laboratory handling, writing, and reading.
Acknowledgement	The authors would like to thank International Development Research Centre (IDRC) for support through the project FGéPro (Training in Industrial Process Engineering for Treatment and Valorization of Agricultural/Agro-industrial Waste in High Added Value Products).