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Waste management: a study on generating organic fertilizer from oil and grease trap systems

Gestión de residuos: estudio de generación de biofertilizante mediante lodos de sistemas de trampa de grasa

Gestão de resíduos: estudo de geração de biofertilizante por meio do lodo de sistemas de armadilha de gordura

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Abstract

The grease and oil trap systems (GOTS) of four university food service establishments (FSE) were assessed and treated to evaluate the potential use of the sludge collected to produce compost. The sludge collected from each FSE was kept in a drying bed for 30 days (SDB), during which time calcium oxide was frequently added for stabilization. The sludge deposited monthly was reduced to half after the drying process and was then deposited in a composter and mixed for a period of 22 days with constant agitation. The compost obtained was treated with degrading enzymes and was denominated enzymatic composting (EC), while the remaining compost was not treated with enzyme and was denominated non-enzymatic compost (NEC). The total composting cycle of the sludge lasted 83 days, during which time various physical and chemical analyzes were conducted in the three types of substrates (SDB, NEC, and EC). The total time of the research was 2.5 years. The percentages of phosphorus, potassium, magnesium, and calcium suggest the use of the three substrates as organic fertilizer. A recommendation resulting from this research is to evaluate the sludge quality by mixing it with other substrates such as fruit peels with high nitrogen content and the sludge from wastewater treatment systems.

Keywords: oil; grease; organic fertilizer; sludge; enzymatic; solid waste

Resumen

Se realizó un diagnóstico y tratamiento de los sistemas de trampa de grasa y aceite (GOTS) de cuatro establecimientos universitarios de servicios de alimentos (FSE) para evaluar el uso potencial de los lodos recolectados para producir compost. El lodo total recogido de cada FSE se colocó durante 30 días en un lecho de secado (SDB); durante este período de tiempo se añadió frecuentemente óxido de calcio para

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estabilizar el lodo. El lodo depositado mensualmente se redujo a la mitad luego del proceso de secado, para posteriormente ser depositado en un compostador y ser mezclado; este periodo fue de 22 días con agitación constante. El compostaje obtenido se trató con enzimas degradantes, este compostaje se denominó compostaje enzimático (EC). El resto del compostaje no tratado con enzimas se llamó compostaje no enzimático (NEC). El período total de tiempo para el ciclo de compostaje de lodo fue de 83 días, donde se realizaron varios análisis físicos y químicos para 3 tipos de sustratos (SDB, NEC y EC). La investigación duró un periodo total de 2.5 años. El porcentaje de fósforo, potasio, magnesio y calcio sugiere el uso de los tres sustratos como fertilizante orgánico. Una recomendación de esta investigación es evaluar la calidad del lodo mezclándolo con otros sustratos; por ejemplo, cáscaras de frutas con alto contenido de nitrógeno y con el lodo de los sistemas de tratamiento de aguas residuales.

Palabras claves: aceites; grasas; fertilizantes orgánicos; lodos; enzimas; residuos sólidos

Resumo

Foi realizado um diagnóstico e tratamento dos sistemas de armadilha de gordura, óleo e graxa (FOG) de estabelecimentos de serviços de alimentação (ESA) de quatro universidades com o objetivo de avaliar o uso potencial do lodo coletado para produzir compostos. O lodo total recolhido de cada FSE foi colocado durante 30 dias em um leito de secagem, e neste período de tempo foi adicionado frequentemente óxido de cálcio para estabilizá-lo. Depois do processo de secagem, o lodo depositado mensalmente reduziu pela metade para, logo, ser depositado em um compostador e misturado a cada mês com agitação constante por um período de 22 dias. O composto obtido foi tratado com enzimas degradantes, sendo denominado composto enzimático (CE). O composto restante não tratado com enzimas foi denominado composto não enzimático (CNE). O período total de tempo para o ciclo de compostagem de lodo foi de 83 dias, em que se realizaram várias análises físicas e químicas para 3 tipos de substratos (LLS, CNE e CE). A porcentagem de fósforo, potássio, magnésio e cálcio propõe o uso dos três substratos como fertilizante orgânico. Uma recomendação desta pesquisa é avaliar a qualidade do lodo misturando-o com outros substratos; por exemplo, cascas de frutas com alto teor de nitrogênio e com o lodo dos sistemas de tratamento de águas residuais.

Palavras-chave: óleos; graxas; fertilizantes orgânicos; lodos; enzimas; resíduos sólidos

Introduction

Restaurants and domestic household discharging wastewaters into public sewers have been a problem for many years, and it becomes greater with a large number of full-service and fast-food restaurants being built both in large cities and rural communities (Shamsuddin *et al*., 2020, Dumore & Mukhopadhyay 2012). These restaurants typically discharge a large amount of fat, oil, and grease (FOG) that would reduce the capacity of public sewers over time (Shamsuddin *et al*., 2020). FOG is a type of waste proceeding from the production of food (Gibbons, O´Dwyer & Curran, 2015). Fats and oils are among the main components of organic matter in wastewater (Ruggieri *et al*., 2008; Saatci *et al* 2001). Solid wastes, especially those produced by the food industry (Ruggieri *et al*., 2008, Galli *et al*., 1997; Mari *et al*., 2003) are fats and oils essentially composed of triglycerides consisting of linear fatty acids attached, as esters,

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to glycerol (Ruggieri *et al*., 2008, Lalman *et al*., 2000). FOG is an ever-growing environmental concern. This waste is usually produced at food service establishments (FSE) or other food preparation facilities. The by-products and wastes from these FSE include meat, sauces, gravy, dressings, deep-fried food, baked goods, cheeses, butter (Hussain *et al*., 2014), food scraps, meat fats, lard, tallow, cooking oil, butter, margarine, sauces, gravy, dressings, deep-fried food, baked goods, cheeses, and butter (Hussain *et al*., 2014; Aziz *et al*., 2011).

Currently, there is only one method to control FOG at the source of generation. This method involves installing a grease interceptor (GI) that separates the FOG from the restaurants´ sludge, reducing its concentration in the effluent (Hussain *et al*., 2014; Aziz *et al*., 2011).

The FOG is collected manually or automatically, after its separation in grease traps, and then, it is recycled into bio-diesel or open dumped with solid waste (Almeida *et al*., 2017; Canakci, 2007). The residual fat material from grease trap, a lipid-base material of low quality, consists of fatty acids, frying oils (soybean y sunflower), animal fats, hydrogenated fats, fatty alcohols, and other compounds (He *et al*., 2011;Ruggierei *et al*., 2008). Therefore, FOG components are introduced into the sewer system either by direct dumping into the sewer or by escape from grease traps (GTs) (Hussain *et al*., 2014). FOG may solidify and form particles that deposit on the surface of the pipe, thus obstructing the wastewater flow (Hussain *et al*., 2014, Prakash *et al*., 2015; De-qing *et al*., 2007). FOG blockage is a worldwide concern. For example, the American Environmental Agency (EPA) estimated that at least 10.350 to 36.000 sanitary sewer overflows (SSO) occur per year in the USA, approximately 47 % of is related to FOG (Hussain *et al*., 2014; Idris and Ahmed, 2003). The block- ages and sewer flooding may result in other environmental problems, both locally and beyond the premises (Hussain *et al*., 2014).

Fat oil and grease tend to stick to the surface of drain and sewer pipes causing clogging that restricts the flow of sewage and may lead to sanitary sewer overflows (SSO). SSOs cause unpleasant odors and insect and rat infestation, and the sewage may make its way into water sources causing ground and surface water pollution (Hussain *et al*., 2014; Sasaki *et al*., 2003).

Recently, extensive effort has been expended to investigate the possibility of treating and reusing FOG to reduce the amount disposed at landfills (Hussain *et al*., 2014). Among the available technologies to recycle organic solid wastes, composting is often presented as a low-technology and low-investment process to convert organic solid wastes to a soil amendment known as compost (Vicencio de la Rosa, Valencia & Ortega, 2013). Composting is a biotechnological process by which different microbial communities initially biodegrade organic matter into simpler nutrients and, in a second stage, form complex organic macromolecules, such as humic acids (Vicencio de la Rosa *et al*., 2013; Roman *et al*., 2013). Composting offers an economical and effective way to treat oil sludge. Composting process which involves the careful control and addition of nutrients, watering, tilling, in addition to suitable microflora and bulking agents (wood-chips or hay) were considered as an alternative option to improve the bioremediation of oil sludge (Torres *et al*., 2005; Albino, 2017).

The main advantage of composting is waste stabilization (Torres *et al*., 2005;

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Robles *et al*., 2017). Composting matrices and composts are rich sources of xenobiotic degrading microorganisms including bacteria, *actinomycetes* and *lignolytic fungi*, which can degrade pollutants into compounds such as carbon dioxide and water. These microorganisms can also bio transform pollutants into less toxic substances and/or lock up pollutants within the organic matrix, thereby reducing pollutant bioavailability (Torres *et al*., 2005; Semple *et al*., 2001).

Composting of fats, oil and grease is inherently difficult due to their nutrients deficiency, with especially low nitrogen and phosphorous content relative to high carbon content (Ruggieri *et al*., 2008; Sasaki *et al*., 2003). This fact usually implies the use of a co-substrate to compensate the C/N ratio of the initial mixture and to act as inoculum. Different types of sludge, due to their typical low C/N ratio, are considered suitable for being composted with FOG or FOG-enriched wastes (Ruggieri *et al*., 2008; Wakelin and Forster 1997).

Therefore, it is intended to evaluate the residues of the grease traps of the sludge from the sodas of the National University by means of an enzymatic composting technique for its later use as an amendment.

Methodology

2.1 Study population

A diagnosis and treatment of grease and oil trap systems (GOTS) from four university food service establishments (FSE) were carry out in order to evaluate the potential use of its sludge to produce an organic fertilizer. The four establishments of study are identifying identified as FSE-1, FSE-2, FSE-3, and FSE-4, where "FSE" means food service establishments, which is a kind of restaurant in the university where students and workers can buy their food or bring their own meals. The average number of people served in each of the FSEs was 4.179, 6.778, 3.523 and 6.543 respectively.

2.2 Sludge (oil and grease) collection and analysis

The total research time was 2.5 years, where from this time for seven months, the type and quantity of meal prepared was evaluated (sampling), as well as the number of users (students and workers) using the service. Besides, data from recent years' surveys was used to estimate the quantity of visitors in each FSE. For one-year period, the purchase of cooking oil was used to estimate the monthly oil consumption rate for each FSE. For each food service establishment, the grease and oil wastes monthly generation were determined by using the amount of cooking oil consumed to prepare fried food (for example patty meals). Once a month (during 9 months) the grease and oil (Sludge) coming from the trap system of each FSE were collected and transported to the Solid Waste University Center (SWUC).

Data related to generation source (FSE), volume produced, sludge conditions (presence of sediments and coloration), appearance, odor, flour content (rice, beans, vegetables) and organic matter content (OMC), by means of the method of Walkle and Black (1934), which consists in carrying out the oxidation of organic matter, with potassium dichromate and H_2SO_4, the amount of non-reduced dichromate is titrated by retrogression.

The biosolid (sludge) collected was stored in hermetic containers (20 kg as maximum weight) and was analyzed on the same day of its sampling, by comparing the data obtained with similar investigations

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and by the requirements that a compost must present to be used as a biofertilizer for plants. The following chemical and physical analyzes were carried out on this collected sludge; production performance, moisture percentage according to the Mexican standard NMX-F-211-SCFI-2012 in an oven at 105 ºC for 48 h, fat and oil content (%), caloric capacity was carried out according to the procedure of the calorimetric bomb of the School of Chemistry of the National University, concentrations of micronutrients (Zn-zinc and Cu-copper), and concentrations of macronutrients (P-phosphorus, K-potassium, Mn-manganese and Ca-calcium) were analyzed by the Atomic absorption medium following the Protocol of Methods of Analysis for Soils and Sludge of Zagal & Sadzawka (2007), for the specific case of Total Phosphorus and Total Potassium, the methods of Bray and Kurtz were used, and atomic absorption of flame, and in the carbon-nitrogen ratio s (C / N) the Kjeldah method was used. In total, seven sludge samples were analyzed.

2.3 Sludge treatment and composting process

The total sludge collected from each FSE was placed during 30 days on drying beds (in order to reduce humidity). During this period of time, calcium oxide was frequently added to stabilize the sludge. Subsequently, the dried sludge was deposited on a food waste composter and was monthly mixed with a co-substrate (sawdust pellets). The sludge and the substrate were stored together with constant agitation during 22 days. After this stage of the process, the composting was generated. Fifty percent of the composting obtained was treated with grease and oil degrading enzymes (Biowish). 2.5 g of enzymes per liter were diluted and applied with a sprinkler once a day on the entire surface of the residue.

The composting treated with enzymes (EC, enzymatic composting) and the untreated composting (without enzymes) named non-enzymatic composting (NEC) were separately dried and sieved. The sludge composting management total period was 83 days (from the sludge collecting until the composting production).

2.4 Composting analysis

The following physical and chemical analysis were determined for a) the sludge coming from the dry bed (SDB), b) the non-enzymatic composting (NEC) and c) the enzymatic; composting (EC), pH value, organic matter content (OMC), carbon and nitrogen relation (C/N), carbon and phosphorous relation (C/P), and concentration of (carbon (C), nitrogen (N), Zinc (Zn), Copper (Cu), total phosphorus (P_2O_5), potassium (K), magnesium (Mg) and calcium, as well as heavy metal concentrations, cadmium (Cd), mercury (Hg) and Lead (Pb).

Analysis and results

Table 1 summarizes the average of population served as well as the average sludge production (kg/month) for each FSE during one-year. A total of 21.023 people attended the different food service establishments. The minimum quantity of visitors corresponds to FSE-3, with a percentage of 16.76 %. On the other hand, the places with a greater number of users are FSE -2 and FSE -4 with a total of 6778 (32.24 %) and 6543 (31.12 %), respectively.

According to the table below, the minor sludge generation rate (15.97 ± 5.56 kg/month) corresponds to the FSE- 4. This low

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Table 1. *Population served and sludge production for each food service place in the university campus*

FSE	Population Served		Sludge Production	
	Amount	Percentage	Kg/month	Percentage
1	4179	19.88	24.26	20.46
2	6778	32.24	53.59	45.20
3	3523	16.76	24.74	20.87
4	6543	31.12	15.97	13.47
TOTAL	**21023**	**100.00**	**118.56**	**100.00**

Note: derived from research

generation is explained because the lack of a grease and oil trap system, and good cleaning practices during the study period; therefore, limited quantity of sludge was retained. The FSE-4 meal menu offer is another reason for this low rate, in this place fried foods are less included in the menu compared to the rest of establishments evaluated. Contrary to the mayor sludge rate generation is for FSE-2 (53.19 Kg/month, 45.20 %), this value is due to the largest population served by this place, and also because of the high content of fatty food on the meal menu. However, according to this research, the main reason of the biggest sludge generation is related to the population served.

Table 2 indicates the sludge and composting average amounts obtained from the food service establishments. A monthly average of 118.56 kg of sludge was collected and then deposited during 30 days in drying beds. After the drying process, this amount was reduced to 55.10 kg/month. This reduction obeys to the loss of humidity. The dried sludge and 12.16 kg of co-substrate (sawdust pellets) were deposited on a food waste composter, both products were constantly mixed to produce the composting. The total monthly composting amount is 39.35 kg.

Figure 1 shows the results of pH values, the concentration (mg/L) of organic matter (OM), carbon (C), nitrogen (N) as well as the carbon and nitrogen relation (C/N) and carbon and phosphorous relation (C/P) for the sludge coming from the drying bed (SDB), the non-enzymatic composting (NEC) and the enzymatic composting (EC). Regarding the concentration of nitrogen, carbon and organic matter, figure 1 shows an organic matter concentration greater than N and C concentrations for the three substrates. On the other hand, nitrogen concentration is the lowest value reported for the substrates. When comparing C/N and C/P relations on each substrate, the higher value corresponds to the C/P relation.

The results obtained when comparing substrates to one each other, indicates a nitrogen percentage for the sludge from the drying bed (SDB) major than the reported for the non-enzymatic composting (NEC) and enzymatic composting (EC). The same pattern is for the percentage of carbon. However, the individual content of carbon and nitrogen are not determinants for the quality of the composting. Nevertheless, it is important to keep an adequate C/N relation, Melendez & Soto (2003) recommend a relation less than 25. According to the data gathered (for the three studied substrates), the C/N relation values are over this standard. This situation obeys to the low nitrogen content in the oil and greases coming from the trap system, the sludge collected is a poor nitrogen source. In contrast, the

Table 2. *Sludge and composting amounts obtained from the food services establishments*

Product	Sludge from the trap systems	Dried Sludge	Pellets added	Composting
Kilograms/month	118.56	55.10	12.19	39.35

Note: derived from research

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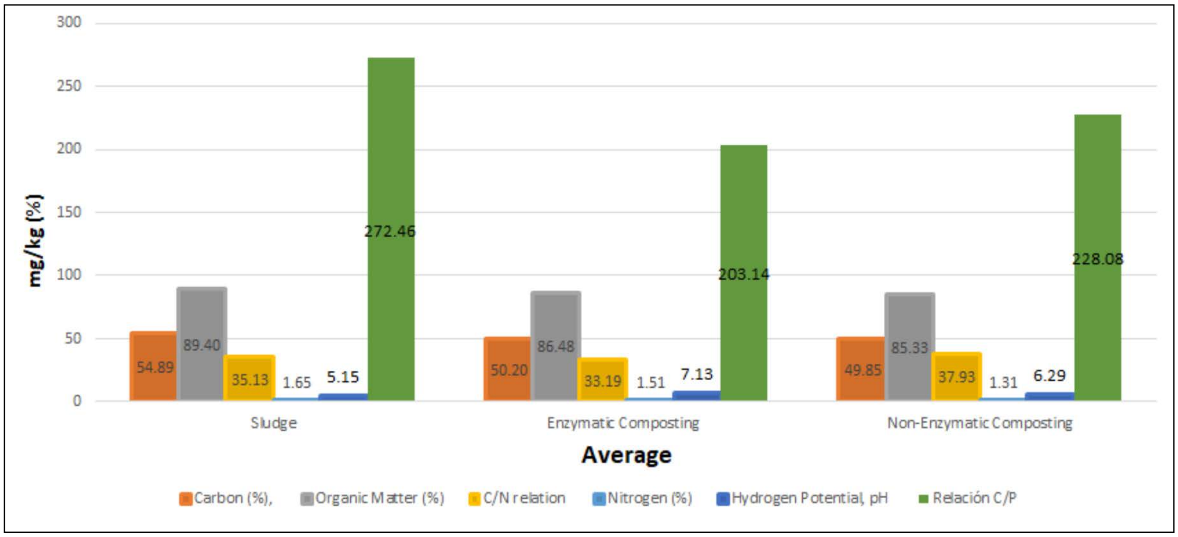

Figure 1. *Results of the chemical basic elementvs for the substrates.* (2012)

original sludge shows a high content of carbon, due to the large and stable carbon molecules existing in the grease and oils previously collected. The low content of carbon could also be explained because of the low mineralization activity during the drying bed process.

Related to the composting samples, figure 1 shows a C/N relation inferior to the enzymatic composting (EC) when being compared to the non-enzymatic composting (NEC). The grease and oil degradation process are more efficient in the EC. This could be associated to the activity of the enzymes, which degrade more carbon, therefore decrease the C/N relation. The C/N relation could also be improved by using substrates with high content of nitrogen; for example, urea, fruit peels, animal excreta and grass, increasing thus, the nitrogen concentration (Vicencio de la Rosa *et al*., 2013).

Related to the C/P relation, Melendez & Soto (2003) point it out as a main aspect to improve the mineralization process. These authors recommend a value minor than 200. However, the data obtained for all substrates is over this standard, 272.46, 203.14 and 228.08 for the SDB, EC and the NEC, respectively. This tendency is due to the same explanation discussed for the C/N relation, especially about the high carbon content existing in the original sludge. It is important to point that regarding to the individual content of phosphorus, the substrates evaluated meets the reference parameter recommended by Roman et al., (2013), which is between 0.1 % and 0.4 %. The %N are 0.20 %, 0.25 % and 0.22 % for the SDB, EC and NEC, respectively (Figure 3).

According to the organic matter content, (Figure 1), the three substrates show an organic matter percentage superior to 80%. Roman, Martínez & Pantoja (2013) suggest a value in the range of 50 % and 70 %. The excess of OM could be explained due the presence of long and stable carbons chain molecules in the original sludge. Nevertheless, it was expected to obtain an organic matter percentage between 50 % and 70 % for the enzymatic composting; however, the results show similar values for the 3 substrates (89.40-86.48 and 85. 33 for the SDB, EC and NEC, respectively). This similitude indicates a weak

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organic biodegradation matter activity by the enzymes in the enzymatic composting. It is recommended to extent the enzymatic process time to have a better mineralization of the organic matter by the microorganisms. Despite the content of organic matter is high for the 3 studied substrates (Roman *et al*., 2013), some other authors indicate that biosolids with an organic matter percentage over 60 are very efficient to use on bioremediation process to recover heavy metals polluted soils (Vicencio de la Rosa *et al*., 2013; Torres *et al*., 2005). Therefore, substrates with OM content superior to 60% decrease through adsorption process of the heavy metals bioavailability of the soils, leading them, the formation of a stable organic metallic complex. According to this, the evaluated substrates (SDB, EC and NEC) could be used as an improving and stabilizing agent to treat metal contaminated soils.

The biggest values of Zn and Cu were found in the sludge, while the lowest values were found for the non-enzymatic composting. The difference between the micronutrient concentrations is because the substrate named SDB has not experienced through biological activity. Therefore, there is a lack of microorganisms to consume the micronutrients, hence, this substrate has a major bioavailability of zinc and copper.

Considering the enzyme activity, it was expected to obtain an inferior micronutrient concentration in the EC substrate when comparing with the NEC substrate. Nonetheless the results show (Figure 2) Cu and Zn concentrations smaller for the NEC substrate. This is due, the non-enzymatic composting substrate contain greater quantity of micro microorganisms than the EC substrate. Therefore, the NEC substrate requires high number of micronutrients, in this case, Zinc and Copper. In the case of the EC substrate, the activity of the enzymes accelerates the substrate biodegradation, hence, there is a superior micronutrients availability in the enzymatic composting compared to the one without enzymes. To consider a substrate non-toxic for the improving and the cultivation of plants and microorganism, this, must have concentrations of Cu and Zinc less than 100 mg/kg and 200 mg/kg respectively (Albino, 2017). In this study, the three substrates (SDB, NEC and EC) show lower values than the one reports by Albino (2017). Thus, these substrates could be considered a non-toxic substrate. For the sludge coming from the drying bed, the concentration (mg/L) of Zinc and Cupper are 71.43 and 19.13 respectively, for the enzymatic composting are 46.29 and 13.53 respectively, and for the non-enzymatic composting are 39.43 mg/L Zn and 10.53 mg/L Cu.

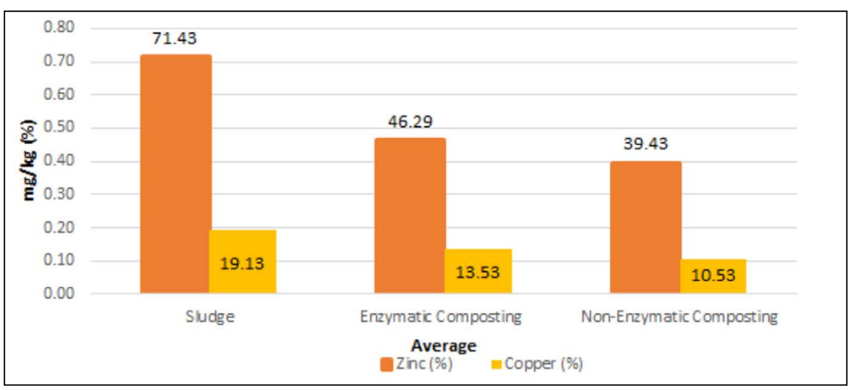

Figure 2. *Microelement concentrations for the substrates; sludge drying bed, enzymatic composting and non-enzymatic composting.* (2012)

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Figure 3 shows the total phosphorus (P_2O_5), potassium (K), magnesium (Mg) and calcium (Ca) percentage obtained for the 3 evaluated substrates. The sludge substrate has the lowest concentrations (mg/L) for P (0.20), K (0.11), Mg (0.11) and Ca (5.93). These concentrations are principally linked with the sludge higher acidity (pH = 5.15) in comparison with the given pH for the NEC (6.29) and EC (pH 6.29). Acid pH values lead to a low magnesium and potassium concentrations (Robles, J *et al*., 2017). Contrary, the highest levels (mg/L) of Ca (6.17), Mg (0.19), K (0.70) and P_2O_5 (0.25) were found in the enzymatic composting, which also have the highest pH value. The enzymatic composting basic pH value allow a high macronutrients availability in comparison with the other two substrates (the sludge and the non-enzymatic composting). For the 3 substrates, calcium shows the higher concentration (Figure 3). The main reason for this situation, is the calcium oxide used to level the sludge previously collected from the trap systems. Albino (2017) suggest a calcium concentration between 20 and 65 % for a substrate that will be used as an organic fertilizer. The calcium concentration found for the 3 analyzed substrates were less than this reference. The main reason for this calcium deficiency obeys to the low content of calcium included on the original substrate (sludge from the oil and grease trap). Nevertheless, considering its low cost, calcium could be added after the composting process.

In relation to the phosphorus concentration, Melendez & Soto (2003), recommend a concentration range in an organic fertilizer between 0.15 – 1.5 %. Data from the above figure indicates a P_2O_5 concentration within this range for the 3 samples studied (0.20-0.25 and 0.22 % for the SDB, EC and NEC respectively). In the case of potassium concentration for an organic fertilizer, Roman *et al*., (2013) recommend a content between 0.3 -1.0 %. For this research, both composting substrates have values between this parameter, 0.70 % and 0.65 % for EC and NEC, respectively. However, some other authors [64] have found phosphorus concentrations over the values recommended by Roman *et al*., (2013), especially in biosolid with high content of grease and from sludge coming from sewage treatment systems. Table 3 shows the heavy metal concentrations for the 3 evaluated substrates. The analyzed metals were cadmium (Cd), Nickel (Ni), Mercury (Hg) and Lead (Pb).

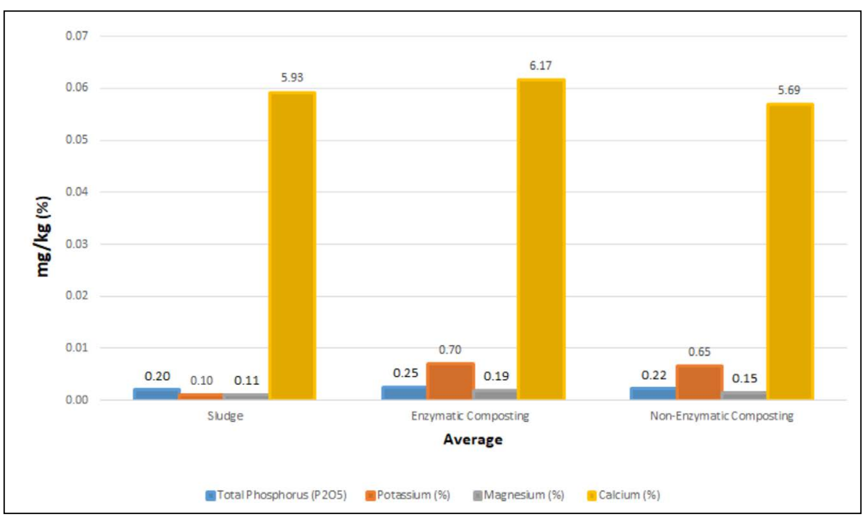

Figure 3. *Total phosphorus (P_2O_5), potassium (KO), magnesium (Mg) and calcium percentage for the sludge coming from drying bed, the enzymatic composting and non-enzymatic composting.* (2012)

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One Costa Rican regulation and seven international regulations were used to analyze the gathered results. The regulations are from the following countries: Costa Rica, Chile, Mexico, Germany, Great Britain, Switzerland, France, and Canada.

The sludge from the drying bed (SDB) was evaluated using 3 regulations (Costa Rica, Chile and Mexico). In the case of the non-enzymatic composting (NEC) and the enzymatic composting (EC) six of the seven national regulations were used (The only regulation excluded was the Mexican Law). The Costa Rican and Chilean regulations are focused in controlling and regulating the heavy metals permissible limits on the bio solids and in the composting used as a substrate to enrich organic fertilizer used in plant crops. The approach of the Chilean and Canadian normative exclusively regulates the content of heavy metals in the composting. In the case of the sludge, the heavy metal concentrations are within the range established by the 3 regulations used as reference. Related to the composting (EC and NEC), cadmium (1.73 mg/kg) is the only heavy metal with a concentration over the Swiss (Cd < 1) regulation permissible limit. However, for the three substrates, the cadmium concentrations, as well as the other metal concentrations, meet the standard reference value recommended in the rest of the regulations. A substrate used as an organic fertilizer containing high heavy metal

Table 3. *Cadmium (Cd), Nickel (Ni), Mercury (Hg) and Lead (Pb) concentrations for the sludge from drying bed, enzymatic composting and non-enzymatic composting*

	Substrate	Cadmium mg/kg	Mercury mg/kg	Nickel mg/kg	Lead mg/kg
Experimental data	SDB	1.73	<1	25.20	12.54
	EC	1.34	<1	12.57	18.63
	NEC	0.88	<1	12.97	14.79
Maximum permissible limit.	[1]Costa Rica RTCR 485:2016	80.00	15.00	NR	200.00
	[2]Chile G-PR-GA-004 Chile	8.00	10.00	80.00	300.00
	3 México NOM-004-SEMARNAT-2002	39.00	17.00	420.00	300.00
	[4]Germany –Quality Label RAL-GZ 251	< 1.5	< 1	< 50	< 150
	[4]Great-Britain PAS 100:2005	< 1.5	< 1	< 50	< 200
	[4]Switzerland –Quality Guidelines for composts 2010	< 1	< 1	< 30	< 120
	[4]France -NF U 44-051	< 3	< 2	< 60	< 180
	[4]Canada -CCME Compost Quality	< 3	< 0.8	< 62	< 150

[1] Ministerio de Agricultura y Ganadería, 2016.
[2] Ministerio de Agricultura Servicio Agrícola y Ganadero de Chile, 2008.
[3] Juárez-Robles et al, 2017.
[4] Trémier, 2012.
Note: Data are averages with an "n"=7.

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concentrations is prejudicial to plant crops growth, to soil microorganisms, to the animal health and to the human being. According to Albino (2017), the sludge and composting substrates obtained for this research could be applied as organic fertilizer, considering its low heavy metal concentrations. During this investigation it was not possible to correlate the heavy metal concentrations (HMC) with the enzymatic activity. The data obtained shows a linear behavior, because there is no exponential increase or decrease in metal concentrations between one sample and another.

Conclusions

Good cleaning practices and a menu with less frying influence that FSE-4 generates less sludge than FSE-2, even though both serve a similar amount of population.

The average amount of sludge collected was reduced to approximately half its original weight after the drying stage. This reduction of the water content prevents the anaerobic decomposition of the sludge, thus improving the composting process.

The collected sludge is not a good energy alternative, since it does not reach the required temperature for this type of exploitation. CE and NEC could be like organic fertilizer. The oil and fat collected are not a good source of nitrogen, due to their high C / N ratio. The three substrates have a high content of organic matter which could be treated in bioremediation processes in soils contaminated with heavy metals. Ca is below the standard level. The Zn and Cu values were found in the sludge, while the lowest values were found higher for non-enzymatic composting.

For future research, some recommendations are:

a) Analyze the content of oil and fat, C, N, among others through the use of higher doses of enzymes on the substrates, to obtain a better quality organic fertilizer.
b) Develop laboratory tests of germination of compost seeds obtained to determine the levels of germination and phytotoxicity
c) Evaluate the quality of the mud (C / N and C / P) mixing it with other substrates; for example, high nitrogen fruit peels and sludge from university wastewater treatment systems.

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