Food processing wastes

M. Brett Borup, Susan L. Fenhaus

GENERAL

Environmental issues such as concerns for safe drinking water, chemical control, pretreatment and biomonitoring programs, and landfill crises are all concerns of the food processing industry. Plants need to have waste management programs that are built around waste reduction.1 An integrated data management system and a diagnostic and predictive expert system is being developed to assist in operating food processing wastewater treatment plants.2

Mikkelsen3 outlined the design and operation strategy of food processing plants that employ a sequencing batch reactor as a pretreatment system to remove BOD and suspended solids. A carbon dioxide system to treat alkaline effluent from food processing is safer, simpler, and more cost effective than a mineral carbon dioxide system to treat alkaline effluent from food processing.4 Shack and Sandhu5 reviewed filament control techniques in activated sludge systems in food industries. Criteria for selection of the proper control requires identification of the specific organisms involved. About 2 million dry metric tons of food processing waste can be produced by 809.2 million liters of ethanol using conventional production methods in a separate system or integrated into the processing plant.6 Composting to produce a highly organic soil additive is discussed by Hayes.7

FRUIT

White et al.8 discussed potential options for anaerobic treatment of apple waste including conventional and phase-separated pomace digestion with separate wastewater treatment. The treatability of apple and concentrated fruit process wastewater by the anaerobic filter process and two alternative aerobic polishing treatment methods was investigated by Laquidara et al.9 Effluent standards of 15 mg/L BOD and 20 mg/L suspended solids were the goal. Maximum acetic acid fermentation efficiency of apples and grapes was achieved by using 10% (w/v) inoculum, 1.5% initial acidity, 6% ethanol, and 30°C.10 Theoretical and experimental conversions were well over 60% using a downflow stationary fixed film reactor as a percolating or anaerobic trickling filter to treat pear canning effluent.11 Anaerobic treatment of wastewater from a lemon peel washing plant using a full scale upflow anaerobic sludge blanket reactor configuration to attain a COD removal of 81% was described by Maat and Gorur.12 El-Nawawi and Shehata13 determined that the maximum yield of citrus pectin extraction was obtained at 90°C.

Blanc and O'Shaughnessy14 noted that composting cranberry wastes will stabilize the material, reduce the volume, and produce a finished product that is marketable. Cranberry wastes were composted by in-vessel techniques and were a suitable substitute for peat when the compost contained up to 50% cranberry waste.15 A pilot-scale anaerobic digester for cull tomatoes was designed and constructed that reduced the total solids by 70% and COD by more than 99%.16 Two-phase anaerobic digestion of a mixture of fruit and vegetable solid wastes was studied by Viturtia et al.17 The biodegradation achieved in 2 weeks was around 75%.

VEGETABLE

Nilsson-Johnsson et al.18 discussed prerefining vegetable oils with citric or phosphoric acid to reduce the phosphorus in the oils to 9–16 ppm. More than 95% reduction in COD of palm oil mill effluent was achieved after 10 to 14 days of fermentation using the fungus Trichoderma viride.19 Penly20 presented a case history that included the startup and operation of an aerated lagoon pretreatment system for a sauerkraut processing plant. A wastewater treatment facility was designed and constructed using the extended aeration activated sludge process to treat mushroom waste and to provide a consistent high effluent quality at a constant discharge flow rate.21 Argonne National Laboratory is developing technology to bioconvert more than 90% of the fermentable starch in solid potato waste to glucose and then to utilize the lactic acid produced from glucose to make degradable plastics.22

A municipal treatment plant uses a pure-oxygen activated sludge process to handle seasonal vegetable canning wastes and a coupled trickling filter activated sludge process during the remainder of the year for maximum energy efficiency.23 An alternative treatment method, Advanced Integrated Ponding System, proposed by Ennsani,24 takes advantage of the high organic content of cannerly wastes. The system described used an algal-bacterial pond arrangement with four ponds to treat cannerly waste. A methodology and subsequent wastewater management plan has been developed to apply canning wastewater to soils in which percolation is restricted.25

GRAIN

According to Wong,26 soybean wastes were used to cultivate algae, which were then used to feed freshwater shrimp. Laboratory results from an aerated fluidized bed biofilm reactor treating corn starch wastewater indicated that good combined carbon oxidation-nitrification could be achieved provided that F/M ratio and mean cell residence time were maintained at less than 1.0 g BOD/g TVS-d and longer than 5 days, respectively.27 Over 70% of feed COD can be removed and 15 L/d of methane can be produced at F/M ratios as high as 3.45 g COD/g TSV-d using an anaerobic fluidized bed biofilm reactor to treat corn starch wastewater.28 Case histories of the thermophilic anaerobic chemostat process used to treat wheat starch wastewater and attain over 80% BOD reduction are described by Flihaerty and Smick.29 Butcher30 concluded that anaerobic digestion of soluble wheat starch has been successful. Anaerobic systems produced energy and provided significant operational and maintenance cost savings.


SUGAR

McManus41 presented a case history of treatment difficulties associated with the stabilization of waste-activated sludge solids from sugar processing in an operation using aerobic digestion. When sugar wastewater was treated in a low loaded activated sludge plant with a selector, BOD and COD removal efficiencies greater than 97% and 92%, respectively, were achieved.42 When the alkaline pretreatment of sugar cane bagasse was optimized and compared with an optimized steam (acid) pretreatment, the steam pretreatment produced higher overall yields and a lower effluent volume.43 A product of 48% protein content was obtained from sugar beet pulp when Candida tropicalis was cultivated for 42 hours at 30°C and pH 5.0. Pretreatment for 6 hours with cellulolytic and pectinolytic enzymes at 40°C and pH 4.8 was required.44 Arntz and Buchholz45 explained that araban and pectin from sugar beet pulp were degraded more quickly than galactan and much faster than cellulose by a mixed bacterial culture under anaerobic conditions.

Sucrose in sugar wastes is used to produce fructose syrups and gluconic acid in a two-step process, according to Alfani, et al.46 Pressmud, a sugar-factory waste rich in organic matter, nitrogen, phosphate, potash, and sterols, has great commercial potential as a raw material for biogas production.37

MEAT

Mortensen48 reviewed the most common methods of pretreating meat wastes in Denmark, namely flotation, anaerobic digestion, and activated sludge lagoons. Dissolved air flotation has significantly reduced BOD and suspended solids in meat, poultry, and livestock processing, and food packing plants.39 Beef processing wastewater is pretreated by dissolved air flotation with COD, BOD, and TSS removal efficiencies greater than 84%, 93%, and 75% respectively.40 A sludge separation system currently being used at meat and poultry plants can separate the sludge of dissolved air flotation systems into oil, water, and solid components by means of heat and centrifugal force.41 The optimal first-phase solids retention time in a two-phase anaerobic process to treat meat wastes was determined to be between 2 and 2.5 days, according to Walling and Sanjou.42 The two-phase digestion resulted in a 95% reduction in COD at an organic loading rate of 3 g/L.d. A rendering plant studied four possible treatment processes that would reduce effluent ammonia: biological treatment, air stripping, ion exchange, and chlorination.43 A book by Okerman and Hansen44 contains chapters on meat, poultry, and seafood by-product processing, along with a chapter on animal processing waste disposal, reduction, and utilization.

POULTRY

McCasky and Martin45 discussed an acid/ammonia process that increased the crude protein content of broiler chicken litter by 34% and reduced the viable count of Escherichia coli and Salmonella by more than 6 log cycles. A combination of screening, diatomaceous earth filtration, and ozonation to treat poultry process water yielded the highest quality effluent. COD, total solids, and the total microbial load including coliform bacteria and salmonellae were reduced by 87%, 65%, and 99.9%, respectively.46 Poultry chiller wastes, scald water, and brine chiller effluents were treated by filtering them through ceramic microfilters with 0.2 and 0.45 μm pores.47 The results of tests on poultry processing wastewater and dissolved air flotation sludge indicated that the sludge filtrate and DAF wastewater contain similar bacterial levels and could be discharged directly into the municipal sewer system. The untreated and the dewatered DAF sludges contained very high bacterial concentrations and may pose a health risk if applied to the land without further treatment.48 Case studies of land application of DAF sludge from the poultry processing industry are examined by Byerly.49 COD at a turkey processing plant could be reduced by as much as 652,500 kg per year by a water conservation program and implementing other wastewater reduction techniques.50 Continuous monitoring at a poultry processing plant determined the times and conditions that caused poor pretreatment when the wastewater wasn’t meeting the requirement of 250 mg/L BOD.51 Jones and Petitgout52 studied land application of poultry waste sludge as a way to reduce sludge disposal costs.

FISH

An aerated trickling filter preceded by an equalization basin were selected to treat seafood wastes for 90% BOD and TSS removal, according to Verscharen.53 Procedures have been developed for isolating both acidic and alkaline proteases from salmon viscera and acidic proteases from cod and mackerel viscera using centrifugation, polyacrylic acid, and ammonium sulphate precipitation, ultrafiltration, and batch ion-exchange chromatography.54 Vega and Brennan55 discovered that the rate of hydrolysis of cod offal in the range of 10% to 20% (w/w) dry matter was not dependent on the concentration of substrate and that the viscosity of the minced offal was reduced considerably at 65°C. Waste tuna broth was ultrafiltered using prepared membranes of polysulfone and dimethylacetaamide with solute recovery of about 90%.56 Crawfish chitosan that is loaded with copper in the form of amino copper showed higher recovery rates of amino acids with reduction at higher pH values.57 Dogfish processing wastes were readily hydrolyzed in the presence of 1.5% formic acid to produce a stable, liquid product free of bones and scales, and maximum digestion was achieved at a temperature of 45°C.58 The optimum conditions for the digestion of dogfish processing wastes under acidic and heated conditions were pH 3.5 and 50°C.59 Sullivan et al50 presented the treatment alternatives evaluated for one clam processor: sequencing batch reactor treatment, high-rate and low-rate UASB treatment, and powdered activated carbon treatment. A system consisting of a microstrainer, a dissolved air flotation clarifier, and a granular activated carbon column used to treat scallop processing wastewater achieved 97.5% COD removal and 94.6% ammonia nitrogen removal.60 Forcing the liquid effluent generated by mechanical shrimp peelers through a 6-inch hydrocyclone at a rate of 100 gpm and a pressure of 70 psi concentrated TON, BOD, turbidity, and Log 10 APC/mL at the underflow to mean levels of 199 mg/L, 1386 mg/L, 95 FTU, and 5.13, respectively.62 Silage prepared solely from fish wastes acidified to a pH of 4.0 with phosphoric acid and with the addition of 0.1% potassium sorbate underwent enzymatic liquefaction after several weeks storage at 20°C without microbial development.63 Research by Mathur et al.64 indicates that it is feasible to compost most types of fish and shellfish waste with peat in passively aerated static window at both small and large scales. The viscera from scallop
processing was mixed with soybeans/soybean meal to produce a relatively low moisture meal to be a protein feed supplement for swine diets. Selected freeze-dried wash water samples from clam plants may be added at 1.75% (w/w) to clam dip in place of clam meat and juice without any significant changes in overall acceptability, taste, odor, texture, and appearance. An aqueous extract of trypsin-degraded fish waste is a good substitute for beef extract in culture media, according to Jassim et al.

**MISCELLANEOUS**

A low-rate ADI-BVF pilot reactor was used to evaluate anaerobic treatability of raw effluent from a candy bar manufacturing facility before a full-scale anaerobic/aerobic treatment system was designed and constructed to meet discharge limits of 200 mg/L BOD, 250 mg/L SS, and 100 mg/L FOG. The high rate Biothane anaerobic pretreatment process was tested on jelly process wastewater, which reduced the BOD by at least 80% at influent loadings of about 10 kgTCOD/m^3·d. Lanting et al. studied the treatability of coffee wastewater under both mesophilic and thermophilic conditions. During thermophilic treatment, using a Biothane USAB system, 60% to 70% of the COD and BOD were removed. Total and soluble COD removal efficiencies were 9% and 34% better, respectively, than during mesophilic treatment of the same wastewater. Egg processing wastewater treated by means of a tubular reverse osmosis pilot plant had a reduction of 96% to 99% COD over untreated wastewater. The design, installation, and operations of a modernization project of a salad dressing and condiment plant was addressed to M. Brett Borup, Civil Engineering, 368 Clyde Building, Brigham Young University, Provo, Utah 84602.

**REFERENCES**


70. Lanting, J., et al., “Thermophilic Anaerobic Digestion of Coffee