

EVALUATION OF PARAMETERS IN AN AEROB INDUSTRIAL FERMENTATION SYSTEM

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Abstract

Meat chicken (broiler) industry continuously increasing all over the world. Due to it, the amount of waste from the chicken industry is also increasing. Therefore, more efficient conversion of chicken manure to organic fertilizer is key problem all over the world.

Therefore, the aims of present study are to investigate the changes in temperature and moisture content during composting of chicken manure in a tank fermentation system and create a model to describe the biodegradation processes. In this study, Hydrus software was used for modelling the moisture and temperature distribution in the oval tank during the decomposing processes.

It was found that the studied oval tank fermenter can be divided into two main parts considering to the changing of temperature and moisture level. In the first phase - after the intake – where the rate of biodegradation is high there is a heterogeneous temperature zone with decreasing moisture content. Moreover, in this stage a special temperature profile was found at the cross-sectional view of the tank. The second phase was more homogenous both in temperature and moisture content. This stage is the weak fermentation part of the technology results an elongated post fermentation section. It was established, that the changes of temperature and moisture content along the tank fermenter are the same and there is a strong connection between them in the examined period. Our results pointed out that the initial turning and mixing results in a large temperature and moisture content drop and later there is sufficient time for composting to take place. The authors recommend that this system could be used as an efficient treatment for chicken manure materials to decompose and get a valuable base organic fertilizer.

Key words: chicken manure, fermentation, decompose, temperature and moisture model

INTRODUCTION

Chicken manure is very high in nitrogen and also contains a good amount of potassium and phosphorus (Szabó et al., 2019). But, the chicken manure as waste from the poultry industry includes a mixture of excreta (manure, feces and urine), bedding material or litter (e.g. wood shavings or straw), waste feed, dead birds, broken egg sand feathers removed from poultry houses. Other wastes include those from cage, conveyer belt and water-flushing systems. Poultry manure is acquired through regular cleaning of the poultry house (Kobierski et al., 2017).

The litter and manure component of this waste has a high nutritional value and is used as an organic fertiliser, thus recycling nutrients such as nitrogen, phosphorous and potassium. These components (poultry litter) have traditionally been land spread on soil as an amendment. The mature

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compost can improve soil fertility and plant growth (Haga, 1999). However, immature compost applied to soil would cause N starvation (Bernal et al., 2009; Moral et al., 2009), phytotoxic effects, and presence of harmful microbes (Fang et al., 1999; Tiquia, Tam, 2000).

The high nitrogen and balanced nutrients is the reason that chicken manure compost is the best kind of manure to use. But the high nitrogen in the chicken manure is dangerous to plants if the manure has not been properly composted. Raw chicken manure fertilizer can burn, and even kill plants. Moreover, over-application of this material can lead to an enriching of water nutrients resulting in eutrophication of water bodies, the spread of pathogens, the production of phytotoxic substances, air pollution and emission of greenhouse gases (Fan et al., 2000; Kelleher et al., 2002). Bitzer and Sims, 1988, reported that excessive application of poultry litter in cropping systems can result in nitrate contamination of groundwater. Excessive application of fresh poultry manure on the farm may result to excess accumulation of ammonia hence may damage the crop roots (Köteles, Pereş, 2017; Tamás et al., 2017; Szöllősi et al., 2018). Proper handling of the manure can be achieved through proper manure composting and appropriate practices of feed management (Bolan et al., 2010).

The production process of chicken manure organic fertilizer is basically includes: selection of raw material (chicken manure, etc.), drying and sterilization, mixing of ingredients, granule, cooling and screening, metering and seal, finished product warehousing.

The complicated production process of chicken manure is: The raw materials of organic fertilizer will be fermented (decomposed) and then entered into the semi-wet material crushing machine; then adding the elements of NPK, such as nitrogen, phosphorus, potassium chloride, ammonium chloride, etc., to meet the required standards; then it is stirred by a blender and then in to the granulating mechanism; after coming out, it will be dried; then sifting through the sieve, and the qualified products will be packaged; the granulation that not be qualified will return to the granule to produce again.

Thus, the chicken manure must be decomposed before casting. The parasites in the chicken manure and the infectious agents will be killed and deodorized by the process of decomposition. A considerable body of literature exists concerning the composting facilities (Elwell et al., 1998; Tiquia, Tam, 1998) and physical operation of chicken litter (Raviv et al., 1999).

Decomposing is the aerobic degradation of biodegradable organic waste. It is a relatively fast biodegradation process, taking typically 4 - 6 weeks to reach a stabilised material. The composted material is odourless and fine textured with a low moisture content and can be used as an organic

fertiliser. Composted poultry litter is easy to handle and pathogen free. Disadvantages are cited as loss of nitrogen and other nutrients during composting, equipment cost and labour, odour and available land (Sweeten, 1988).

Decomposing processes affected by several factors. Temperature, moisture content, C/N ratio have a great effect on the decomposing processes. A high moisture content, of more than 75 %, inhibits a quick start to the composting process. The moisture content (or the degree of material drying) is a major influence on the decomposition rate and the tendency to stabilise, since the metabolic heat generation during decomposition drives evaporation. Factors that contribute to moisture loss include evaporation, leaching and aeration, natural or forced. Rynk et al., 1991, reported that moisture content should be maintained between 40 % and 60 % during the composting process, although Fernandes et al., 1994 have reported that successful composting of poultry manure mixed with peat or chopped straw has been obtained in a passive static-pile at high initial moisture levels (73 – 80 %).

MATERIAL AND METHOD

The oval tank fermentation and drying technology is a Japanese-developed alternative method is to poultry and pig manure, launched in 1970, which is still being developed today.

A study was undertaken by Georgakakis and Krintas, 2000, to investigate and optimise a composting system known as the oval tank system in composting poultry manure in a typical layer poultry farm in Greece. The fermentation system is one of the two treatment systems that have been applied for the treatment of wastes. The other is the Okada system and both are of Japanese origin. Both systems are based on the operation of specially designed manure turning and chopping mechanical system (MTCM). The system consists of a series of rotating metallic knives or forks with which the waste is completely turned, aerated and gradually pushed to the end of the specific tank. This installation consists of an open, shallow, oval shaped concrete tank (Fig. 1). The standard size of the tank is 60 m x 8.3 m.

Fresh manure is batch fed daily to the oval tank and an equivalent quantity of final material is removed from the exit. The tank is filled with the waste material up to a total depth of 1.0 – 1.2 m. The stirring machine with double rotors results in continuous mixing of the manure in the fermentation tank.

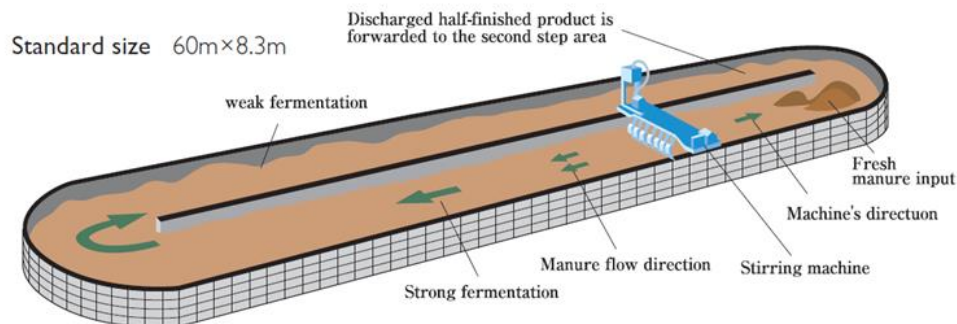


Fig. 1. Arrangement and processes of industrial fermentation system

The MTCM in the fermentation system completes a full run along the oval tank in approx. 2.5 h. On a daily basis, a maximum of 5 full runs can then be completed. One complete run results in the displacement of 1.5 m of manure along the tank or a maximum of 7.5 - 8.0 m after 5 runs completed in 24 h. Therefore, the minimum travelling time for fresh manure to reach the exit of the 120 m long channel is 12 - 14 days. During the turning and pushing of manure by the MTCM, surrounding air is incorporated and moisture is lost by evaporation. The fermentation system controls the initial moisture content by mixing the incoming fresh manure with the recirculated dry old material in the channel and this helps to start the composting process. Moisture control of the material in the oval tank is necessary to avoid blockages of the MTCM operation (Hosoya & Co., 1996). A particle size of less than approx. 12 mm is formed from the initially muddy-textured raw material due to the turning effect of the MTCM in the oval channel. The reduction of particle size enhances degradation due to the greater surface area available to microbes and an increase in void space for oxygen.

In this paper the performance of the oval tank fermentation system is studied by taking samples of poultry manure during a run and analysing them for moisture content, dry matter content, different nitrogen forms such as organic nitrogen and inorganic forms (nitrate and ammonium). The temperature of the material during the fermentation was also monitored.

In the fermentation procedure deep litter chicken manure and dehydrated hen manure from the Kisvárda slaughterhouse are used as a raw material. The capacity of the plant is 11000 t/year, which is 30 t daily usage. The mixing ratio of the raw materials in the fermentation tank is partly broiler and partly chicken manure (33 and 66 %). The moisture content of incoming chicken manure is varied between 20 and 40 %. For the optimal fermentation the moisture of the raw material must be adjusted to 40 - 45 % moisture by adding water (150 l/intake).

In the technology, 3 - 5 cm thick fermented manure remains at the bottom of the fermentation tank as a microbial starter.

To create a model of temperature and moisture distribution of the oval tank temperature measurements and sample collecting were made. Temperature measurement and samples collected in May, June and July to represent the effect of hot and dry circumstances on the processes of the fermentation. Sampling sites were adjusted to the sensors of the tank and our earlier observations (Fig. 2).

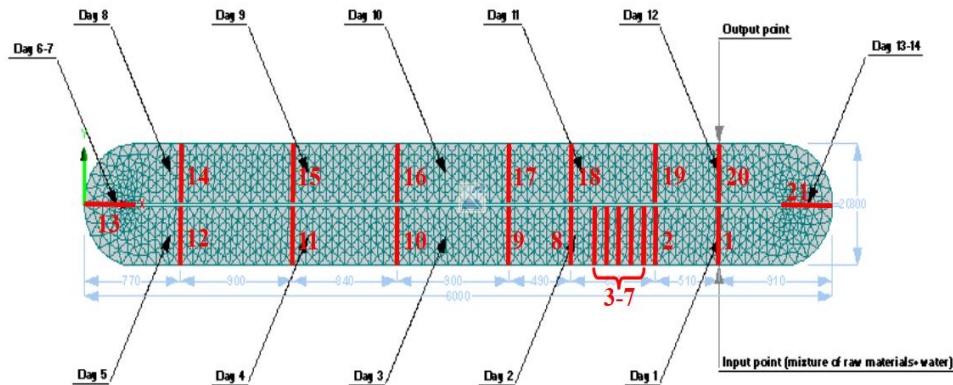


Fig. 2. Sampling strategy

The temperature of the material was measured at three points. One was the middle of the tank and two measuring points were 30 cm from the edge of the tank. Every measuring point were on the bottom of the tank. Testo 922 mobile thermometer was used to temperature measuring. From collected samples the moisture content was determined by weight loss in laboratory ($T = 105\text{ }^{\circ}\text{C}$) (MSZ-08-0221-1:1979). The moisture content was measured by drying in an oven at $105\text{ }^{\circ}\text{C}$ for 12 h, or until no change in the dry weight was observed.

Modelling environment

The two dimensional version of the Hydrus software was used for modelling the water and temperature distribution in the oval tank during the biodegradation processes. The software applies finite element model for simulating the movement of water, heat, and multiple solutes in variably saturated media. The mathematical background of the software is the Richards equation for saturated-unsaturated water flow and convection-dispersion type equations for heat and solute transport.

Model description - Applied parameters and boundary conditions

The 2D geometry of the fertilizer oval tank was created as a first step, where the target finite element size was adjusted to 0.1 m. The duration of biodegradation processes was set to 14 days in the model according to the

fermentation technology. The applied main parameters of feed material were 800 kg/m^3 bulk density, 55 % solid content and 70 % organic material content. In addition, the previously carried out results of in situ water content and temperature measurements were used as initial conditions. Finally, “no flux” boundary condition was applied at the inner and outer circumference of the model tank.

RESULTS AND DISCUSSION

I. Sampling and measurement (May, 2019)

The highest moisture content (49.50 m/m %) was measured between the sampling points 1 and 2, where the feeding point can also be found (Fig. 3). After the input point, the moisture content starts to decrease rapidly within a few meters, as a result of the intensive heat generation of biodegradation processes. The other part of the oval tank (after turning point) shows a slightly decreasing moisture content until reaching the output point. At the end of the fermentation process, the moisture content stabilizes approximately at 12 %, which is appropriate for pellet production from the composted material by pressure agglomeration technologies.

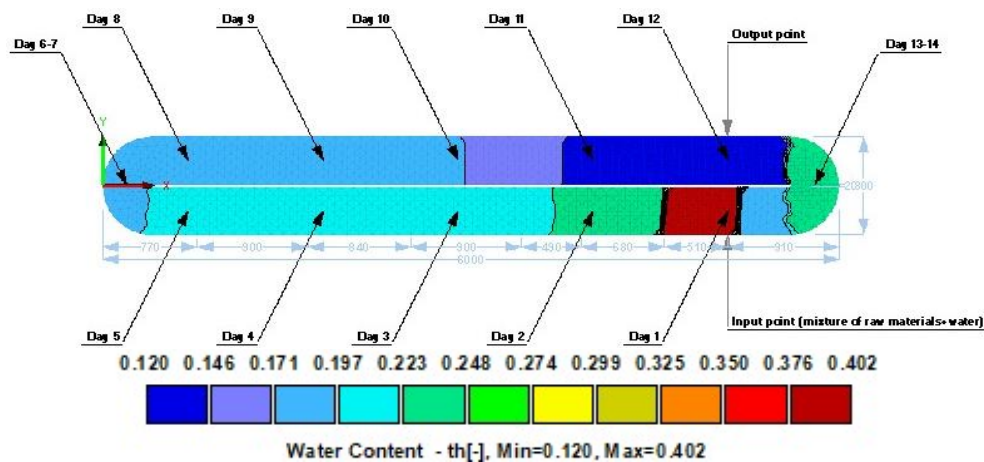


Fig. 3. Moisture distribution model based on the measured parameters in May, 2019

The fermentation tank can be divided into two parts based on the temperature distribution model. Heterogeneous temperature was observed from feeding point to sampling point 12 among the inner (45 meters), centre and outer part of the tank (Fig. 4). The highest temperature values arise in the centre of the mentioned sampling cross sections (on average higher than $7.99 \text{ }^\circ\text{C}$ compared to the inner parts and $10.17 \text{ }^\circ\text{C}$ compared to the outer parts). Strong variability was found between the inner and outer parts of the tank proved by relatively higher standard deviation values ($\pm 7.30 \text{ }^\circ\text{C}$ at inner parts, $\pm 8.82 \text{ }^\circ\text{C}$ at outer parts). After the turning point of the oval tank,

between sampling points 12 and 21 (76 meters) no significant difference was found in temperature values. The average temperature is 22 °C, where the standard deviation can be characterized by relatively low (± 0.55 °C) values. The temperature heterogeneity in the fermentation tank can be explained by the exact location of the stirring machine. According to the above mentioned, higher microbiological activity and heat generation were formed, where the stirring machine passed through earlier.

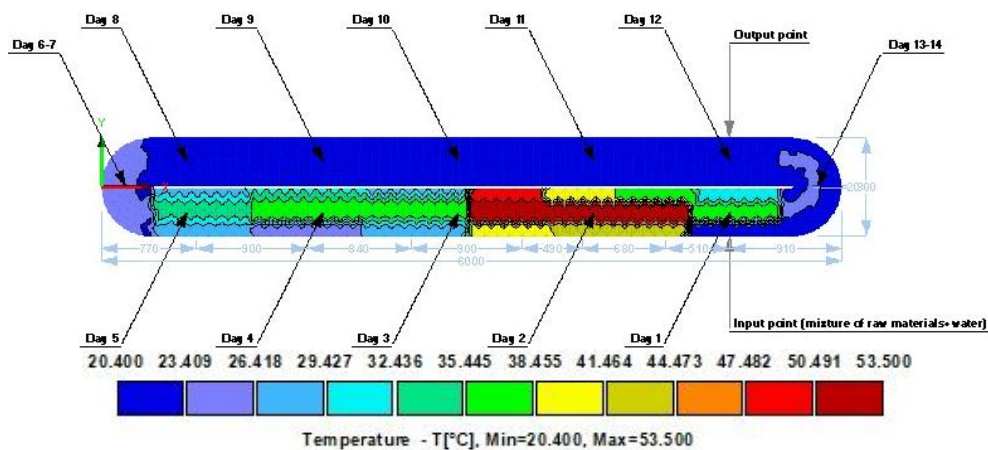


Fig. 4. Temperature distribution model based on the measured parameters in May, 2019

II. Sampling and measurement (June, 2019)

The moisture distribution model shows different characteristics compared to May, 2019, especially around the input point (Fig. 5). The highest moisture content (42.8 m/m %) was measured at the feeding point as in the previous month, however this value was adjusted for optimization at the beginning of the biodegradation processes and remained constant until the sampling point 9 (16.8 m).

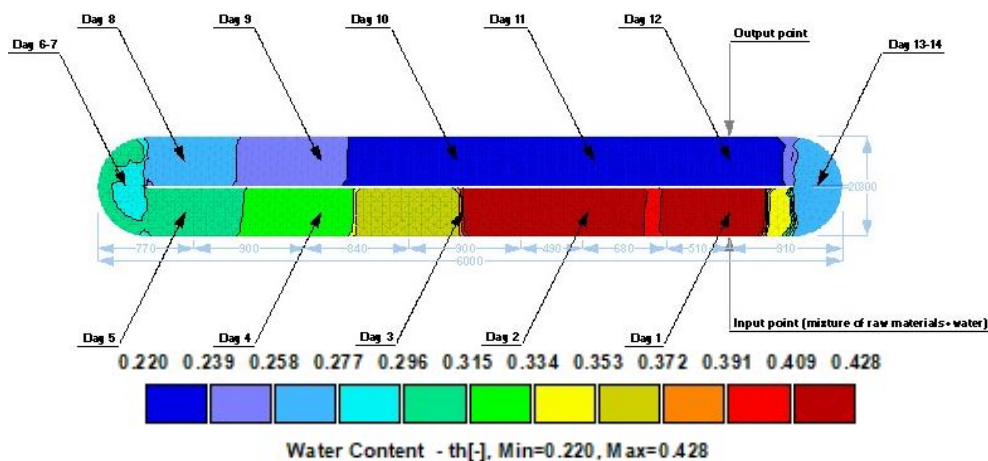


Fig. 5. Moisture distribution model based on the measured parameters in June, 2019

A rapid decrease can be observed after the high moisture content section. The other part of the oval tank (after turning point) shows a slightly decreasing moisture content, similarly to the results of May, 2019. The moisture content of the output material represents approximately double the value compared to May (20.4 m/m %).

Similar temperature characteristics were formed in June, 2019, as in the previous month. The fermentation tank can be divided again into two zones with the same boundaries (sampling point 1-12 and sampling point 12-21) based on the temperature distribution (Fig. 6).

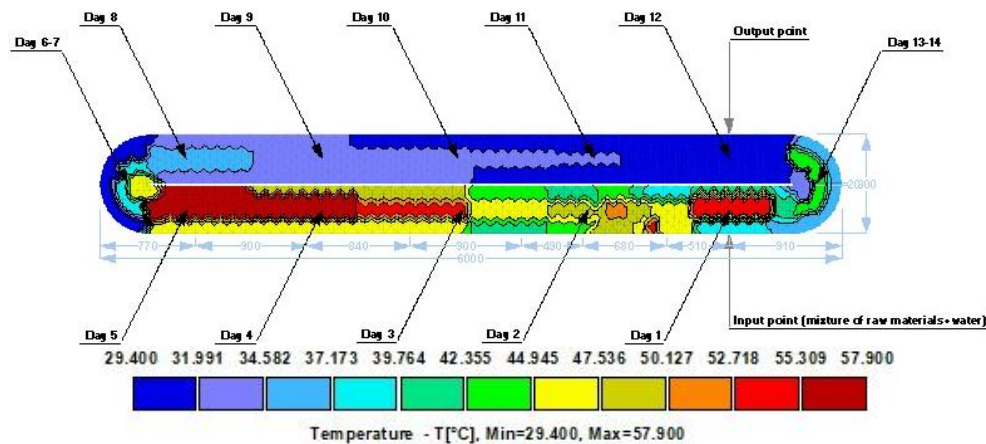


Fig. 6. Temperature distribution model based on the measured parameters in June, 2019

Heterogeneous temperatures were measured between sampling points 1 and 12 (strong fermentation zone), as a result the inner, centre and outer parts of the oval tank can be separated from each other. The centre part has the highest average temperature value (50.55 °C), higher on average than 7.27 °C compared to the inner parts and 3 °C compared to the outer parts. Weak fermentation zone was observed from the turning point (sampling point 13) to the output point. The average temperature in this zone is 33.42 °C, which is higher than 11.5 °C compared to the results of May, 2019. The calculated standard deviation is ± 1.54 °C, which means a higher temperature fluctuation in May. The ambient temperature was 26 °C.

III. Sampling and measurement (July, 2019)

The highest moisture contents were found between sampling points 2 and 5 (3 meters), which is the shortest section compared to the previous two months (Fig. 7). The maximum moisture content was 38.4 m/m % in the oval tank, representing the measured lowest maximum value during the three months long period. A local minimum value of moisture content can be observed at sampling point 6, thereafter the values start to increase until

reaching sampling point 11. At the other part of the fermentation tank, the moisture content stabilizes in narrow ranges (between 25.4 m/m % and 24.3 m/m %). The moisture content of the composted material is 22.6 m/m % at the output point.

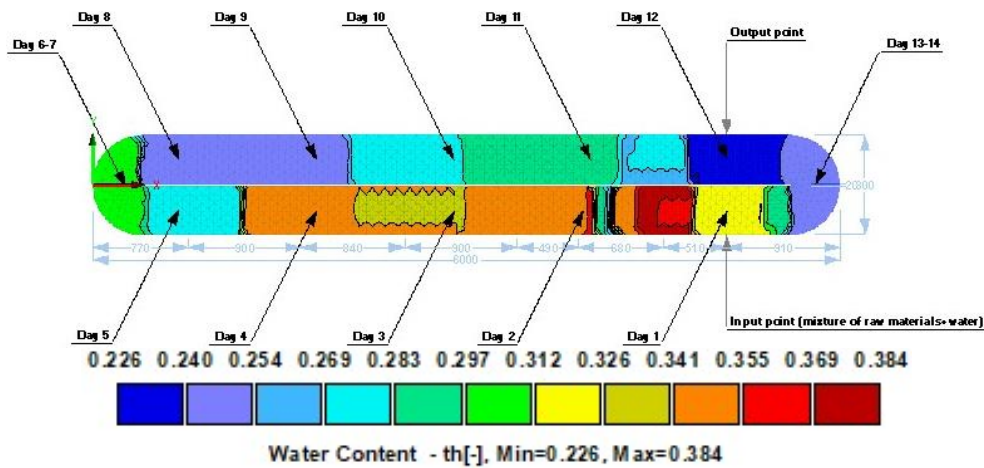


Fig. 7. Moisture distribution model based on the measured parameters in July, 2019

The heterogeneous and homogeneous temperature zones cannot be separated sharply based on the temperature distribution model of July, 2019 compared to the previous months (Fig. 8). It can be seen, that the highest temperature values formed again in the middle part until reaching the sampling point 11. The average temperature of the middle part is 52.1°C, which can be characterized by relatively lower standard deviation values ($\pm 1.82^\circ\text{C}$). At the sampling points of inner and outer parts, lower temperature values were measured, where the data fluctuation is relatively high (standard deviation values: $\pm 4.97^\circ\text{C}$ and $\pm 5.05^\circ\text{C}$).

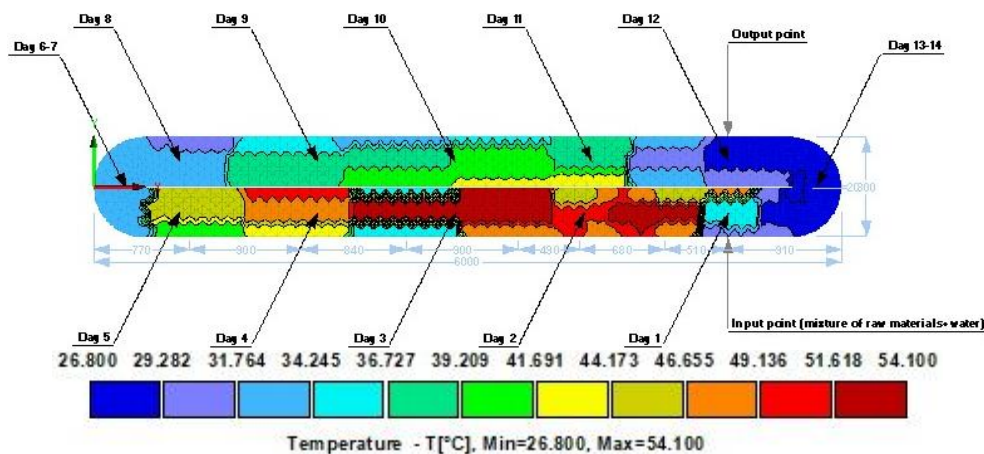


Fig. 8. Temperature distribution model based on the measured parameters in July, 2019

After the turning point of the stirring machine, the temperature tendency shows also heterogeneous distribution (average temperature of inner part: 38.08°C, average temperature of middle part: 36.65°C, average temperature of outer part: 33.99°C), supported by relatively high standard deviation values (inner part: $\pm 7.30^\circ\text{C}$, middle part: $\pm 6.58^\circ\text{C}$, outer part: $\pm 4.70^\circ\text{C}$). The ambient temperature was 26°C in the sampling date.

CONCLUSIONS

The performance and efficiency of an oval tank fermentation system studied by taking samples monthly from May to July of chicken manure during the run and analysing them for moisture content and temperature. The two dimensional version of the Hydrus software was used for modelling the moisture and temperature distribution in the oval tank during the biodegradation processes.

Our results pointed out that the initial turning and mixing results in a large temperature and moisture content drop. It was found that the studied oval tank fermenter can be divided into two main parts considering to the changing of temperature and moisture level. In the first phase, where the rate of biodegradation is high, there is a heterogeneous temperature zone with continuously decreasing moisture content of pile. Moreover, in this stage a special temperature profile was found at the cross-sectional view of the tank. The second phase was more homogenous both in temperature and moisture content. This stage is the weak fermentation part of the technology results an elongated post fermentation section. The changes of temperature and moisture content along the tank fermenter are the same and there is a strong connection between them in the examined period. Our results pointed out that after the initial, warmer “thermophilic” stage there is sufficient time for composting. Therefore, this system could be used as an efficient treatment for chicken manure materials to decompose and get a valuable base organic fertilizer.

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