THE UNIVERSITY OF MANITOBA

# CONTROL OF TURBIDITY AND BETA-AMYLASE IN POTATO RINSE WATER RECYCLING

by

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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TO MY BROTHER

WHO SUPPORTED AND ENCOURAGED ME

THROUGHOUT MY UNIVERSITY YEARS

# ABSTRACT

## Control of Turbidity and Beta-Amylase in Potato Rinse Water Recycling

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Stringent government regulations and guidelines on water pollution now call for a higher degree of water purification and recycling in the food industry, prior to disposal. The "total system approach" is the most ideal solution to meet these needs. Methods for enabling process waters to be used for long periods, while maintaining good quality control, are now required.

A laboratory study on potato rinse water recycling was carried out, primarily to control turbidity problems during recycling. The rinse water was recycled with intermittent carbon treatment. It was shown that a carbon dosage of 1g/l applied after every rinse was efficient in suppressing the build-up of turbidity for up to 8 hours at 22°C during reuse; while simultaneously allowing the levels of organics to accumulate to an equilibrium level. An alternate treatment of 5g/l of carbon after every fifth rinse was also found to be satisfactory in controlling the turbidity of potato rinse water, under these conditions.

Turbidity levels of the recycled potato rinse water (with intermittent carbon treatment) increased to an unacceptable level when stored

at 22° C for 16 hours. It was shown by millipore filtration that bacterial growth played a major role in causing the development of turbidity.

An increased amount of beta-amylase in recycled potato rinse water was found to support a higher population of bacterial growth, through release of glucose from starch. Carbon treatment alone was not sufficient for the adequate removal of beta-amylase. It was found that the pH of the recycled potato rinse water should be lowered to at least 4.5 with citric acid, or a combined treatment of citric acid and powdered activated carbon should be used, before the water was to be stored for more than 16 hours at 22° C, for further reuse purposes.

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# INTRODUCTION

## 1.1 U.S. Environmental Legislation Relating to Industry Effluents

During the late 1975's and through the 1976's, several U.S. Congressional Acts were passed. Most of these Acts were the precursors to the environmental legislation established to date. The Federal Water Pollution Control Act Amendments (FWPCA) 1967 publications, series No. 3 (89) stated that by 1972, there should be removals of 68 percent of biochemical oxygen demand, 77 percent of the suspended solids and about 19 percent of the total dissolved solids in the wastes, and it was projected for 1977 that 73 percent of the biochemical oxygen demand, 82 percent of the suspended solids, and 25 percent of the total dissolved solids would be removed. On October 18, 1972, the Federal Water Pollution Control Act Amendments of 1972 were established by the Congress (89). According to the Act, by July 1, 1977, the extent of the aforementioned parameters in the effluents should be reduced through the use of "best available technology economically achievable". By July 1983, the limitations are based on application of the "best available technology economically achievable" and zero discharge. Later, in addition to the parameters included in the publication of 1972, the guidelines stated that some other components in the effluents must be considered. This included color, total phosphate, fecal coliforms, temperature, total organic compounds and total dissolved substances. In order to meet this goal, the Administrator of the Environmental Protection Agency (EPA) has established a set of effluent guidelines and limitations. These limitations are to be based on pollutant reductions which are attainable through in-plant process changes, and wastewater treatment (74).

## 1.2 Canada Food Industry Effluent Guidelines (1)

Environment Canada also has developed guidelines and regulations for the food industries. The aim of the Regulations and Guidelines is to ensure that the food processing plants operating in Canada apply "best practicable process and treatment technology" in their plants. The "end-of-pipe" loadings are to be minimized through the installation of "best practicable process technology". To date, the guidelines for the effluents of the meat and fish processing industries have been established and gazetted. It is expected that the guidelines for the dairy and fruit and vegetable industries will be gazetted in the near future. The regulations and guidelines for the potato processing have already been established. The maximum daily discharge in lb/ton is set at biochemical oxygen demand (B.O.D.), 9.5, total dissolved solids (T.S.S.), 17.5 in 1977, and B.O.D., 1.6 and T.S.S., 2.7 in 1983 (8). Any plants which come on stream after the guidelines are in force, must comply with the new regulations and guidelines while existing plants will be treated in exactly the same manner as plants falling under existing Environment Canada regulations and guidelines.

## 1.3 U.S. Programs on Compliance with Regulations

In dealing with guidelines listed in section 1.1, a national program was established by the U.S. Food Processing Industry and Environment Protection Agency. In 1970, the First National Symposium on Food Processing Waste was held at Oregon (90). The purpose of this Symposium was to develop a cooperative, coordinated program between industry and government, in solving water pollution problems of the food industries. The latest efforts to reduce water pollution from the food processing industry were also being reviewed. The objectives of the First Symposium included the modification of conventional methods of waste treatment; the development of industrial methods to reduce the quantity of water required for processing; the introduction of completely closed-loop systems and the development of by-products recovery.

At the Fourth Symposium in 1973, it was recommended that a "total system approach", as suggested by Gallop (91), was the most ideal solution to water and waste management in the food processing industry. The concept of the "total system" is that the entire plant is considered as a whole with the waste product ranked as equally important as the commercial products. The process water is recycled with in-plant treatment, such as physical methods, e.g. centrifugation and filtration; physicochemical methods, e.g. activated carbon adsorption. Solid wastes produced could be recovered and sold as animal feed, or coverted into activated carbon for use within the plant (90, 74).

Environment Canada is hoping that plants will not follow the conventional biological treatment approach, but will take a close look at in-plant controls and physical/chemical treatment alternatives, in order to eventually come to a total recycle and reuse system. Many programs such as DPAT (Development and Demonstration of Pollution Abatement Technology) and UP (Unsolicited Proposal) programs are underway, with steady movement towards employment of technology that will lead to maximal by-product recovery, with water conservation and reuse.

## 1.4 Purpose of Project

In the case of potato processing, Gallop (32) showed that the potato plant water system can be closed by 90% or more. Most of the water can be reused to make up a cyclic system. Partial purification (i.e. removal of heat, troublesome solids, or inactivation of enzymes, or removal of organisms) is only required for recycling of effluents, unless the final effluent is required for drinking purposes. For potato processing, partial purification includes controlling:

(1) Physical factors e.g. color, turbidity, silt.
(2) Chemical factors e.g. potato enzymes, starch, sugars, proteins.
(3) Biochemical/microbiological factors e.g. enzymes, microorganisms.
(4) Aesthetic and legally significant factors.

Previous and current work in this Department, has shown the merits of using activated carbons, especially in the powdered form, for rapidly, efficiently, and cheaply purifying such recycled water, in every respect, by "subtractive" methods. But with repetitive use, the "background" levels of various factors in the water, must change quantitatively, proportionally and possibly in type too. Since these interact closely with the surface of the potato slices, they also can affect the composition beneficially or adversely. In addition, the ability of the water to change, in every respect, during repetitive use, especially over extended times, of days, weeks and months is also dependent on the interactions between the constituents of a flow, which can occur during time. For instance, the ability of recycled water to sustain microbial flora and growth, is very much dependent on the composition of the water, as regards energy sources and micronutrients.

In this project, research was focussed on the potato rinse water produced at the slice-rinse stage, to study a problem of turbidity which developed, during repetitive use over extended times (8-72 hours), with a view to recommending a possible solution.

Beta-amylase is one of the hydrolytic enzymes in potato rinse water that causes the breakdown of starch into maltose. This molecule can easily be broken down by maltase into glucose units and utilized by bacteria as one of its essential nutrients. Beta-amylase was therefore studied in this project, with a view to investigating its ability to sustain bacterial growth in potato rinse water, and to develop possible methods for controlling its activity, if the potato rinse water is intended for repetitive use over extended time periods.

# LITERATURE REVIEW

## 2.1 History of Activated Carbon

Historically, activated carbon was used in medicine since 1550 B.C. as mentioned in an Egyptian papyrus (15). The earliest recognition of the adsorptive phenomenon of carbon was in 1773 when Scheele (37) observed the uptake of gases by charcoal. In 1785, attention was drawn to the adsorptive effect of carbon on solutions by Lowitz (56). The evidence of the use of carbon in food industries dated back to the early 17th century when wood char was employed for purification purposes in the cane and beet sugar industries (23).

Activated carbon was first produced from wood and bone (23). During the 19th century, studies were made to produce activated carbon from various other sources, including petroleum residues, wood, coal on a laboratory scale (20, 43). Due to engineering difficulties, activated carbon could not be prepared in commercial scale until 1901, when Ostrejko (68) developed a modern method of manufacturing commercial activated carbon using steam activation. Today there are many patented thermal processes for production of carbon (37).

During the First World War, constant efforts were made to generate highly activated carbons for use in gas-mask filters. From then on, activated carbons of improved quality have been used on a commercial scale in the purification of gases and liquids. Today activated carbon is being recommended for use on a wide scale for water purification since an Environment Protection Agency survey has reported the drinking water of over eighty cities in the United States contain small amounts of carcinogenic substances (6). A standard of not more than 150 parts per billion for chloroform and other Trihalomethane (THM) chemicals has been established. It is required that the cities should filter the water through the granulated activated carbon bed, instead of the traditional sand filtering bed, unless they can show that their supplies are not significantly polluted by industrial or agricultural chemical sources (7). The nation-wide construction costs of the required carbon filters in U.S. waterworks are estimated to be $350–450 million and annual operation costs are budgeted to be $60 million.

## 2.2 Elementary Aspects of Adsorption of Carbon

Adsorption is described as the phenomenon by which the molecules of gases, or dissolved substances of liquids are taken up by physical or chemical forces to the surfaces of solids or liquids with which they are in contact (37). If the adsorbent has a very porous structure, it will have a large surface area for the adsorption of molecules.

Activated carbon was described by Weber (94) as a highly porous material. Two types of pore size exist in activated carbon particles. The macropores are large, having diameters of 30-10,000 Angstrom units, they permeate the carbon particles and allow for solute diffusion, but contribute little to the surface area. The micropores are 10-30 Angstrom units in diameter. The boundary surfaces of the micropores are largely responsible for the adsorption action of the carbon. This type of pores contributes to a surface area of approximately 400-1000 sq. m/g for an activated carbon particle.

Three kinetic steps occur consecutively in the adsorption process: transport of solute to the outer surface of the adsorbent, diffusion through the pore spaces (macropores), and the adsorption occurring at an active site on the surfaces around the inner pore space of adsorbent.

### 2.3 Use of Activated Carbon in Food Industries

Activated carbon was first used in the sugar industry over a hundred years ago for the removal of color and organic contaminants (37). It was observed by Owen (37) that microorganisms in cane juice could also be removed by activated carbon.

Mercer et al. (64) and Fox (30) reported the purification of brines for reuse, by using activated carbon filters to adsorb phenolics. Activated carbon is used extensively in sugar and syrup industries nowadays. Treatment with activated carbon reduces the content of protein, hydroxymethyl furfural, iron, lime and gives a stable, colorless syrup which does not darken with age (37). Schultz et al. (79) reported the use of activated carbon for adsorbing volatiles in commercial apple essence. In the fat and oil industry, activated carbon is employed for adsorbing the impurities which interfere with the complete neutralization of the fatty acids in the subsequent treatment with alkali (47). Lapter (52) reported that carbon could remove soap and other substances which had detrimental effect on the catalyst when the oil was subsequently hydrogenated. Blumenthal (18) reported carbon could be used to maintain quality standards of alcoholic beverages. He found that cloudy wines could be improved by a 48-hours contact with small quantities of activated carbon. Ballos (12) reported that treatment of beer with activated carbon could remove the chill-sensitive protein precipitates.

## 2.4 Use of Activated Carbon in Industrial Waste Treatment

Since industrial wastes contain highly toxic and refractory contaminants, the use of conventional biological treatment systems for these industrial wastes will not always be effective (33). Treatment by activated carbon is an effective method of purifying industrial wastes. It has been used widely in the major areas such as food, textile, paper, chemical, petroleum and metal industries (35).

Hager in 1976 (35) conducted a laboratory adsorption study of 107 industrial wastewaters. Activated carbon effected the following dissolved organic contaminant reductions: 85% of total organic compounds in 79 of 102 samples (77%), 95% color removal in 16 of 16 samples (100%). In addition, he found that up to 99% of toxic chemicals were removed from synthetic waste in 9 out of 9 samples using the activated carbon treatment.

Carbon treatment is an effective method for the removal of organic chemicals including a wide range of organophosphorus, organochloride and polycyclic aromatic hydrocarbons compounds (4, 24). Cheremisinoff (20) reported that most of the dissolved organic toxic chemicals as cited by the Environmental Protection Agency can be removed from water by activated carbon. References for the use of activated carbon in treating industrial wastes are now very numerous.

The Water Pollution Control Federation Annual Literature Review (2) issues updated references on a variety of these applications including the industrial treatments of food, paper, textile and petroleum wastes.

## 2.5 Use of Activated Carbon in Municipal Waste Treatment

Activated carbon is used in municipal waste treatment. Since carbon preferentially removes the bio-resistant compounds (e.g. polycyclic organics, such as phenols, tars, oils, etc.), it can be used as a complementary partner to biological waste treatment (44).

Both laboratory and full scale field evaluations performed from 1972 to 1974, have shown that the addition of powdered activated carbon to anaerobic digestors is beneficial and can reduce sludge disposal costs. Because activated carbon is so porous, it provides sites for the anaerobic reaction to occur. By adsorbing organics such as grease and scum that can clog digestors, the efficiency of the system will be comparatively high. By the activated carbon adsorption of inhibitory substances that could be toxic to the anaerobic bacteria, the working capacity of existing digestion tanks is increased (3).

Powdered carbon systems also show promising applications in physicochemical treatment of either raw sewage or primary effluent. But it appears that it is not competitive with granular carbon systems for tertiary system (84). Suhr and Culp (84) made a study on the use of powdered carbon in the treatment of municipal wastewaters. They found that carbon contact as preceded by chemical coagulation and sedimentation of the raw waste, the influent soluble chemical oxygen demand (COD) of 80 to 100 mg/l was reduced to 12 mg/l with 300 mg/l of powdered carbon and to 30 mg/l with 75 mg/l of carbon. The laboratory process of utilizing powdered carbon has been evaluated on a pilot scale in Albany, New York (80). The raw wastewater following comminution and grit removal, is contacted with powdered carbon, coagulated with alum, settled with a polymeric settling aid and passed through a trimedia filter. The results showed that in using doses of 600 mg/l of carbon, 200 mg/l of alum, and 2.5 mg/l of polyelectrolyte, total organic compound removal is greater than 90% and the turbidity of the settled effluent is seldom greater than one Jackson turbidity unit (J.T.U.).

## 2.6 Use of Activated Carbon in Treatment of Food Industrial Wastewaters

The constituents of food plant wastes are highly rich in carbohydrates, fats and proteins. The common practice of disposing waste effluents into rivers and lakes causes serious pollution problems. A report recently revealed that 45% of water pollution is caused by industry, of which 85% of the total is contributed by food processing effluents (4). Conventional biological treatment processes are mainly used to treat food processing wastewaters. However, the Legislative Guidelines in the U.S. have set standards for a higher degree of purification which cannot be achieved alone by the conventional treatment methods. In order to meet the deadlines set for 1977, 1983 and 1985, the U.S. food processing industry in 1970 began a national program of pollution control methods capable