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RESEARCH ON HEAT RECOVERY IN THE COMPOSTING PROCESS

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Abstract: The current trend manifested globally is to find new solutions using non–conventional energy and renewable energy (solar, wind, flowing waters, biological processes and geothermal heat) in socio–economic activities, as an alternative to classical energies. In this paper we intend to present some research on how to recover the thermal energy released in the biological process of composting biodegradable waste, research which will be finalized by creating and testing a composting container, equipped with recovery plant heat resulting from the aerobic fermentation (composting) of biodegradable waste.
Keywords: heat recovery from compost

INTRODUCTION

Mainly, known three types of heat recovery systems results from the fermentation of aerobic (composting) of biodegradable waste, as follows:

- heat recovery system in open compost pile formed, with natural ventilation;
- heat recovery system in compost open heaps achieved (dumps), aerated forced;
- heat recovery system made compost in closed container achieved, forced aerated.

Known limited studies on the heat recovery of composting have shown that it is a critical condition to strictly control the temperature in the heap. To prevent the temperature from falling below the temperature required for high–temperature composting, too much heat can't be removed during composting (Chroni et al., 2009). On the other hand, losing a large amount moisture is not conductive to heat accumulation, but also slow down the composting process, so keep the entire composting process from over–ventilation.

The current method of controlling the temperature of the composting process is usually to maintain the oxygen content of the reactor or to control the air content of the reactor by adjusting the temperature (Xiao et al., 2009).

In principle, two methods known of composting heat recovery, respectively, direct and indirect methods.

Direct recovery method

First direct method is to extract heat from the composting material in the form of heated water.

This method is by circulating water pipes inside the heap or in the concrete slab. This method is more suitable for personal use. The process of piling up and disassembling requires installation and removal of pipelines, and the time and labor available to them for help. This is not the case for commercial use for the waste of time and labor (Smith and Aber, 2014).

Another downside is the lack of mechanical agitation. But also easy to take away some of the heat in the cold water in the pipeline. The above situation is not conducive to the growth of microorganisms, and may also lead to corrosion (Smith and Aber, 2014).

The method of extracting heat directly from manure is a simple and effective method pioneered by Jean Pain. One of the heaps is to set water pipes in them, with pipes in 10 inches. When there is air through the heap will produce heat, water is taken away by the water pipes, as a radiation source for greenhouse.

Studies conducted by (Lekic, 2005) showed that the water temperature increases as it passes through the entire pipeline, theoretically 73% of the heat is absorbed by the water. The limitation of this study is the laying of pipes (Lekic, 2005). A solution proposed by (Seki and Komori 1992) is to use packed column heating tower to concentrate the heat discharged into water.

The second method in direct composting heat recovery is use air heating, where air is pushed out (forced aeration) or pulled through (negative aeration) a composting heap. Most commonly accomplished by placing the compost pile on a well–ventilated and level floor, pouring the perforated PVC pipes into the concrete, covering it with a perforated cover and finally covering it with 8–inch sawdust. By moving the whole body mechanically, air enters the heap, removing excess heat while generating heat (Rynk, 2000; Epstein, 2011; Smith and Aber, 2014).

However, this method requires that there be a strong microbial population in the heap and that it is difficult to collect the heat with a mere 13.4% availability, thus it has some limitations (Themelis, 2005). The invention was originally derived from the New Alchemy Institute, they warmed a greenhouse with compost vapor by biofilter in the winter (Fulford, 1986). Although this study is mostly used for horticulture, it plays an important role in prolonging the season time and reducing greenhouse energy loss under cool climatic conditions.

Indirect recovery method

An indirect recovery method involves harvesting the heat indirectly by altering the form of the bio–waste material itself (Lee et al. 2014) reformed an Advanced Compost and Energy System (ACES).

In the ACES, technically speaking, the moisture in the feedstock is evaporated by the biological response of a specific set of well–fed fermenting microorganisms that produces heat above 80°C and thus evaporates residual materials and food waste were compared,18.82 MJ/kg, in a heating value test. One of the advantages of ACES is that it does not require the removal of waste water compared with the traditional method, ACES is more like a method does not need to rule out any substance, but does not require additional energy. Microbials can consume organic matter in the raw material and emit heat, and can be the temperature reached 80°C–90°C.

The use of heat generated, the raw water can be volatile out, which is the rest of the traditional methods can't be achieved (Lee et al., 2014).

About how to handle the liquid in livestock excrement. How to deal with these liquids is the biggest problem converting raw materials into heat. Because raw materials are mixed with up to 90% moisture, the remaining solids have very high potential for energy production, such as 10.46–14.64 MJ kg^{-1} (Lee et al., 2014), which requires reasonable treatment of the liquid. The usual approach is to evaporate. If electricity or natural gas is used for evaporation, the cost of the project will be increased. In addition, since the moisture inside the raw material itself is not easily dried, it takes a long time to evaporate, and the dried material also has unpleasant odor (Shin, 2002; Kim, 2012).

Direct recovery method is the most used in the industrial composting due to its simplicity. The heat transfer calculation models normally could be used to simulate the specified composting process. There are many more to do for the heat recovery both in research and application, such as more simplified models for heating predictions of potential heat from composting, and high efficient heat recovery method.

MATERIAL AND METHODS

Regarding heat energy recovery results in the composting of biodegradable waste in the world have made significant progress for the development of such systems, most being mounted in conventional systems composting (in the pile, rick, dumps composting) but also tanks (containers) composting or complex industrial systems.

Heat recovery system in open compost pile formed with natural ventilation

The ingenious system is constructed as a heat generator based on the natural fermentation of biodegradable waste and can provide thermal energy required for heating or hot water for a period of 12–16 months (**** 2). In general compost pile has a diameter of approx. 5 meters and a height of approx.2.5 meters. Some sources give much larger, 10 x 6 meters. In any case, they are major cylindrical shape and a ratio of 1:2 between height and diameter, Figure 1.

Figure 1 – Heat recovery system achieved in compost heap

The main disadvantage of this system is that the fermentation process requires a period between 70 and 90 days.

Not insignificant advantage of this system is that the starting materials – pipe, pump, and fence, can be reused for 10–15 years, with the same efficiency and costs are relatively low.

Composting system in open dumps static aerated forced with heat recovery system

This system was well documented in the extensive research conducted at the University of New Hampshire Department of Natural Resources, US, (Matthew M. Smith, John D. Aber, 2018).

Research shows operational information for aerated composting system developed on a commercial scale ASP (static aerated cells) with energy recovery, one of the few currently in operation worldwide.

The heat was captured directly and predictably related to the difference between the vapor temperature of the compost and the heat sink, a vapor temperature range of 51–66°C compost.

There is a lag time of 5 days, the heap of compost to the formation of vapor until the temperature of the compost has been sufficiently large for energy recovery (≥50 ⁰C).

A second temperature difference existed also during each cycle of aeration, where the inlet temperature vapor, immediately after coming out of the compost heap, differs from reaching the heat exchanger, a difference of almost 4.4⁰C after the first minute of aeration and 1.3⁰C after six minutes.

Following these gaps, composting plant operators may reconsider energy recovery ventilation system design and aeration cycles to achieve maximum energy capture.

In Figure 2 is shown such a system for recovering heat energy from the high–capacity compost.

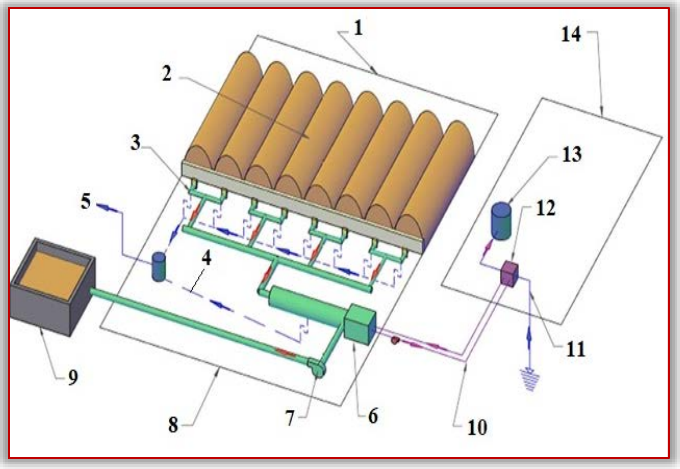


Figure 2 – Heat recovery of high capacity composting system – Schematic diagram –
1 – composting chamber; 2– compost; 3 – pipeline for collecting equipped with automatic valves; 4 – condensation collection circuit; 5 – condensing water outlet pump; 6 – isobaric heat exchanger; 7 – fan; 8 – mechanical room (the location of the heat recovery system); 9 – bio–filter to eliminate odors; 10 – hot water circuit; 11 – preheating water network; 12 – heat exchanger with flat elements; 13 – hot water tank; 14 – space for end use hot water.

The results of experiments in which the parameters measured are identified, are shown in the diagrams of Figure 3. The efficiency of energy capture and predictably varies strongly with the temperature difference between Vapor Heat Exchanger and Heat Sink Tank.

Heat recovery system in industrial composting system

This system was implemented at Diamond Hill Custom Heifers by Agrilab Technologies Inc. and the composted waste is manure and bedding material used in cattle (**** 5), Figure 4.

The system is essentially self–powered, with the exception of a small amount of electricity needed to power at 120 VAC four fans in line, 1/8 hP motor systems.

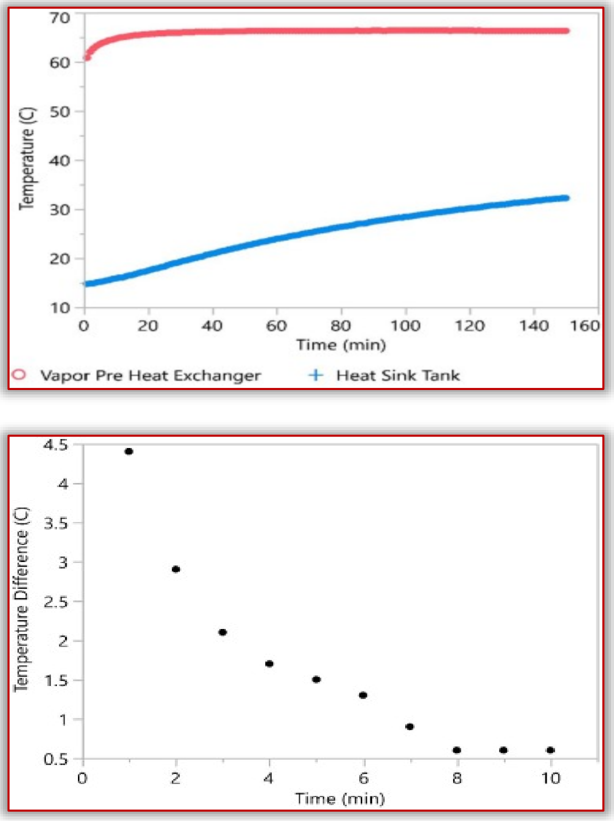


Figure 3 – Parameters variation in the composting process

Figure 4 – Industrial system implemented at Diamond Hill Custom Heifers

The system consists of two separate composting hall through a central gallery closed. Each of the waste composting heaps is approximately 15.5 m wide and 18 m in length allows the active composting between 700 and 800 tons of materials concomitantly itself. In each hall may form four piles (furrow) where the current can reach and maintain a temperature of 120 to 165 degrees F for four to eight weeks after the initial training.

The floor is made of reinforced concrete with a thickness of 6 "to 10" poured over the sand compacted to apply the foam of the type used in the installation of electrical systems in floor heating.

Semi–concrete and embedded in the insulation installed over a network of pipes made of PVC. In addition, these pipes are insulated with a material is coated "Techfoil" that increases the amount of insulation around the pipes. The connecting pipes are, in fact, the collection of vapor, have a diameter of 10 "and are vertically mounted fan by a record flexible 10", after which they are attached a pipe greater corrugated PVC, diameter 24 " in which are arranged six conductors Isobar superthermal.

The conductors of the isobaric superthermal devices are defined technically heat exchange in two phases, in this application are accomplished of the stainless steel tubes 3”, sealed at each end and loaded with a fluid for work.

Isobars are insulated devices, which constant achieving uniform temperature on the surface of the heat contributions due to random. In this particular application, hot water vapor condensed on Isobars are immediately transferred to that part of Isobar which is in contact with water in the tank

As long as the bulk water in the tank is at a lower temperature than the water vapor in the hot compost, the transfer will take place. Isobars are self–powered, they do not need electricity or other external power source to activate only a temperature difference from one location to another on its surface.

The advantage of the transfer Isobar Agrilab is that it provides the supply of hot water accumulated in an insulated tank of bulk storage to be used directly, most often by providing all the necessary hot water, or as an adjunct to heating classical hot water

Heat recovery from the compost made in tunnel vessel (containers)

Investigations have been conducted by a group of researchers in Scotland, on the recovery of thermal energy from the system composting tunnel, composting system Deerdykes Facility (Irvine G., et. Al, 2010).

The achievement was completed in 2006 and supports the location of green waste, industrial sludge and liquid wastes. Main components are offices, tunnel composting vessels, the aeration of compost and the compost material mixing.

There are 8 tunnel composting vessel sizes, as follows: 1–4 tunnels is 5 m wide and 25 m long; tunnels 5 and 6 are 5.3 m wide and 35 m long; 7 and 8 tunnels is 5 m wide and 35 m long (SD Last, et.al, 2005).

The tunnels are approximately 5m high, however, the height of the compost loading was about 3m, Figure5. Vessel composting process was fully controlled by a computer software package designed specifically for the trial. Air flows for all fans of the air were varied automatically depending on the measured levels of temperature, pressure and oxygen within the tunnel.

The hot air extracted from the vessel by the fan pos. 6, is directed to a heat exchanger to recover heat from it, before being passed through the biofilter.

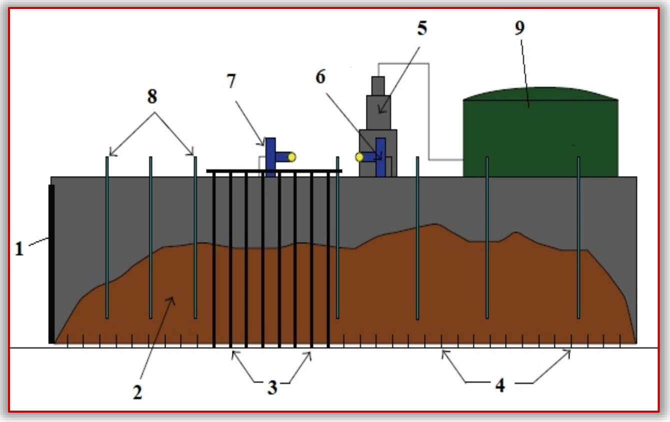


Figure 5 – Section through the composting vessels tunnel
1 – composting unit; 2 – compost; 3 – recirculation;
4 – holes aeration of the compost; 5 – noxious wet scrubber; 6 – ventilator circuit to the bio–filter;
7 – suction fan; 8 – measuring system of the composting temperature; 9 – bio–filter.

For the dimensioning of the recovery of heat from the compost made in the container, which is necessary in a livestock farm, is based on the amount of waste (manure) in a one–year on the farm itself, C_d, which is determined by the relationship (1).

$$C_d = n_a \cdot q \quad [m^3] \qquad (1)$$

where:

na – the number of animals on the farm;

q [m3] – the amount of manure produsăde an animal in a year.

Also determine the volume of the container for composting V_c occupied by the material subjected to the process of composting, depending on the amount of waste in the holding and the expected duration of the ongoing phase fermentation process in a composting container, so that the system compost all of waste produced of a year, to which are added the energy material required by composting process, C_e, according to the equation (2).

$$V_c = (C_d + C_e) \cdot \frac{t}{365} \quad [m^3] \qquad (2)$$

where:

$C_e[m^3]$ – the amount of energy material required composting;

t [days] – estimated period of performance of the fermentation phase in a process of composting.

Depending on the volume of air generated by the fan, air temperature and water consumption needs, to be estimated size of the heat recovery unit of the compost.

RESULTS AND DISCUSSION

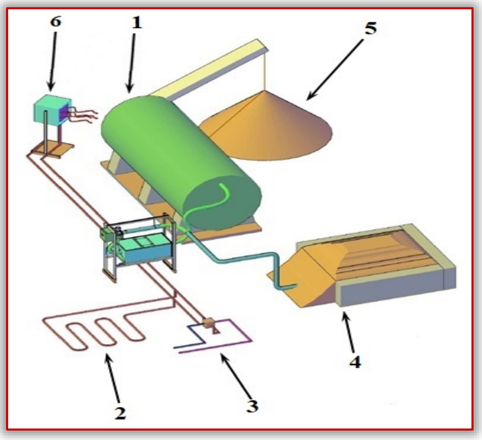
Heat recovery from compost system proposed is composting container fitted with the recovery of thermal energy from the hot air generated in the process of composting biodegradable waste.

The heat sources in the form of wet vapor captured in the warm compost is conducted through specialized heat exchangers in which water is heated.

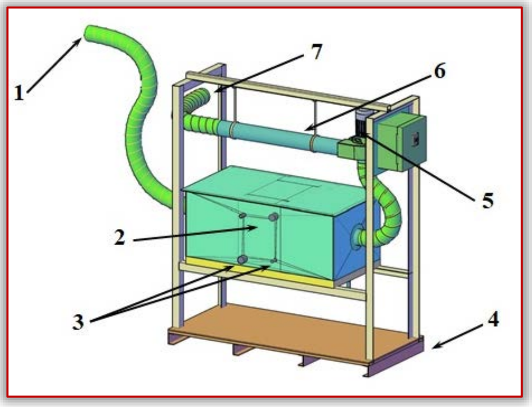
The exhaust air can be sent back automatically to optimize compost moisture and the entire process or directly into a bio–filter to eliminate odors.

The hot water can be used in industrial installations for washing farms as water or for space heating.

Schematically, the complete composting system, with heat recovery, is shown in Figure6a and the heat exchanger in Figure 6b.



a)



b)

Figure 6 – Container composting system with heat recovery facility – Schematic diagram
a) 1 – composting container; 2 – heat sink; 3 – water preheating system; 4 – bio–filter for odor reduction; 5 – finished compost; 6 – heating installation with energy recovered;
b) 1 – the hot air inlet hose connected to the compost; 2 – stainless steel heat exchanger is thermally insulated; 3 – connector of hot water and condensate drainage connector; 4 – stainless steel frame covered with epoxy resin; 5 – Fan; 6 – oxygen, temperature and flow of the vapor sensors; 7 – drain hose to the bio–filter.

The calculation of the thermal load for heating domestic hot water using heat recovered from the compost will be achieved, in the case of paper, a small family farm livestock with 5 dairy cows.

According to [**** 4], the amount of manure for a dairy cow in a week is about 0.315 m³, or about 17 m³ /year.

In this case the amount of manure produced in a year by the 5 dairy cows, complies relationship (3).

$$C_d = 5 \cdot 17 = 85 m^3 \quad (3)$$

For proper development of the composting process, in addition to the base material, using energy material.

The amount of energy material necessary for composting, from case to case, is about5–15% of the basic amount of biodegradable waste, in this case the manure and is calculated according to the relationship (4), considering an average of 10%.

$$C_e = 85 \cdot \frac{10}{100} = 8.5 \quad m^3 \quad (4)$$

We consider a fermentation period, t = 30 days [**** 3], for the situation that the composting process is carried out in forced aeration system.

Substituting the values considered in (2), result the volume of the container occupied by the composting materials will be developed and tested, according to the relationship (5).

$$V_c = \frac{(85+8.5)\cdot 30}{365} = 7.68 m^3 \quad (5)$$

The container volume will be about 10 m³ because it will not be completely filled with the composting material.

CONCLUSIONS

In principle, two methods known of composting heat recovery, respectively, direct and indirect methods:

- first direct method is to extract heat from the composting material in the form of heated water;
- the second direct method in composting heat recovery is use air heating, where air is pushed out (forced aeration) or pulled through (negative aeration) a composting heap;

An indirect recovery method involves harvesting the heat indirectly by altering the form of the bio–waste material itself namely Advanced Compost and Energy System (ACES). In the ACES, technically speaking, the moisture in the feedstock is evaporated by the biological response of a specific set of well–fed fermenting microorganisms that produces heat above 80°C and thus evaporates residual materials and food waste were compared,18.82 MJ/kg, in a heating value test;

Heat recovery systems results from the fermentation of aerobic (composting) of biodegradable waste is classified according to the embodiment of compost and known: heat recovery system in open compost pile formed with natural ventilation; heat recovery system of the compost piles open achieved (dumps) aerated forced; the heat recovery system of composting carried out in closed vessels, container aerated force;

The recovery of heat resulting from the fermentation aerobic (composting) of biodegradable waste proposed in the present work, has been designed for a family farm agro–zootechnical with 5 dairy cows and resulting a construction volume necessary of the container of 10 m³.

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