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Prevention of Food-Processing Wastes

Processes can be changed to reduce wastes, maintain product quality, and improve product yield.

Sam R. Hoover

Although technology for treating wastes resulting from food processing is available, and is moderately successful by today's standards, it does not meet national goals set forth in the Clean Water Restoration Act of 1972. This act, the culmination of the several clean water acts passed since 1962, provides that discharge of pollutants into navigable waters be eliminated by 1985. Therefore, in recent years a new look has been taken at food processing, with some notable successes and the promise of more. The question is, "Can we change existing processes so that less waste is produced, while maintaining or improving product quality?" The following is a discussion of major processing steps.

Peeling

The Western Regional Research Laboratory of the Agricultural Research Service, U.S. Department of Agriculture (USDA), decided to study first the peeling of white potatoes; more potatoes, by weight, are produced in this country than any other vegetable (*1*). There were many plants processing a million pounds a day (1 pound = 0.45 kilogram), with a 5-day biochemical oxygen demand (BOD_5), equivalent to that of a city of 300,000 people. About 75 percent of this BOD was directly associated with the peeling process.

Traditionally, potatoes were peeled by dipping them in a 16 to 20 percent lye solution at 95° to 120°C for 3 to 5 minutes, followed by a 2- to 5-minute holding period at the boiling point. They were then peeled in a rotating reel with high-pressure water jets.

After studying the variables involved in the process, the Western Laboratory developed a process which it put to use in a pilot plant. The new process consisted of a 1-minute dip in 12 percent lye, a 3- to 5-minute holding period, a 1-minute heating with infrared, and mechanical peeling with rotating rolls that have ½-inch rubber studs. It is called, not absolutely accurately, dry-caustic peeling. The peel is thrown off the rubber-tipped rolls and accumulates as a pumpable, 25 percent solid residue (Fig. 1). The peeled potatoes go through a finisher, which uses wire brushes with water spray to remove gelatinous (cooked) material from the

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surface. The waste stream of the peeler and finisher are combined to make an approximately 15 percent solid waste. This is combined with trim material, is fermented to reduce the *p*H, and is fed to steers as 80 percent of the dry weight of their ration. A major equipment manufacturer adapted one of its abrasive peelers to this process and ran it successfully in parallel with a standard commercial line at 4500 to 5000 kilograms per hour.

The results of this test were convincing: the peeled potatoes were of equal quality, the process required 50 to 70 percent less lye and produced no effluent, and the peeling loss was 13 percent, compared to 18 percent on the commercial line. Naturally, the industry adopted the dry-caustic process rapidly. One plant has 22 lines, each with a capacity of 9,000 to 10,000 kg/hour.

With the potato peeling process successful, the Western Laboratory went to work on peaches and other fruits. Cling peaches are halved and pitted before peeling. The stud rubber peeler was much too tough for fruit, and the infrared heaters were detrimental. Small peelers, which used rubber disks of various dimensions, were developed (*2*) (Fig. 2). In 1970, a pilot plant was installed in a major cannery, in cooperation with the National Canners Association Laboratory in Berkeley, California, which secured funds from the Environmental Protection Agency to support this project (*3*). This plant peeled cling peach halves at a rate of approximately 3 metric tons per hour. Peeling quality was equal to that of the commercial line. Water use was reduced 90 percent, and the peel, with a solids content of 12 to 13 percent, was removed as a pumpable slurry for disposal on land or for animal feed. This successful demonstration project led to the development of analogous systems by equipment manufacturers and canneries. Such systems are used for other fruits and vegetables, notably tomatoes, which are second only to potatoes in tons processed. Over 100 peeling machines of various designs, using the principles developed, are in use on white and sweet potatoes, beets, carrots, cling and freestone peaches, and tomatoes.

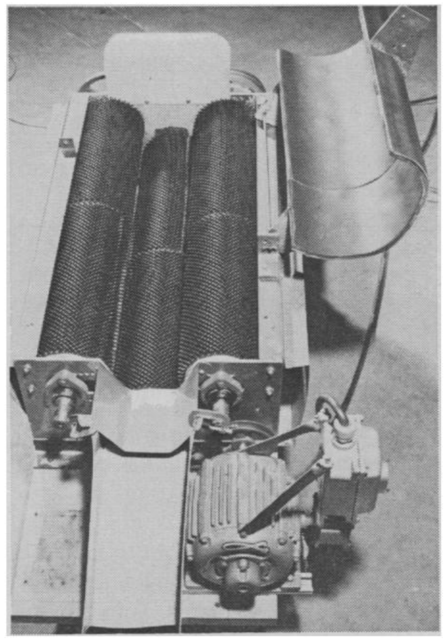

Fig. 1. Pilot-plant potato peeler.

Solvent Dewaxing

A process was proposed in 1964 and 1965 (*4*) for dewaxing apples with isopropanol, which has solvent properties much like those of ethanol, but does not have the same restrictions in industrial use. It was suggested as a preliminary step to the conventional use of lye to peel apples.

A California tomato packer picked up the idea and applied it successfully to tomatoes. Evaluation of a full season of plant-scale dewaxing of tomatoes before peeling them with lye showed increased yield of a higher quality, better colored product. Lye consumption was cut to one-third, and, most important, peeling loss to one-fifth of the previous level. Thus, the process transferred about 15 percent of the incoming tomatoes from the waste stream, as peeling loss, to the product stream, as improved yield. The improved yield and the need for less lye far offset the cost of solvent dewaxing. No attempt has been made to recover the relatively small amount of isopropanol used and the wax removed. Other plants have installed this process.

Cleaning

The same kind of equipment used in fruit peeling has been used in preliminary studies of cleaning tomatoes. Washing is another important source of pollution, yet a necessary one. A washing unit that employs flexible rubber disks to wipe the tomatoes, a foam or water mist spray, and a final rinse has been tested in the laboratory (*5*). The result is clean tomatoes with a 67 to 90 percent reduction in water use, a 35 percent reduction in suspended solids, and a 45 percent reduction in chemical oxygen demand (COD) because of reduced contact time with water. A field test of this concept, in connection with the National Canners Association, was carried out this summer. This study confirmed the practicality of the process—it resulted in a 90 percent reduction in water use. A major manufacturer has put this equipment on the market (*6*).

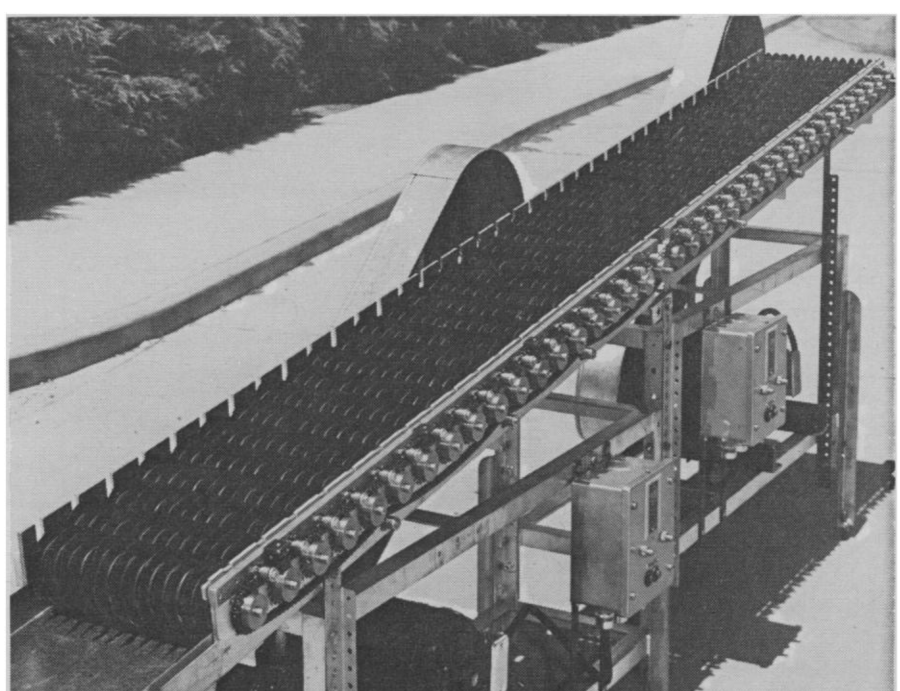

Fig. 2. Pilot-plant fruit peeler.

Blanching

An essential step in processing many vegetables is blanching—that is, heating to destroy enzymes that produce off-flavors, softening of the tissue, and color changes. Traditionally, blanching has been done in hot water, an inexpensive heat-exchange medium. However, the leaching of constituents into the water has contributed greatly to waste. Two approaches to water conservation and reduction of wastes from blanching have been studied—the individual quick blanch and hot-gas blanching.

Individual quick blanch, performed after heating the product, has been developed through experimental work at the Western Laboratory. Whole food, such as lima beans or peas, or pieces of food, are spread in a single layer and exposed to steam long enough to raise the mass average temperature to blanching temperature. They are then piled in a deep, adiabatic bed in order to achieve uniform blanching (Fig. 3). This treatment has been combined with preliminary partial dehydration, say 5 to 8 percent, which enables the product to absorb the condensing steam and thereby essentially eliminate losses caused by leaching (*7*). This process has not been tested in full-scale production.

Hot-gas blanching was developed by the Berkeley Laboratory of the National Canners Association through pilot-plant and in-plant tests. Combusted gases from a natural-gas furnace are blown down through the product, which is held and conveyed by two wire mesh belts. Steam is used to reduce dehydration losses and to increase heat transfer of the gas medium. Production runs of many hours have achieved steady-rate operation, with almost no leaching or wastes from blanching and with comparable quality for spinach, beets, green beans, and corn on the cob. Tests with green peas, asparagus, and pumpkin have also been successful (*8*) (Table 1).

Table 1. Reduction of waste water volume and chemical oxygen demand (COD) by hot-gas blanching of vegetables, compared to commercial blanching. [Source: table 26 (*8*)]

Commodity	Reduction	
	Waste water (%)	COD (%)
Spinach	99.9	98.0
Green beans	99.8	99.8
Corn on the cob	46.0	44.0

Disregarding costs of waste treatment, hot-gas blanching is, on the basis of these tests, more expensive than conventional blanching for the products studied, except green beans, for which it is slightly cheaper. The economic benefits that would result from increased efficiency of operation of a commercial-scale unit, compared to the experimental one, can be expected to lower the costs of production for the other commodities. Also, the production of 3600 gallons of waste per hour by hot water blanching of spinach, with a COD of 200 to 500 parts per million, or 1800 gallons per hour with a COD of 4000+ parts per million from conventional steam condensate blanching, cannot be ignored (1 gallon = 3.78 liters). Clearly, further development studies are needed.

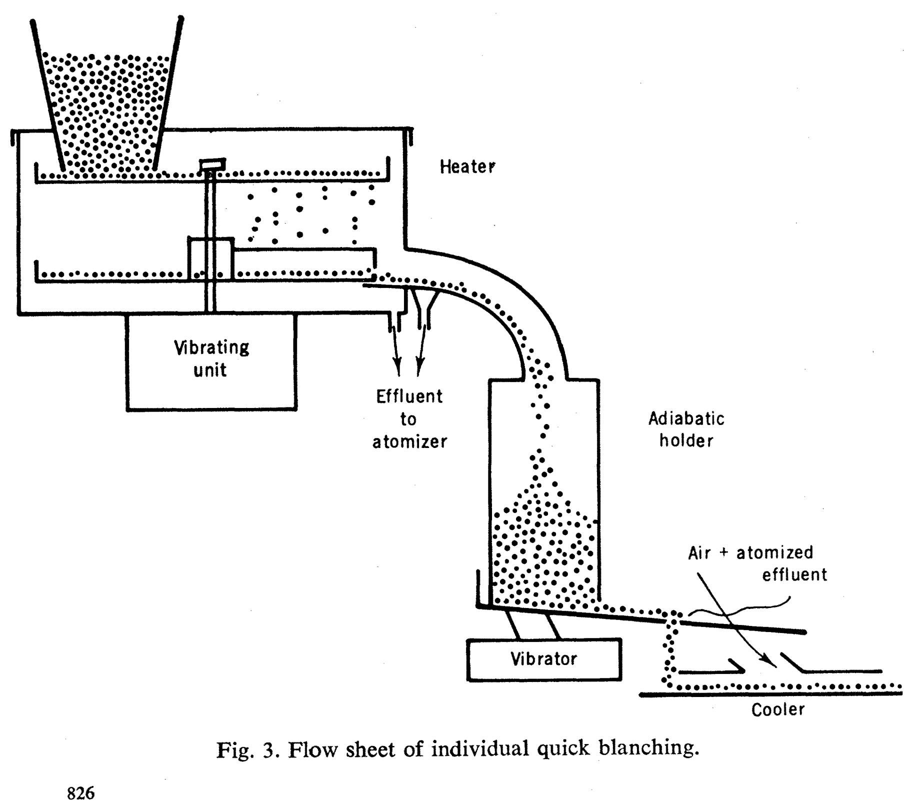

Fig. 3. Flow sheet of individual quick blanching.

Pickling

One of the oldest food industries is pickling. Sauerkraut, pickles, olives, tomatoes, and other vegetables have been preserved by pickling for centuries, probably for millennia.

In 1935, the USDA set up a laboratory in Raleigh, North Carolina. This laboratory has worked cooperatively with North Carolina State University (in which its work is done), the pickle-processing industry (now known as Pickle Packers International), Michigan State University, and private firms. This remarkably successful small laboratory has introduced many innovations into the pickling industry, some of them before many of us knew the word "ecology." A number of the innovations have contributed to reduced pollution from the brines, increased product yield, and better product quality.

Some 40 percent of the crop of cucumber pickles is now made directly into fresh-pack or pasteurized pickle products by methods developed some years ago in this laboratory (*9*). The customary brining of the cucumbers is thus avoided, but they must be processed quite soon after harvest. In this process, fresh cucumbers are packed with brine and vinegar; dill or other herbs, or both; and essential oils. They are then pasteurized in the sealed jar. The normal fermentation is thereby omitted, and a relatively fresh texture and color result. Whole dill pickles, spears, chips, and sweet sliced pickles are the major types produced by the fresh-pack process.

Another development, "pure culture" fermentation, is now rapidly approaching commercial use. It is a technique for pickling in which "pasteurized" cucumbers, acid-forming lactic acid bacteria, and requisite salt and flavoring are put in a retail container. There are several organisms that produce the desired acidity and flavor (*10*), and probably a mixture of these will be

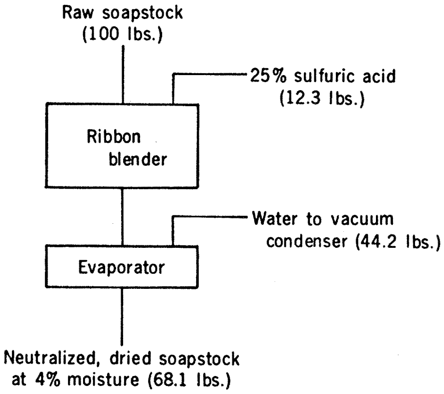

Fig. 4. Flow sheet of neutralized, dried soapstock process.

used. There are essentially no wastes from this process.

Work on recovery of brines from pickling cherries and olives is promising but is not, as far as I know, in commercial use.

Wheat Starch Manufacture

Traditionally, starch has been made from grains and from potatoes, cassava, and other root crops by processes that are essentially mechanical grinding and water flotation (to separate the soluble protein and sugar from the starch granules). Such processing resulted in a large volume of high BOD waste in the effluent stream.

There have been several major developments in the production of starch from wheat, not all of which are clear to me. The Western Laboratory studied the quite old Fesca process, in which flour is mixed with an optimal (or minimal) amount of water to keep the gluten dispersed. The starch is then separated centrifugally, and the gluten-containing fraction, a protein concentrate, can be dried with the functional properties (dough-making, texture) intact (*11*). There are no liquid effluents.

Two major companies in the United States are producing starch and gluten by new, wet processing of wheat. There are patents and trade secrets involved, but I think the processes are at least partially based on the principle of the Fesca process and the work of the Western Laboratory.

Potato Starch

Potato starch is produced from cull or overaged potatoes as a recovery operation. The soluble proteins, amino acids, and sugars in potatoes produce effluent streams with high BOD when potato starch is manufactured. Some years ago it was estimated that the effluents from Maine's potato starch factories, operating at capacity, had a BOD equivalent to that of a population of 950,000; the population of Maine at that time was 981,000 (*12*). (This calculation is somewhat fictitious, for the plants do not operate at, or near, capacity when good markets for potatoes for food exist.)

Dry milling and air classification have been proposed as a useful technology for recovering products from potatoes (*13*). The potatoes are dehydrated, finely milled, and put through air classification and screening in conventional wheat-milling equipment. Two products result: an animal feed of relatively high protein content (26 percent) and a starch fraction with 99 percent purity. The purity of the starch fraction is obtained by washing it with water; the wash water is partially evaporated and the residue is dried and added back to the feed portion. This process produces no liquid effluent. In more recent unpublished studies, starch with a protein content of less than 1 percent has been produced by mechanical separation without the washing step (*14*) (Tables 2 and 3).

Soybean Oil Refining

Vegetable oils are commonly refined by treating them with a caustic soda solution to convert free fatty acids to oil-insoluble soaps and to precipitate other nonglyceride components. Centrifugal separation of these solids from the oil yields "soapstock." The oil from the primary centrifuges is washed continuously with hot water (77°C) to remove the remaining sodium salts of free fatty acids. This mixture is separated in secondary centrifuges, producing refined oil and a water layer containing both soap and emulsified oil, which is commonly discharged as waste. Soapstock is often acidulated to precipitate free fatty acids and phosphatides, and the water phase from this separation is also discharged as waste.

The Northern Regional Research Laboratory at Peoria, Illinois, has successfully modified the processes to eliminate both of these waste streams. Soapstock, which is usually 38 percent water, can be neutralized with sulfuric acid and dried to produce neutral dried soapstock (NDSS). A possible source of free fatty acids, NDSS appears to

Table 2. Comparison of product yield from the conventional wet process and the proposed dry process for potato starch manufacture, with a daily input of 250 metric tons of potatoes.

Product	Wet process (metric tons)	Dry process* (metric tons)
Starch	30	30
Pulp	6.8	
Animal feed		22.1
Soluble waste	11.9	0
(BOD)†	5.35	0

* Calculated from pilot-scale data. † Both sets of data are based on washed potatoes. The BOD loss in washing is small and is not considered here.

Table 3. Composition of products from the dry starch process on a moisture-free basis. [Source: J. W. White, Jr. (*18*)]

Component	Starch	Feed
Protein	0.27	26.2
Ash	0.37	5.0
Starch	99.2	61.9

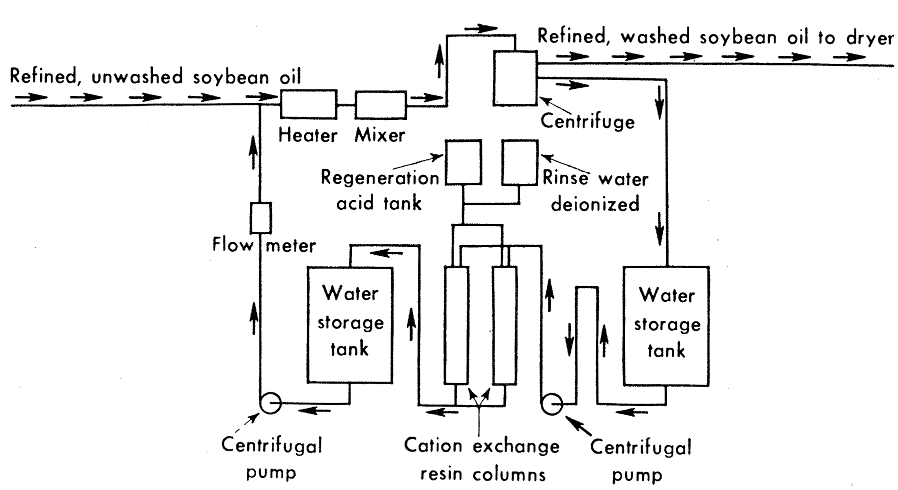

Fig. 5. Flow sheet of ion-exchange treatment of alkali-refined soybean oil.

be put to best economic advantage as a constituent of poultry feeds. The xanthophyll in NDSS (approximately 250 micrograms per gram) gives broilers better pigmentation and, as 4 percent of the diet, increases the caloric density of the feed. Estimated processing costs are 1.55 cents per pound (*15*) (Fig. 4). There are no effluents from this process except the distilled or evaporated water taken off.

As stated above, the alkali-refined oil is washed with water to remove remaining free fatty acids, and these washings are commonly discharged as waste. In the new process, the wash water is put through a bed of cation exchange resin in the acid form and is reused continuously. Minor amounts of water lost by evaporation must be replaced. Because the water recycled from the resin is slightly acidic, problems with soap and emulsified oil are eliminated (*16*) (Fig. 5).

In this process, the resin must be periodically regenerated by rinsing it with acid. This excess acid must be discarded. In the proposed method of treating soapstock described above, this acid solution, plus additional strong acid, could be used to neutralize the alkaline soapstock, and the water evaporated in drying the NDSS could be used to rinse the regenerated resin. Such a combined system would essentially eliminate this source of stream pollution and would produce marketable products from the wastes.

Cheese Whey

Besides major changes in processes, many other ways of utilizing wastes are being studied. Under investigation are a number of means for recovering food values from the ever-increasing amount of cheese whey produced in the United States. Electrodialysis has been in commercial operation for some years. Reverse osmosis and ultrafiltration are now in industrial use, as is gel filtration on Sephadex. All of these processes recover products, especially the whey protein, which is of excellent nutritional quality. However, the residual wastes from these "wet" processes constitute a treatment problem.

Liquid whey has long been fed to dairy cows in Europe. Recently, there has been increased interest in the United States in feeding whey to steers and dairy cattle as a means of both disposing of wastes and recovering feed values. A milking Holstein will consume about 80 kg of cheese whey daily, gaining appreciable nutrition from it. Major aspects of whey utilization were covered in a whey products conference sponsored jointly by the Eastern Regional Research Laboratory of the USDA and the Whey Products Institute (*17*).

Discussion and Conclusions

Although these examples of process changes that have an actual or potential value in drastically reducing waste from food processing are striking, there is much research throughout the industry that is not published.

Meat and poultry slaughtering industries have major pollution problems that are closely regulated by federal or state inspection. Innovations in a slaughtering process must be instituted with caution if the microbiological quality of the product is to be maintained. I have not discussed the considerable amount of research going on in these industries because I think that some time will elapse before it has a major effect on the amount of waste produced. A "dry" slaughtering operation is difficult to imagine.

The primary responsibility of industrial management is to return a profit to the investors in or owners of the company. Necessary waste treatment is that which will meet the requirements of the local, state, or federal regulatory agency with authority over the effluents from a particular plant. In most cases, waste treatment is an added cost, which is passed on in the price of the product.

The basic point of this discussion, so well illustrated by the dry-caustic peeling of potatoes, is that the process alterations are often economically advantageous, in that more of the incoming raw product emerges from the plant as finished products of high quality. In situations where an economic return cannot be clearly shown, the reduction in waste treatment costs will have to be taken into account. An additional benefit of the process modifications discussed is the decreased use, or elimination, of water, thus conserving this natural resource.

Meeting the goal of no discharge of pollutants by 1985 will require modifications which will produce (i) concentrated waste fractions that can be dehydrated, (ii) extremely effective biological treatment, or (iii) dry processing methods.

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