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# Preliminary Study on the Use of Lactic Acid Fermentation in Terra Preta Sanitation

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## Abstract

The acidic state that lactic acid fermentation (LAF) produced has been highly used in many purposes. Terra Preta Sanitation (TPS) applies LAF in the treatment of human excreta. Effective microorganisms (EM) contain lactic acid bacteria. This experiment investigated LAF in stored faecal substrate added with 100 milliliter (ml) of EM. Substrates were analyzed using standard chemical parameters following the German "Methods Book for the Analysis of Compost". Results showed that pH did not go down to acidic level in all substrates. Without EM, total Nitrogen deceased from 523 milligram per liter (mg/l) to 495mg/l after 1 month but has shown increase from 523mg/l to 547.66 with EM. Total organic carbon (TOC) with EM was higher than without EM after 1 month but opposite results were found in substrates stored for 4 months. Without EM, total Phosphorous increased after 1 month from 282mg/l to 302mg/l but decreased after 4 months from 282mg/l to 257.50mg/l. In conclusion, changes in chemical characteristics of the faecal substrates could be due to EM but the effects could hardly be attributed to LAF.

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**Introduction**

LAF has been used in a number of applications aside from food preservation. Its capacity to hygienize was tested in poultry wastes (El-jalil *et al*., 2008) and pig excreta (Kamra and Srivastava, 1993). It was also used in deodorizing kitchen garbage by targeting responsible bacteria (Wang *et al.,* 2002). These studies take advantage of LAF's ability to reduce pH to acidic level that inhibits a number of undesirable microorganisms. The fermentation process caused by EM is natural and not chemically engineered or genetically synthesized (Talaat *et al*., 2015). EM is a product in liquid form which has several beneficial microorganisms like lactic acid bacteria (Safwat and Matta, 2021).

Human excreta contains pathogens. Ecological Sanitation (ecosan) as well as the World Health Organization (WHO, 2006) provided guidelines for the treatment and reuse of the separately collected faeces for agricultural applications. It is well-known that human faeces can be processed as source of nutrients for plants. One person produces about 50 kilogram of faeces per year (Otterpohl, 2000). An urban area with high population is a good source of considerable amount of faecal material that can be converted into soil amendment. In TPS, two treatment procedures are involved – LAF of faecal matter followed by vermicomposting (Factura *et al*., 2010) to ensure a hygienically safe end product.

TPS is inspired by the Terra Preta soils in the Amazon. Terra Preta are anthropic soils that were created by Amerindian populations between 500 and 2500 years ago (Lehmann and Rondon, 2006). Large amounts of bio-char derived carbon stocks remained in these soils today, hundreds and thousands of years after they were abandoned (Lehmann *et al.,* 2006). The soils are highly valued by farmers for their sustainable fertility and production potential (Lehman *et al.,* 2003). Estimates show that crop productivity in Terra Preta soils is twice higher than in other nearby soils (Lehman, 2006). Bio-char, the biomass-derived black carbon using incompletely combusted organic matter such as charcoal (Glaser *et al.,* 2002), is used in TPS to cover the separately collected faeces. Creating soils like Terra Preta in the present time using TPS-processed faecal matter is a sustainable practice in achieving soil fertility and combating soil degradation. This paper presents findings of preliminary TPS experiment that investigated LAF in faecal substrate (mixture of faeces and bio-char) with the addition of EM and examined changes in the substrate's chemical characteristics.

**Materials and methods**

This experiment was part of the author's doctorate studies at the Institute of Wastewater Management and Water Protection – Hamburg University of Technology (TUHH) in Germany during the period 2008 – 2011. A laboratory scale set-up was conducted where faeces were collected using bucket toilet (waterless) from male members of the institute. Urine was separately collected as well as used toilet papers. Ground charcoal (bio-char) was used to cover faeces after defecation and the bucket is closed with its lid. From the collected faeces, two groups of faecal substrates were stored separately: for 1 month and for 4 month period, using plastic buckets under room temperature. The buckets were covered but the condition was not strictly anaerobic. One group was added with 100ml solution containing EM (indicated as EM) and the other group has no EM (indicated as NO). Storage process started during winter season. After storage, the substrates were analyzed using chemical parameters following the standard methods as described in the German "Methods Book for the Analysis of Compost" (BGK, 1994), whereby extractions with $CaCl_2$ solution were used for determination of pH, TOC and Nitrogen compounds, and CAL solution for Phosphorus compounds.

**Results and discussion**

Initial pH was 7.42. After 1 month storage, there was a slight decrease (7.23) and increase (7.53) in pH found in NO and EM respectively. The same pH pattern was observed in the substrates stored for 4 months. Total Nitrogen deceased from 523mg/l to 495mg/l in NO after 1 month but increased from 523mg/l to 547.66 in EM (Table 1). However,

opposite pattern was observed in the substrates stored for 4 months where total Nitrogen increased from 523mg/l to 560mg/l in NO and decreased from 523mg/l to 319.66mg/l in EM. TOC increased in all substrates after storage. Highest increase in TOC was found in NO after 4 months. TOC was higher in EM after 1 month but opposite results were found between the substrates stored for 4 months. Total Phosphorous increased after 1 month from 282mg/l to 302mg/l in NO but decreased after 4 months from 282mg/l to 257.50mg/l. Lower total Phosphorous was observed in EM than in NO after 1 month which is opposite to the results found between the substrates stored for 4 months.

**Table 1.** Chemical characteristics of treated and untreated substrates.

| | Total Nitrogen (mg/l) | | TOC (mg/l) | | Ammonium (mg/l) | | Total Phosphorous (mg/l) | | Phosphate (mg/l) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial | 523 | | 1480 | | 275 | | 282 | | 280 | |
| | NO | EM | NO | EM | NO | EM | NO | EM | NO | EM |
| 1 month | 495 | 547.66 | 1870 | 2210 | 307 | 347.33 | 302 | 283.33 | 291 | 257.33 |
| 4 month | 560 | 319.66 | 2650 | 1860 | 406.50 | 254.66 | 257.50 | 285.33 | 254.50 | 272.66 |

Clearly, pH did not go down to acidic level in all substrates. One main reason could be due to bio-char because charcoal is basically known to have high alkalinity. It could also indicate that with high pH during the storage process, production of acids hardly occurred. The amount of lactic acid that can be produced depends on the type of carbon source used (Buruleanu *et al.*, 2010). Aside from that, carbohydrate metabolism of different species of lactic acid bacteria also varies (Dan, 2001). By definition, lactic acid bacteria are bacteria that ferment sugar (e.g. Glucose) predominantly to lactic acid (Liu, 2003). In this experiment, lactic acid bacteria in the EM were not identified nor quantified and the sugar content in faeces was not measured.

The amount of sugar present in raw materials must be sufficiently high enough (at least 40 gram per kilogram) for an optimal course of LAF (Kopec, 2000). Addition of molasses could cause a greater decrease in pH and stimulated synthesis of lactic acid during fermentation (Kamra and Srivastava, 1993). In general, fermentation of sugars can take place at relatively low pH values of 5 to 6 (Hafid *et al.,* 2010).

It was demonstrated that kitchen biowaste and sugarcane molasses can be used as sugar supplements for the application of LAF process on human excreta (Yemaneh, 2015). Temperature is also a factor and for organic acids production, mesophilic range (30 to 40 degrees Celsius) was reported suitable (Ong, 2001). In contrary, this experiment was conducted during winter time when the surrounding temperature was not within the reported suitable range for acid production.

## Conclusion

Inducing LAF in faecal substrate in the TPS system requires that all the necessary factors of the fermentation process must be considered. Changes in chemical characteristics in the faecal substrate could be the result of microbial actions caused by EM but could hardly yet be attributed to LAF in this preliminary experiment.

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