Wastes and Wastewaters from Vegetable Peeling Processes

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Abstract
Potato and vegetable processing is becoming more common on agricultural farms in Finland. Fresh peeling waste is valuable feed and it can be fed to production or game animals. Wastewaters from vegetable peeling processes cause serious environmental pollution when discharged untreated because of their high concentrations and organic matter contents. The large amounts of different types of compounds and the high biochemical oxygen demand (BOD₇) in these waters make it complicated to treat. Different kinds of treatment methods were evaluated in this study. Sequencing batch reactors are one of the most competent means of treating wastewaters on farms. Biological-chemical wastewater treatment systems are able to attain high nutrient removal efficiencies. Composting is complicated in waste peels with high water content. Compost made from peeling waste and peeling waste incorporated with other materials has good nutrient content for soil enrichment and fertilization.

INTRODUCTION
There are some hundreds of vegetable and potato peeling farms in Finland. Disposal of untreated wastes generated through vegetable and potato can have a significant effect on the environment. One of the aims of the IPPC directive (96/61/EC) is to minimize waste discharges and pollution from farms to soils, waters, and air. Vegetables and potato processing enterprises in Finland are usually small and their resources are modest, for this reason they have inadequate systems to treat the complicated wastes and wastewaters generated by their operations. Furthermore, treatment of these wastes and wastewaters has to be on-farm-scale as the farms are usually situated far from each other. Another difficulty is with the use of biological processes due to cold climatic conditions in Finland.

During the peeling process, 30–40% of the potatoes and vegetables become waste. In addition to this, some of the vegetables and potatoes are rejected during sorting. Waste generated by peeling commonly called peeling waste is very wet, with about 90% water content. There are different methods of handling wastewater generated during the peeling process. These include conveying of wastewaters to communal wastewater treatment plants, use of sequencing batch reactors, and the use of different kinds of filtration or sedimentation systems. Wastewaters can also be spread on agricultural fields.

Peeling waste can be composted or anaerobically digested, or fed to production or game animals. Composting of peels is difficult because the waste is very wet and therefore it needs a large amount of bulking material. There are also some treatment methods that separate solid matter and water from the peel waste, and then the dryer solid
matter is easier to compost. The peels can be composted in drums or in compost piles. Drum composting has many advantages as the moisture, temperature, and oxygen conditions can be controlled. Composting in piles is a cheaper alternative but the method has problems as changing weather conditions affect the process. There is also the need for machines like a front loader to turn the compost.

Before end-use, peel waste must be treated in order to destroy plant pests. The processes at composting facilities should be managed in such a way that the thermophilic temperature ranges are reached and a high level of biological activity are maintained over the composting period. This can be achieved when conditions are favourable with regard to humidity and nutrients, as well as with a suitable structure, which guarantees optimum air conductions. The water content should be 40-60%, the pH value about 7, and the carbon/nitrogen-ratio near 30. In the course of the composting process, the entire quantity of material treated must be exposed to a temperature of at least 40 °C during the period, or alternatively to a temperature of 70 °C for a period of one week (Hoitink and Poole 1980).

Plant pathogens like *Sclerotinia sclerotiorum* and *Sclerotinia minor* cause sclerotonia disease of carrot and this is one of the most harmful storage diseases in vegetable farming. *Plasmodiophora brassicae*, which causes clubroot to the brassicas, is spread through the soil. The dormant spores of pest plants can survive in the soil for many years and may germinate when they find the right host plant. High temperature ranges in composting can destroy microbe-spreading pest of plants.

Wetlands can also by used for treating potato wastes. Kadlec et al. (1997) and Burgoon et.al.(1999) have studied wetland treatment of potato processing waters in Washington and Oregon. In this study we evaluate the different kinds of methods used in treating wastes and wastewaters from vegetables and peeling plants. The aim is to find the most suitable method that can be used on farms. The study is still in progress. We present the preliminary results here.

MATERIALS AND METHODS

We performed case studies on some farms in Finland. The major points of interest were the peeling processes used, the volume of water used, the quality of the wastewater, the wastewater treatment method, the efficiency of the purification systems, and the kind of peeling waste and its handling methods.

Wastewater

Wastewaters are generated from washing of the vegetables, peeling, and washing of the peeling machines. There are two main methods of peeling vegetables, dry peeling and wet peeling with water. There are big differences as to how these processes use water. The amount, concentration, nutrient, and organic matter content of the wastewater generated are very different depending on the method. The machines used are carborundum peeling machines and knife peeling machines. When vegetables are peeled with carborundum machines, the abrasive rollers generate fine and wet waste. The vacuolar fluid, which is very concentrated with organic matter and nutrients, gets into the wastewater. In the dry processes where knife peeling is used, wastes and wastewaters are easier to handle because wastewaters and solid materials are separated in the process.

The most important principle in environmental protection is to minimize the use of water. To be able to recycle the wastewater generated from the peeling process, the dry matter should be separated from the water when possible. Hygienic factors must be taken into account at every stage of the process, especially when water usage is minimised.
The volume of water generated from the peeling process fluctuates a lot, usually the volume ranges between 1 and 50 m$^3$ per day depending on the production volume. The concentrations of BOD$_7$ (biochemical oxygen demand) of these wastewaters are usually very high, with BOD$_7$ of 1000–7000 mgO$_2$/L. The concentration of total nitrogen is usually 50–100 mg/L and that of total phosphorus 50–80 mg/L. Table 1.

Wastewaters may also be spread on fields but according to the nitrate directive (91/676/EEC) this is prohibited during the wintertime as the soil is frozen. To be able to spread all the wastewater generated over the whole year on fields, the farms must have large containers to store the wastewaters half of the year during which the ground is frozen. The best way to handle wastewaters from the peeling process on a farm is to convey these waters to a communal wastewater treatment plant.

A potential method of treating wastewaters on farm is by conveying them to biological-chemical wastewater treatment plants. These treatment plants usually achieve good removal efficiencies with respect to organic matter and nutrients.

We studied two different on-farm-scale biological plants and one system where the wastewater is conveyed into an artificial pond. We grouped them into cases.

**Case A:** This plant is on a farm where about 10 tonnes of carrots is peeled per week. In addition to this, other vegetables like onions and red beets are also peeled. About 10 tonnes of carrots are washed and bagged per week. About 7.5 m$^3$ per day or 37.5 m$^3$ per week of wastewater is generated from this production. The wastewater is piped through three sedimentation basins into an aeration reactor. The volume of this concrete reactor is 35 m$^3$ and it is placed below ground level. A warm cubby is built above the reactor. Phosphorous is precipitated with ferrosulphate during the aeration. In addition, there is filtration field for the post-treatment of the wastewater. Fig 1 and 2.

**Case B:** The farm generates 12 tonnes potato peels per week in addition to peels from carrots and other vegetables. About 7 m$^3$ of wastewater per day is generated by the peeling process. Dry peeling is used. The wastewater is first transported to a sedimentation basin, after that to a 10 m$^3$ container, in which a sedimentation chemical, Al$_2$SO$_4$, is added to precipitate particles in the wastewater. After sedimentation, the water is piped into a trickling filter, a container filled with plastic particles. The wastewater is trickled through plastic material. The micro-organisms in the wastewater attach themselves to the plastic particles, which are covered with bacteria. The bacteria breaks down the organic waste and remove pollutants from the wastewater. The containers are placed in a warm room in the same building where the vegetables are peeled. Fig. 3 and 4.

**Case C.** On this farm, 8 tonnes of potatoes are peeled per week. The peeling method is dry and for that reason about 3 m$^3$ of wastewater is produced per day. The wastewater is then conveyed to a sedimentation basin where phosphorous is precipitated by an aluminous polymer. The wastewater is acidic, and therefore the pH is adjusted with liquid lime. The wastewater is conveyed to a 60 m$^3$ artificial pond (sedimentation pond). The wastewater remains in the pond for about 20 days. After that, the water runs to a dike on the field.

**Wastes**

One way of handling peel waste is to feed it to animals, but usually other means, like composting, are also needed. All potato products are good sources of energy for ruminants. Potatoes consist of 80% water and the water content of the peeling waste is usually more than 85%. Process waste should be mixed to other feed so that the dry-matter content of the mixture is adequate. In addition to potatoes, bovines need protein,
minerals, vitamins, and fibre because potatoes do not contain fat or fibre (Boyles 2004). When feeding potato peel waste to cattle, attention must be paid to its handling and mixing ratio to other feed-stuffs. (Crickenberger 1996). The waste can only be stored for limited periods. It has been shown that after one week of storage, potato processing wastes lose almost 20 % of their starch through degradation, and after three weeks of storage the losses exceeded 50 % (Woods end research laboratory 1990).

It is not practical to use dry feeding automats for feeding potato peel waste to animals because the feed used should be dry. Since peeling waste is wet, it is not a problem in liquid feeding automates. Potato peeling wastes should be cooked before feeding to monogastric animals (pigs and fur animals). Cooking increases the digestibility of the feed. (Subcommittee on etc.1983).

When the peeling waste is composted, lots of mixing materials are needed to make the compost fluffy to improve air circulation, to make the compost drier and to adjust the C/N ratio to the right level. Separating drum and screw screens can be used to remove water from the peeling waste to prevent freezing and make handling easier if the waste is to be stored during the winter.

In our tests, we collected and composted peel waste from carrots for three months in a laboratory room with controlled environment. The temperature and humidity were kept constant, at 20 °C and 70 % respectively. The volume of the compost was about 50 litres. The temperature in the compost was monitored during the composting period, and the nutrient and carbon content was measured before and after the composting. Different materials and mixture ratios were used in the composts.

RESULTS AND DISCUSSION

Wastewater
The wastewaters from the peeling processes and their resulting treated waters in the various cases were analysed in the laboratory. The results are presented in table 1. The quality of the wastewater varies a lot because of fluctuations in production and raw material.

There are not so many full-scale biological treatment plants on farms for vegetable peels due to the lack of knowledge about the process. Authorities have not yet educated all peeling farms about the appropriate and proper ways to treat their wastes and wastewaters. It is also quite expensive to build wastewater treatment plants. All treatment methods also need care and control.

The temperature of the biological process should over 2 °C, and in Finland the ambient temperature is usually below zero during wintertime. Biological-chemical treatment systems can be placed below ground level or in a warm building.

There is no uniform requirement about the reduction efficiencies for treatment systems, but the order of magnitude when the wastewater volume is under 10 m³ is as follows: BOD₇ for the treated water should be <50 mg/l, COD_C₅ <400 mg/l and Phosphorous (Pₜₒ₉) <2 mg/l. With biological-chemical wastewater treatment plants on farm it is possible to reach these requirements. An artificial pond can also be used to pre-treat the wastewater.
Wastes

We performed laboratory tests to determine the feed value of Swedish turnip and carrot peeling waste. Dry matter, crude protein, crude fibre, fat, NDF (neutral detergent fibre), and ash content were also analysed. The results are presented in Table 2 together with the typical feed values for wilted grass silage, which is common cattle forage on farms.

The dry matter content varies in peeling waste. The dry matter content affects the chemical composition and biological quality of the waste. The crude fibre and NDF contents indicate the feed value of the waste. From the results it can be realised that Swede turnip peeling waste can serve as a good feed. Carrot peeling waste is of lower quality. The content of crude protein, crude fibre, and ash in swede turnip peeling waste is the same as in good grass silage. In carrot peeling waste, the contents are lower. Table 2. Before feeding to animals, the peeling wastes should be mixed with other feeds in order to improve their feed value.

From the tests on composting we realised that when composting wastes, the mixture ratios 43% of peeling waste, 43% of peat, and 14% of woodchips (vol/vol) seems to be the optimum in order to prevent the spill out of liquids from the compost. Results from the tests also showed that after three months of composting in buckets, the mixtures lost half of their weight and most of the liquid nitrogen was in the nitrate form. Carbon/nitrogen ratio of the composts, in which manure of chicken was added, gave the best results and the composting process was also better. The potato waste was acidic; the pH ranged between 4 and 5. By adding lime or ash to the potato waste compost it was possible to raise the pH.

Literature Cited


Tables

Table 1. The preliminary results of analyses of untreated and treated wastewaters in cases A-C.

<table>
<thead>
<tr>
<th>Case</th>
<th>Untreated</th>
<th>Treated</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>BOD₇ mg/l</td>
<td>COD₇ mg/l</td>
</tr>
<tr>
<td>Case A</td>
<td>2000-3000</td>
<td>4500-5000</td>
</tr>
<tr>
<td></td>
<td>20-30</td>
<td>180-220</td>
</tr>
<tr>
<td>Case B</td>
<td>1500-2000</td>
<td>2500-3000</td>
</tr>
<tr>
<td></td>
<td>30-100</td>
<td>500-1000</td>
</tr>
<tr>
<td>Case C</td>
<td>1200-2000</td>
<td>1700-2000</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>1300</td>
</tr>
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</table>

Table 2. Quality of the feed from Swede turnip, carrot and grass silage

<table>
<thead>
<tr>
<th></th>
<th>DM %</th>
<th>Crude protein g/kg/DM</th>
<th>Crude fibre g/kg/DM</th>
<th>Crude fat g/kg/DM</th>
<th>NDF %</th>
<th>Ash g/kg/DM</th>
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</thead>
<tbody>
<tr>
<td>Swede turnip peeling waste</td>
<td>9</td>
<td>163</td>
<td>153</td>
<td>16</td>
<td>1.6</td>
<td>88</td>
</tr>
<tr>
<td>Carrot peeling waste</td>
<td>10</td>
<td>50</td>
<td>97</td>
<td>20</td>
<td>1.6</td>
<td>120</td>
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<tr>
<td>Grass silage</td>
<td>30</td>
<td>160</td>
<td>280</td>
<td>38</td>
<td>58</td>
<td>92</td>
</tr>
</tbody>
</table>
Figures

Fig 1. The disposition of the buildings, the wastewater treatment, and the filtration field in case A.

Fig. 2. The processes of the sequence batch reactor produced by Envex International.
Fig. 3. The biological wastewater treatment plant by Green Rock Oy. A sedimentation basin (right) and a trickling filter (left) are placed in a building.

Fig. 4. Flow diagram of the wastewater treatment system produced by Green Rock Oy.
Traitement des Déchets et Effluents Résultant du Pelage des Légumes

Mots-clés : traitement, réacteur discontinu séquentiel, compostage, alimentation animale

Résumé

La transformation des pommes de terre et des légumes devient une pratique courante dans les exploitations agricoles en Finlande. Les déchets végétaux frais résultant du pelage des légumes constituent un produit utilisable pour l’alimentation des animaux de rente ou de compagnie. Toutefois les eaux usées résultant du pelage provoquent une pollution sérieuse de l’environnement si elles sont libérées sans traitement préalable, du fait de leur forte charge en matière organique. Les grandes quantités en divers composés et la valeur élevée de la demande biochimique en oxygène-7jours (DBO7) de ces effluents les rendent complexes à traiter. Les systèmes de type réacteur discontinu séquentiel sont l’un des procédés les plus efficaces pour les traiter à l’échelle des exploitations. Ces systèmes de traitement biologique et chimique des effluents permettent d’atteindre un pourcentage élevé d’élimination des composés organiques. Le compostage des déchets de pelage des légumes est compliqué lorsque leur teneur en eau est élevée. Toutefois le compost obtenu par le mélange d’épluchures avec d’autres matériaux présente de bonnes aptitudes pour l’amendement des sols et leur fertilisation.