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AEROBIC, THERMOPHILIC CO-TREATMENT OF CATTLE SLURRY WITH WHEY AND/OR JAM WASTES

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ABSTRACT

We have aerated cattle slurry alone or with whey and/or jam waste in a well heat-insulated reactor for 10 m^3. The aeration was vigorous and a rapid increase of temperature - even to 70 °C - could be recorded in spite that the process was done in wintertime so that the temperature of raw material was less than 10 °C at the beginning. Thus the hygiene problems would be avoided and the compost product could be transported to other farms. Cattle slurry alone fitted well as a raw material if the high temperature is the main aim. A part of slurry could also be replaced with the industrial side products. Whey waste fitted better for co-composting than jam waste. The end product contained almost all nitrogen from raw material and would be useful as a fertiliser and increase organic matter content of Suonenjoki agricultural fields, which had been used often for berry production (mainly strawberry). The process would reduce the wastewater and solid waste problems by using whey wastes and jam wastes from the local dairy and berry industry, respectively.

INTRODUCTION

The main agricultural production in Suonenjoki bases on the production of milk and berries, especially strawberries. Berry cultivation has continued already decades on the same fields, so that soil structure has often degraded and soil organic matter should be increased. Because most berries are eaten raw, the fresh, non-processed cattle slurry would probable mean hygiene risk for berries. Some cattle farm fields situate so close to dwellings that the spreading of fresh cattle slurry would cause smell problems. The dairy is very important economically for Suonenjoki, but it comprises also 35 % of BOD_7 for wastewater treatment plant, because of whey lead to wastewater treatment plant. The locally cultivated strawberries and other fruits and berries are processed to jams by industry. The jam residues can cause problems to the local wastewater treatment plant but the berry industry had to pay high fees for solid waste dumping which will be more limited in the next future (Finnish Governmental decision, 1999).

To solve partly the slurry problem of cattle farms and waste problems of dairy, berry industry and wastewater treatment plant and the soils structure and fertiliser problems of berry cultivation farms we studied the aerobic co-treatment of these wastes in order to change them as a fertile soil organic matter. If the other animal wastes should be treated for 1 h at 70 °C to get fertiliser, which could be used also by consumers outside manure producing farm, as written in a proposal for European Union to animal by-product treatment (Council of the European Union 2001).

MATERIALS AND METHODS

Materials: Freshly formed slurry during winter indoor feeding period from calf and heifer house was lead to the reactor. The dry matter of slurry was typically 12.0-12.6% and the total nitrogen content was 3.8 g/l.

Whey with dry matter of 6.0% and pH 4.6 (between 3.9-4.6) was formed in the local dairy from soft-cheese processes using non-fatted milk as raw material. Jam wastes studied were thick sucrose containing fruit jams, which contain natural and added organic acids and their salts as preserving compounds. Its dry matter was 4.8 % and pH only 3.6 (between 3.0-4.1).

Degradability abilities of slurry, whey and jam: A degradability abilities of whey and jam with the mixture of slurry were studied in a laboratory aerations so that the volume was 1600 ml or 2400 ml leading air through slurry-water mixtures adjusting to dry matter to 8.0%. The raw materials were mixing up 60 % of slurry and 40 % of whey or jam or 60 + 20 + 20 % of slurry, whey and jam. The degradability ability was evaluated by using respiratory rate test according to OECD (1984) or by following the redox potentials.

Hygiene control: Hygiene was measured by determining somatic coliphages, RNA-coliphages (without RNAase), total coliforms, faecal coliforms, enterococci and faecal clostridia (Rajala & Heinonen-Tanski, 1998). Heterotrophs and streptomycetes were studied from some samples co-composted at high temperatures as described by Heinonen-Tanski et al (1985).

The pilot plant fermentor trials: A heat-insulated reactor of 10m^3 slurry had been constructed from an old stainless steal milk tank and placed to a private cattle farm. A light cabin had been build outside the reactor to protect the control unit from rain. The reactor had been originally built to get its oxygen for aeration from pure oxygen. For these experiments the aeration was rebuilt so that air (4-6 m^3/h) could be pumped to the bottom of the fermentor and mixed with a propel aerator (Hesver, Finland) and a foam cutter was set on.

The process was carried either by batches or semicontinuously. If only slurry was used in aeration, the dry matter of slurry was adjusted to 8% with water. The semicontinous aerations with slurry and mixtures whey or/and jam were carried. The maximal mixing ratios between slurry and whey and jam were 45 % + 27.5 % + 27.5 % and with slurry and whey up to 70 % + 30 %.

RESULTS AND DISCUSSION

Tests with pure oxygen as oxygen source: No heat formation could be found in 10 m^3 of slurry or other mixtures containing also peat. Pure oxygen can not therefore be recommended to be used as oxygen source in liquid composting. It is assumed that oxygen is too reactive for cell function (Chamnongpol et al. 1995).

Laboratory scale aeration tests: The raw materials in laboratory aerations showed respiration rates up to 53 mg/l h suggesting that it was necessary to pump air in order to get positive redox potentials. If the amounts of whey or jam were too high (appr. 35%) the pH decreased up to less than pH 5 and the respiration rates were on the level of 10-20 mg/l h. Increasing again the portion of slurry, the respiration rates increased again.

The reduction of smell was evident and the aerated mixture was easier to be pumped than the non-aerated mixture. Foaming was typical for aerated mixture. Reductions of 90 % were found in faecal coliforms and 99 % in somatic coliphages in 16 days in spite no temperature increase could be found.

Due to small volume of the aeration the temperature increase could not be found.

Co-aeration of slurry + whey + jam up to 60 + 20 + 20 % was found to be successful - possibly more successful than slurry alone. None of the raw materials contained so much inhibiting compounds that they would not allow composting. Whey fitted better for co-composting with slurry than jam.

Pilot scale fermentation tests:

Slurry as only raw material: The batch aeration of 9m^3 slurry and 1m^3 water showed a temperature increase from 10 °C to 30 °C in five days despite that the aeration was discontinuous due to daily electrical installation work. During the next 19 days the temperature increased to 70 °C and pH from 8.3 to pH 9.0. The numbers of enterococci decreased from $2 * 10^6$ to 100 cfu/ml and faecal clostridia from 300 to 35 cfu/ml. All the other tested microorganisms destroyed to less than the detection limit (10 cfu/ml for bacteria and 1 pfu/ml for coliphages), although their original numbers had been on the same levels as those of enterococci. The reductions were thus at least 3-5 log units.

If the process using slurry as the only raw material, was semicontinuous with appr. 5 days retention time, the temperatures of 70-72 °C could be reached. The temperature increase was highest in batch aerations at the temperature ranges of 20-50 °C. The net heat energy formed by aerobic respiration was maximally 17,000 kcal/day m^3 if the energy escaping as heat was not considered. This heat energy production corresponds to 8.2 kWh, which is clearly more than the electrical energy of 1.5 kWh needed at the same time by aeration pump. We, anyhow, assume that the heat formation was more powerful, because the effective aeration forced warm water vapours out of the reactor and this heat had to be lead outdoors to protect electrical control units. Thus the aeration process was energetically profitable even in Nordic winter climate, in which the experiment was carried.

The heat production efficiency was approximately 10,000 kcal/day m^3 still, if the temperature was at 58-68 °C.

If only slurry was aerated, pH increased and approximately 8% ammonia losses by evaporation were measured. The total nitrogen content was 3.5 g/l in the aerated slurry.

Mixtures of slurry with whey and/or jam: The mixtures of slurry and whey (up to 50% + 50 %) and slurry and jam waste (up to 62.5 % + 37.5%) could be treated reaching at least the temperatures of 55-60°C in batch aerations. The temperature increase was not as rapid as was the case if more slurry were used. Whey fitted again better than jam waste for aerobic co-treatment with slurry. Increasing of the proportion of both whey and jam waste decreased the pH (even to less than pH 5), which reduced the microbial activity and increased retention times needed. The decreased pH reduced, on the other hand, the ammonia losses, which were only 4%. In this case the total nitrogen content was 1.9 g/l in aerated mixture of slurry, whey and jam.

The mixture of cattle slurry + whey + jam waste (45 % + 27.5% + 27.5%) produced maximal heating efficiencies (temperature 68°C). The retention times could as short as only three days being thus lesser than those using only slurry. The heat production might be the same or even better than that with slurry alone. Foaming, however, was a more serious problem in this aeration and this problem still must be solved. The numbers of heterotrophs were reduced from 2.0 * 10^7 to 3.5 10^4 cfu/ml and the streptomycetes from 2,300 cfu/ml to less than the detection limit (100 cfu/ml).

CONCLUSIONS:

1. It is possible to make a high temperature aeration process, which is energetically profitable so that the extra heat could be used for pre-heating of water etc.
2. The heating claims of 70°C for 1 h were reached. They are so high that the liquid-composted product could be used without any hygiene risks for fertilisation and increasing of organic matter of strawberry field.
3. The reactor sizes for this heat-insulated process can be moderate, because the retention times can be only on the level of three-five days.
4. The reducing of waste treatment fees of dairy, jam industry and wastewater plant would nowadays be still more economical than the heat energy.
5. Cattle slurry and different carbohydrate-rich food industry side-products can be aerobically co-treated, but the mixture rations must be studied for each case. The foaming problems, if they exist, must still be solved.

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