



Stabilization by co-composting dry drain sludge with fermentescible fractions of household garbage from the city of Sokodé (Togo)

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ABSTRACT

The management of fecal sludge is a recurrent problem for the actors in charge of the urban environment of Sokodé. Often, the sludge emptied is poured on empty spaces or used, without treatment, on urban and suburban agricultural land and for market gardening; in fact, a survey of market gardeners in the city of Sokodé found that around 40% of them directly use untreated dried sludge to amend their production areas. Consequently, bacteria and worm eggs can adhere to vegetable products and infect consumers. In view of these potential risks, the objective of this work was then to stabilize the organic matter of dried sludge with a view to their hygienic use for the agricultural amendment. In this research it has been developed compost obtained from fermentable fractions of household waste and compost obtained from the fermentable fractions of household waste with sludge (co-composting). Results have shown that both types of compost have a high content of nutrients, which is an advantage for use in the agriculture. Therefore, the assessment of stability and maturity parameters shows that co-composted sludge produces mature compost and can improve soil fertility without biological risk.

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Keywords: Bacteria, worm eggs, sludge, organic materials, market gardening.

INTRODUCTION

The accelerated growth of the population in the developing countries generates an increase of the food demand (FAO, 2017). To satisfy this demand, agricultural intensification appears as an unavoidable option which is putting pressure on the ecosystem and in turn leading to reduced soil fertility, so farmers apply nutrients in the form of chemical fertilizers and animal manure to provide the nitrogen

and phosphorus that crops need to grow. Chemical fertilizers increase crops costs; besides, the excessive use of fertilizers produces negative environmental impact because not fully utilized nitrogen and phosphorus can be lost from the farm fields producing soil salinity, heavy metal accumulation, water eutrophication and accumulation of nitrate, to consider in terms of air pollution in the air of gases containing nitrogen and sulfur, giving and can lead to

problems such as the greenhouse effect (Savci, 2012).

An alternative to chemical fertilizers is the use of drained sludge to reduce pathogens, but also to eliminate odor and reduce organic matters, preventing or inhibiting future decomposition (Ouedraogo, 2016). Stabilized drained sludge results on organic amendment properties, but also on a source of nutrients as nitrogen, phosphorus and potassium which give them organic fertilizer properties (Ouedraogo, 2016), so they can therefore be a substitute or supplement to synthetic mineral fertilizers, thereby closing carbon and nutrient cycles (Savci, 2012).

In developing countries, urban areas are estimated to have higher sanitation coverage than rural areas (Carlton et al., 2012), but statistics had often not come out clearly to show the severity and complexity of sanitation challenges affecting towns and the urban poor (Letah et al., 2019). Besides not landfilling of this waste reduces environmental impact (Ouedraogo, 2016), in the developing countries, in terms of sanitation, drained sludge is most often discharged near watercourses, empty spaces or reused without treatment on agricultural land. Thus, the establishment of a fecal sludge management plan is necessary for the adequate protection of the environment and public health (Douanla et al., 2019). But usually, an agreement has been reached between some farmers and mechanical dumpers and the sludge is being dumped in their fields without any sanitation. For example, in Sokodé (Togo) a survey of market gardeners in the city revealed that because of poor soils, around 40% of them directly use untreated dried fecal sludge to amend their production areas (PEAT2, 2018). Since the sludge is not treated, bacteria and worm eggs can adhere to plants (market garden and agricultural products) and infect people who consume them raw or poorly washed (Ouedraogo, 2016). Human excreta are used to support food production in many countries all around the world. However, reuse of untreated feces for agricultural purposes can bare a great health risk, because a great

number of pathogens can be found in human excreta (Gallizzi, 2003). It has been shown that fecal sludge in Ouagadougou after drying for three months, still contains an average of 615 helminth eggs, 25 eggs / g and 932 protozoan cysts, 37 cysts / g of dried mud (Ouedraogo, 2016). Thus, drying alone does not eliminate all pathogens. In consequence it is necessary composting sludge to improve quality but several studies on composting of sludge have shown that a sufficiently high temperature for the destruction of pathogens is difficult to achieve because temperatures normally increase by 10 to 15 °C above ambient (Bjorklund, 2002). Thus the use of sludge only for market gardening and agriculture is a danger for consumers. However, the co-composting with the fermentable fractions of the solid waste with this dewatered sludge could produce hygienic composts because during the co-composting process, the sludge is disinfected because the pathogens present in the sludge are destroyed or inactivated during the thermophilic phase (temperature between 40 and 70 °C) (Gallizzi, 2003). In addition, this fecal sludge will integrate into the production cycle not as waste, but as a source that can contribute to improving the living conditions of the population by increasing agricultural production. Thus, the objective of this work was to stabilize the organic matter of the dried sludge by co-composting the sludge with the fermentable fractions of the household waste for their hygienic use for the agricultural amendment.

The pretreatment of these sludges by co-composting, in combination with the fermentable fractions of the solid waste of the city of Sokodé, could be an added value for these market gardeners and farmers while limiting the financial efforts of the poorest to buy chemical fertilizer.

MATERIALS AND METHODS

Materials

Organic waste used in this research came from Sokodé, capital of the Central Region and the Prefecture of Tchaoudjo, located between 8 ° 57 'and 9 ° 03' of Latitude

North and 1 ° 05 'and 1 ° 11' of Longitude East, 346 km north of Lomé, it has long been the regional capital of the northern zone and especially the second center of settlement of the country. With a population estimated at 111258 inhabitants, Sokodé enjoys a tropical climate of transition between Guinean (wet) and Sudano-Sahelian (dry).

Two fractions have been used for co-composting process: organic matter from municipal solid waste which are a mixture of household waste, hotels, markets, restaurants and training centers; and dried sludge from dry pits, septic tanks and public septic tanks have been used to study co-composting process.

In the co-composting swath, dried sludge accounts for 1/3 and fermentable fractions of solid waste 2/3 (photo1) (Remy, 2007; ADEME, 2015). These proportions make it possible to obtain an essential lacuna mixture to the air circulation (Remy, 2007). Standard compost here is compost made only from fermentable fractions of household waste. It was done in order to compare decomposition processes with co-compost.

Turnaround times correspond exactly to a fixed duration (every two weeks). The windrows were returned two (02) times during the fermentation phase in the (2nd and 5th) week and two (02) times (7th and 9th week) during the ripening phase to promote their homogenization (Koledzi et al., 2011). The co-composting period was set at three months and maturation was done under the shed (covered area). The resulting compost was screened and then stored.

Methods

Agronomic characteristics of dried sludge and FFOM

Dryness, organic matter, total organic carbon content, total phosphorus content (P_2O_5), magnesium and potassium content have been determined to characterize dried sludge and FFOM used in this research. Dryness indicates the water content of the sludge, and it was obtained after drying at 150 °C for 2 hours. In the fermentescible fractions of household waste (FFOM), dryness has been obtained after drying at 105 °C for 2 hours.

The organic matter content was determined in the dried sludge and in the fermentable fractions of the solid waste by the loss-to-fire method. The total organic carbon content and total phosphorus content (P_2O_5) were determined after oxidation and Spectrometric assay, respectively. Total Kjeldhal Nitrogen (NTK) was obtained by mineralization of the samples in acidic medium and in the presence of catalyst. Finally, the magnesium concentration and the potassium content in the samples were determined by titration with Ethyl tetra acetic diamine (EDTA) after aqua regia extraction and by Atomic Absorption Spectrometry, respectively.

Co-composting process control

Humidity, temperature, pH, organic matter and the C / N ratio have been monitored to control co-composting process. They were evaluated every two weeks throughout the process.

The moisture content is determined by drying at 105 °C (Yobouet et al., 2010), the temperature by electronic thermometer, the pH by an aqueous suspension according to standard method AFNOR NF ISO 10-390 (Belyaeva et al., 2009) and the rate of organic matter by calcination at 550 °C (Unmar et al. 2008).

Total phosphorus was determined by colorimetry using ammonium molybdate and ascorbic acid (Bustamante et al., 2008).

Compost quality

The quality of the compost was evaluated by the total nitrogen content (TNK), the C / N ratio, total phosphorus. In addition, the application of the respirometric test, self-heating tests (TAE), the determination of the index germination (GI), exchangeable cations (Ca, Mg, Na and K) and the cation exchange capacity (CEC) and then the heavy metal content were used to evaluate the maturity and stability of the composts produced.

Kjeldahl nitrogen (NTK) is determined by the Kjeldahl method (Barrena et al., 2010) as described by AOAC (Association of Official Analytical Chemists). Total phosphorus was determined by colorimetry using ammonium molybdate and ascorbic acid (Bustamante et al., 2008).

Stability and maturity were evaluated by performing the AT4 respirometric test at four days, determining the germination index (GI) and the cation exchange capacity (CEC). To do that, the composts were placed under specific conditions of temperature, humidity and thermostatically controlled chamber at 20 ± 1 °C inside a Dewar vase, and the temperature has been monitored for 10 days, so the maturity index is a function of the highest temperature reached during the test.

Respiratory test is based on the measurement of the Biological Oxygen Demand (BOD) obtained will be facilitated by the use of Oxitop® WTW (Barrena et al., 2010; Unmar and Mohee, 2008).

Phytotoxicity of composts has been determined by the effect of aqueous extracts of compost on the germination of corn seeds (*Zea mays*), cowpea (*unguiculata* of *Virgna*) considered staple crops in Togo and cress (*Lepidium sativum* L) (Miyuki et al., 2005). The GI was calculated by the formula of (Koledzi et al., 2019):

$$GI = \frac{Nm_{gg} \times L_r}{Nm_{ggt} \times L_{rt}} \text{ Eq.1 where}$$

Nm_{gg}: Number of sprouts; L_r: average length of the root;

Nm_{ggt}: Number of seeds sprouted from witness; L_{rt}: average length of the control root

Self-heating tests (TAE), developed in Europe, is recommended by the German standardization body (Bundes Gütegemeinschaft Kompost BGK) (F.C.Q.A.O, 1994). The maturity index is a function of the highest temperature reached during the test. The latter is qualified as: ripe for a degree of ripening of V (temperature <30 °C) or a degree of IV (temperature <40 °C); fresh compost for degree III

Cation Exchange Capacity (CEC) is the maximum total amount of cations compost can trap at a given pH. The exchangeable Cations (Ca, Mg, K and Na) and the content of metallic trace elements (Zn, Cu, Ni, Cd, Pb) were determined by Atomic Absorption Spectrophotometer (Koledzi et al., 2019). For a compost to be used as an organic fertilizer, its metallic trace element content must respect certain ecological standards. Since Togo does not have a standard, international standards have been used (Table 1).



Photo 1: Co-composting dry fecal sludge and organic solid waste.

Table1: Standard NFU 44-051 of metallic trace element in compost at the end of the process.

Items analyzed	Cu (mg/kg)	Zn (mg/kg)	Ni (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
NFU 44-051	300	600	60	3	180

RESULTS

The results are discussed in a first part in relation to the characterization of organic sources used, followed by follow-up of the co-composting process and in a second part in relation to the quality of the compost obtained. The results of co-composting are compared with those of standard composting in order to highlight the interest of this process.

Agronomic characteristics of dried sludge and FFOM

Given the absence of national standards on the nutrients of recoverable bio-solids, the AFNOR NFU 44-095 standards applicable to composts were used to exploit our results of the agronomic parameters of the substrates (dried sludge and fermentable fractions of solid waste). The standard NFU 44-095 is specific for the placing on the market of composts containing sludge from water treatment. The standard NFU 44-051 is specific for the placing on the market of all other types of composts.

Table 2 shows dried sludge and FFOM characterization, including a comparative analysis of the fulfilment of agronomic parameters with the requirements of NFU 44-095 and of NFU 44-051.

In the case of dried sludge, dryness is 80.20%. They also contain 54.72% organic matter relative to the dry matter. Indeed, the nutrient content gives 0.31% nitrogen, 1.30% phosphorus and 0.19% potassium and 0.48% MgO for the dried sludge. These grades are lower than those required by NFU 44-095.

The fermentable fraction of solid household waste contain 60.2% organic matter relative to the dry matter. The nutrient content gives 0.74% for nitrogen, 0.18% for

phosphorus and 0.14% for potassium. Finally, the C / N ratios were 21% and 15.3% for dried sludge and FFOM, respectively.

Control co-composting process

The moisture content reached 62% in the standard compost pile and 65% in the co-compost pile. The moisture content was maintained between 35-62% for standard compost and 38-65% for co-compost during the process (Figure 1). The moisture content at the end of the process is 35% for the standard compost and 43% for co-compost.

The daily temperature recorded during the co-composting process showed that, after four days, the temperature in the windrows reached 65 °C for co-compost and 70 °C for standard compost. These temperatures undergo an increase after each turn before decreasing. Temperatures varied between 45-65 °C for co-compost and between 38-70 °C for standard compost in the fermentation phase and between 29-45 °C and then between 30-36 °C in the ripening phase (respectively for co-compost and for standard compost).

By correlating the evolution of pH with organic matter, there are contrary variations. The pH increases while the organic matter content decreases (the organic matter content decreases more quickly in the pile of co-compost than in the standard compost). pH values remained between 6 and 8 ± 0.01 for the standard compost and between 6.5 and 8 ± 0.01 for the co-compost in the fermentation phase. At the end of the process, the pH is 8.3 ± 0.01 for standard compost and 8.1 ± 0.01 for co-compost. The evolution of organic matter during the process shows that initially the rate of organic matter is high in compost piles. This rate then undergoes a gradual decrease over time from the fifteenth day to a minimum

value of about 36% for standard compost and 45% for co-compost.

The ratio C/N decreases during composting (Table 3).

Compost quality

Compost quality has been analyzed in terms of nutrients content and the study of the maturity and stability of the compost.

Content of nutrients

% of MO, %Ntotal, C/N ratio, %P₂O₅, %K₂O and %MgO have been analyzed to determine the quality of compost produced. Table 4 summarizes values obtained for both compost and co-compost produced.

Concerning nitrogenous matter content, at the end of process the results show 0.92% for the standard compost and 1.1% for the co-compost.

The quality of the compost at the end of the process could be also evaluated by its C/N ratio. The results obtained show that the C / N ratios presented are average but close to the value recommended by the standard NFU 44 - 051 which is 13 for mature compost. The

C/N ratios of the two types of compost are comparable.

For the total phosphorus, the result show that the content is higher in co-compost (2.2%) compared to that of standard compost (1.8%).

In the case of the potassium, the content are 1.62% for standard compost and 1.54% for co-compost.

Finally, both types of compounds also have a high content of other nutrients such as Na₂O, MgO, and CaO (Table 4).

Maturity and stability of the compost

Table 5 shows a practically constant consumption for the fourth day (for a degree of maturation of IV (temperature <40 °C)) for both types of composts.

Values of GI in Table 5 shows that the composts produced have a germination index greater than 50%. Finally, higher cation exchange capacity value is than 60meq / 100g for both composts.

Metallic trace element content

The contents of metallic trace element are reported in Table 6.

Table 2: Agronomic characteristics of dried sludge and FFOM.

Parameters	Dryness (%)	%MO	%COT	%Ntotal	C/N	%P ₂ O ₅	%K ₂ O	%MgO
Dried sludge	80.20	54.72	6.51	0.31	21	1.30	0.19	0.48
FFOM	39.2	60.2	11.35	0.74	15.3	0.18	0.14	0.12
NFU44-095	>50%	>30%	-	<3%	≤25	<3%	<3%	-
NFU44-051	-	>30%	-	<3%	13	<3%	<3%	-

Table 3: C/N ratio during the process.

Parameter	Initial phase (fermentation)		Final phase (maturation)	
	Standard compost	Co-compost	Standard compost	Co-compost
C/N ratio	38	35	20	18

Table 4: Content of nutrients.

Items analyzed	Standard compost	Co-compost
%MO	36	45
%N Total	0.92	1.1
%C	11.8	14
C/N ratio	12.83	12.72
P ₂ O ₅ (%)	1.8	2.2
K ₂ O (%)	1.62	1.54
Na ₂ O (%)	0.8	0.67
MgO (%)	0.42	0.56
CaO (%)	2.6	3.7
pH	8.3	8

Table 5: Measurements of AT4, GI composts produced and Cation exchange capacity.

Items analyzed	Standard compost	Co-compost
Self-heating capacity (AT4)	Degree IV (temperature <40 ° c)	
Germination index (IG) (%)	65	75
Cation Exchange Capacity (CEC) (mg eq / 100g)	64	68

Table 6: Content of compost in Metallic trace element compared to standards NFU 44-051.

Items analyzed	Standard compost	Co-compost	NFU 44-051
Cu (mg/kg)	23	17	300
Zn (mg/kg)	161	222	600
Ni (mg/kg)	6	9	60
Cd (mg/kg)	1	2	3
Pb (mg/kg)	17	20	180

DISCUSSION

Agronomic characteristics of dried sludge and FFOM

Concerning the dryness value of dried sludge is greater than 50% required by the standard. This sludge is well dehydrated and can easily be transported to fields or compost sites. The content of organic matter meets the requirements of NFU 44-095, according to which the organic matter must be greater than 30% relative to the dry matter. The nutrients content are lower than those required by NFU 44-095.

For the fermentable fraction of solid household waste the content of organic matter meets the requirements of NFU 44-095 and of NFU44-051. The low content compared to that of fermentable fractions of solid wastes is due to the fact that most of the organic matter of raw sludge is lost through mineralization in the sanitation works (Ouédraogo, 2016).

The analyzes on the dried sludge show an organic matter in advanced state of decomposition compared to that of the fermentable fractions of the solid waste and whose nutritive elements would be more or

less easily available for the plants (Ouedraogo, 2016).

The nutrients that found in the fermentable fractions of solid wastes are the main required for crop production. The values of C/N ratio that found in dried sludge and in FFOM are lower than 25%, limit established in guidelines considered. This ratio measures the relative proportions of carbon and nitrogen, nutrients essential for the life of microorganisms. Low values of dehydrated sludge and FFOM show that they cannot be used alone for compost at the risk of witnessing the putrefaction of the material accompanied by release of foul odors hence the need for co-composting with the biodegradable fractions of solid wastes for an improvement of the C/N ratio. The contribution of fermentable fractions of solid waste is therefore a potentially important enrichment in nutrients. A compostable waste must have a C/N ratio close to 15 in order to observe a sufficiently rapid degradation of the biodegradable organic matter (Koledzi et al., 2011). Thus, the fermentable fractions of the solid waste of the city of Sokodé, are of interest from the point of view of compostability, a C/N ratio is 15.3.

In terms of normative references, it is possible to conclude that the contents of the major fertilizers of dried sludge and fermentable fractions of solid wastes meet the quality requirements of NFU 44-095. Thus, this garbage can be used to produce compost as an organic amendment to reduce the excessive use of chemical fertilizers.

It can be concluded from these characteristics that these substrates can be directly used for soil amendment. But it has been shown that drying alone does not eliminate all pathogens. Thus the use of sludge only for market gardening and agriculture is a danger for consumers. In addition, the organic matter of both of dried sludge and FFOM is not stabilized hence the need for composting before use as soil amendment.

Control co-composting process

The results of the four parameters monitored during the composting and co-composting (Photo 2) process such as the

moisture content, the hydrogen potential, the organic matter content and the temperature are shown in Figures 1, 2, 3 and 4.

The rate of the moisture content decreased in both types of compost during the process. The small variation observed are due to the watering during the reversals. The moisture content is medium and sufficient for degradation of the organic matter, the optimum being between 40% and 60%. The moisture content at the end of the process is in the range indicated in the literature which is between 35-45% for a mature compost (Koledzi, 2011).

The temperature decreases during the co-composting process to stabilize after three months. The values obtained during the co-composting process are comparable to those found in the literature. Indeed, during a process of co-composting temperature between 40 and 70 °C (Gallizzi, 2003). For standard compost, the temperature range during the process is a normal process (Koledzi et al., 2011); in fact, the maximum temperature reached in the fermentation phase is sufficient to destroy certain pathogens and reduce the risk of contamination of vegetable products. Thus, the co-composting has the advantage of increasing the temperature that can destroy some pathogenic germs.

The values of pH are similar to those found by Koledzi (2011) which are between 5-8 for the initial phase and between 7-8.5 for the mature compost. The slightly acidic pH at the beginning of the process indicates that there is thus production of organic acids and thus substances containing simple sugars. The pH remained basic for all piles by ammonia gas production (Sánchez et al., 2017) associated with the degradation of amine-releasing proteins and the decomposition of organic acids (Sánchez et al., 2017) after the sixth week of production at the end of the process. This would also be related to the contamination of solid waste by wood ash and charcoal (Koledzi, 2011) because wood and charcoal are the energy sources for most households in the city of Sokodé.

The decrease of organic matter during the process could be explained by a degradation of organic matter by microorganisms. These grades indicate that

the organic matter is stabilized and the composts have reached maturity. The organic matter content at the end of the process (mature compost) is greater than 35% for standard compost and more than 40% for enriched compost (Koledzi, 2011). Organic matter levels are higher than those found by Koledzi et al. (2011) in maturing composts.

The ratio C/N decreases during composting (Table 3); this can be explained by the fact that the microorganisms consume more carbon than nitrogen (Sánchez et al., 2015). The carbon consumed is metabolized and released as carbon dioxide (CO₂) while the nitrogen is metabolized and released as volatile compounds such as NH₃ (Sánchez et al., 2015).

Compost quality

Content of nutrients

The organic matter contents in both types of composts comply with standards NFU 44-051 and NFU 44-095 and indicate that the composts obtained are mature and stabilized for use as soil amendment (Rafolisy et al., 2015). The content of organic matter in co-compost is greater than the content in standard compost, confirming that sludge is richer in organic matter than the fermentable fraction of solid waste.

Concerning nitrogenous matter content, at the end of process, the values are in accordance with compost quality standards, although co-compost is richer in nitrogen than standard compost so its contribution to the improvement of the yield in agriculture will be higher. The low values of total nitrogen, NTK correlate with pH values (8-8.3).

The C/N ratios presented are average but close to the value recommended by the standard NFU 44 - 051 which is 13 for mature compost. The C/N ratios of the two types of compost are comparable, so it can be concluded that co-composting has made it possible to improve the C/N ratio. Ammonia nitrogen and readily mineralizable organic nitrogen from sludge and fermentable fractions of solid waste in compost will be readily available to plants. The C/N ratio is less than 20 indicating that composts will be able to mineralize rapidly and release

significant amounts of nitrogen to crops (Bipfubusa et al., 2006).

Concerning the total phosphorus, the difference between co-compost and standard compost would be related to the nature of the substrates, the fecal sludge being richer in phosphorus than the solid waste. Indeed, foods especially cheese, livers, nuts, fish, meats, poultry, eggs particularly rich in phosphorus are generally consumed by the populations and can be found in high quantities in sludge more than garbage. These rates are high and will ensure the proper development of plant roots (Ouedraogo, 2016). The content of potassium in both types of composts is also in line with the standards NFU 44-051 and NFU 44-095. These contents could help to promote flowering and fruit development (Ouedraogo, 2016).

Finally, both types of composts also have a high content of other nutrients which are comparable to those obtained by ADEME (2007). These contents could be an advantage for using these composts in agriculture.

According to discussed results and comparing the contents of the two composts, it has been possible to conclude that the compost obtained from the fermentable fractions of solid waste and sludge in the proportions of 2/3 and 1/3 (respectively) has a higher potential for amendment (MO > 40%) and fertilizer (N + P₂O₅ + K₂O ≈ 5%) than only FFOM.

Maturity and stability of the compost

The results of phytotoxicity show that both composts produced are already highly stabilized (Koledzi, 2011). The values of Germinating index prove that the composts produced are not toxic for cowpea (Koledzi et al., 2019) and they are also stable and ripe (Koledzi et al., 2011). Finally, higher cation exchange capacity value obtained for both composts is characteristic of mature compost (Bernal et al., 1998); in any case, co-compost produces has shown a slight higher value, so it is a bit more stable than standard one.

Metallic trace element content

The contents of metallic trace elements are below the threshold allowed to be applicable in agriculture. The use of these composts as organic fertilizers is therefore not an environmental problem.



Photo 2: Co-compost.

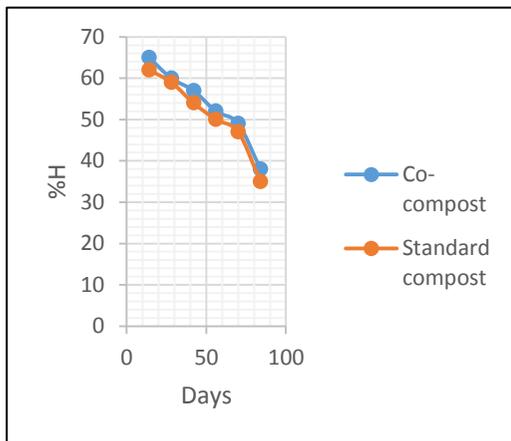


Figure 1: Variation of humidity.

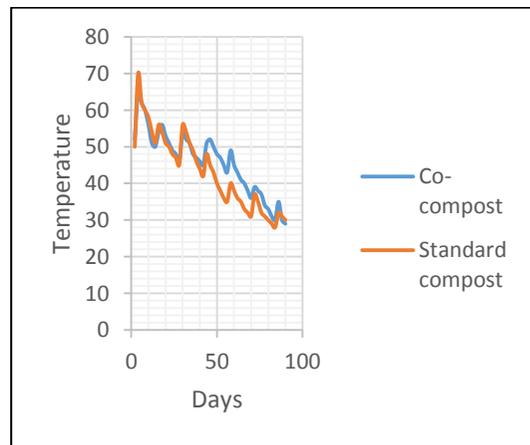


Figure 2: Variation of temperature.

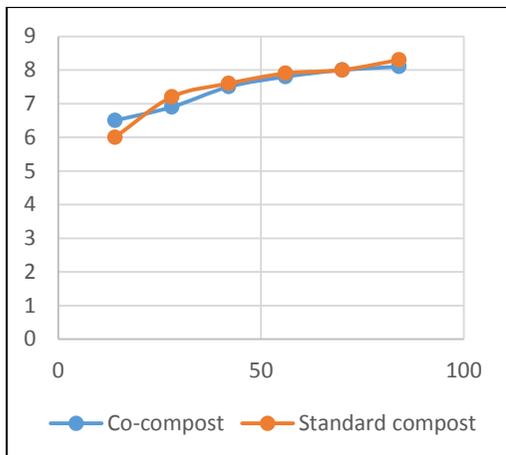


Figure 3: Variation of Hydrogen potential.

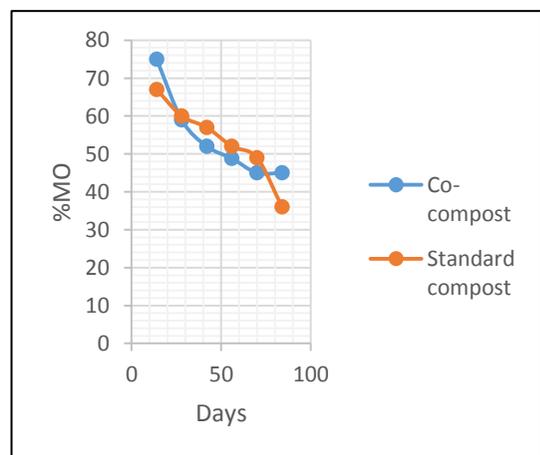


Figure 4: Variation of organic matter.

Conclusion

At the end of this study, it should be said that the prior characterization of the dried sludge and the FFOM has shown that these substrates are rich in organic matter, in nutrients such as nitrogen, phosphorus, potassium and magnesium. The analyzes on the dried sludge show an organic matter in advanced state of decomposition compared to that of the fermentable fractions of the solid waste and whose nutritive elements would be more or less easily available for the plants. The agronomic characteristics of these substrates lead to the conclusion that they can be used as a soil amendment. But drying alone is insufficient to destroy all pathogens and that the organic matter is not stabilized in the two substrates, it was necessary to compost them. In this research two composts were produced; the first one only using fermentable fraction of household waste and the second one mixing fermentable fraction of household waste and dried sludge in a ratio 2/3 of fermentable fraction of household waste (FFOM) and 1/3 of dried sludge. The physico-chemical analyzes on the composts carried out to follow the co-composting and standard composting process have resulted on differences in the degradation process during co-composting and composting, showing a greater and faster degradation of organic matter during co-composting compared to the standard composting process. Humidity content, organic matter content and C/N ratio decreased during the composting process. The pH values at the end of the process, in composts are basic (8-9), due to the presence of ash in the waste. The organic matter contents at the end of ripening in both of compost are in accordance with standard NFU44-051. The maximum temperature reached in the fermentation phase in the co-compost pile and in standard compost pile is sufficient to destroy certain pathogens and reduce the risk of contamination of plant products. Thus, co-composting has made it possible to increase the temperature which can destroy certain pathogenic germs, unlike the

composting of sludge only, during which the temperatures obtained are insufficient to destroy the pathogenic germs. Nutrient content, phytotoxicity, AT4 and CEC) on the composts were carried out and allowed to obtain the indicators that define the quality, maturity and stability of two types of compost produced. The C / N ratios at the end of the process are average but close to the value recommended by the standard NFU 44 - 051. The comparative study of the two types of compost showed that the compost obtained from the fermentable fractions of solid waste and sludge in the proportions has the highest potential for amendment (MO > 40%) and fertilizer (N + P₂O₅ + K₂O ≈ 5%). The AT4 test gives a practically constant consumption for the fourth day (for a degree of maturation of IV (temperature < 40 °C)) for the two composts. The germination index is greater than 50%. The values of these parameters show that the composts are ripe. The contents metallic trace element are lower than the standard NFU 44-051, so the use of these composts will not cause a problem for the environment. This research has concluded that co-composting dried sludge and fermentable fractions of solid waste in the city of Sokodé attests consequently that both organic fraction results on a substrate that could be used in agriculture. In consequence these fractions should be considered as resources that can contribute to improving the living conditions of the population by increasing agricultural production.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

NMK was the principal investigator of the study. GB was the supervisor of the work. JM-P provided technical assistance and advice in the laboratory analyses and contributed to the writing of the paper. MZT contributed to the analyses, which were carried out in her laboratory, and to the writing of the paper.

ACKNOWLEDGMENTS

I would like to thank European Union (UE) for the generous mobility that I grant by the ERASMUS + program.

Analyses were carried out in the Laboratory of Civil Engineering, Department of Chemical Engineering, University of Granada (Spain). I would like to underline the warm welcome I received during these three months of my stay, the quality of the support I received, the kindness and the availability that Professor Montserrat ZAMORANO TORO and Doctor Jaime MARTÍN-PASCUAL and their staff have shown me. I am really grateful.

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