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PROCESSING AGRICULTURAL AND MUNICIPAL WASTES

PROCESSING FRUIT AND VEGETABLE WASTES

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Fruit and vegetable wastes are generated on harvesting as well as in processing. Only the latter will be discussed here. Application of conventional biological oxidation to soluble processing wastes will also not be discussed. This is an active field and has been the sole subject of many symposia. The time is long past when secondary treatment of processing wastes could be avoided; it must be a part of the cost of doing business. These costs are being brought home to management more and more, and to reduce them provides a powerful incentive to consider processing fruit and vegetable wastes. To recover a useful material from processing wastes would seem to be an ideal solution - not only is the strength (and treatment cost) of the waste stream reduced, but a credit also arises from sale or use of the recovered product. We see numbers of proposals in this area, and there are indeed some examples of success but most of them won't stand up under economic scrutiny, either because of the high cost of technology or a questionable marketing situation for the by-product.

If a major part of the waste is material that is similar to a current product, it appears advisable to consider processing changes to reduce the waste and improve primary product yield; not only is the product usually a higher-value material, but the need for marketing a by-product is eliminated. The two processes that contribute most of the solid and liquid wastes in fruit and vegetable processing are, of course, peeling and blanching. I will describe two processing changes that have increased the yield of primary product in commercial operation: an improved peeling process and a recovery of solubles lost in blanching.

Substantially all processing tomatoes in California are harvested mechanically. Once started, the change-over was nearly complete within five years, and has been a success because special varieties of tomatoes had been developed for this purpose. These tomatoes, resistant to damage during harvesting and sorting, also seem to be somewhat resistant to efficient chemical peeling. A progressive California tomato packer applied isopropanol vapor dewaxing as a pretreatment in the 1969 season. This process was proposed earlier at the ARS Eastern Regional Research Laboratory to remove the wax surface from apples to facilitate lye peeling (Harrington and Hills, 1964, 1965) and reduce heat exposure during the process.

Evaluation of a full season of plant-scale dewaxing of tomatoes before lye peeling showed a better yield of a higher quality, better colored product. Lye consumption was cut to one-third, and the peeling loss reduced to one-fifth of the previous level.

Thus the use of this system transferred about 15% of the incoming fruit from the waste stream, as peeling loss, to the product stream, as improved yield. To the increased income from yield improvement was added the saving in reduced waste disposal and caustic requirement. The latter off-set the cost of the isopropanol, and savings soon paid for the equipment.

The process was used in several canneries in 1971 and appears due for a major expansion in tomato processing. It is also being applied to other fruits and vegetables on a reduced scale.

A major innovation in peeling of potatoes is the USDA-Magnuson Engineers "dry" caustic peeling process which is firmly established with at least 40 10-T/hr installations. It originated at the Western Regional Research Laboratory (Graham et.al., 1970; Cyr, 1971). The major advantages over the conventional lye-peeling operation are a reduction of water use and soluble BOD production to about one-fifth. In this case, the recovered material does not appear as primary product, but as a semi-solid peel waste slurry which is more readily disposable than when dispersed in a large volume of water. This waste, highly alkaline when produced, becomes neutralized by bacterial action in a short time when mixed with other potato processing waste and may then be fed to cattle. Where feeding is impractical, landfill disposal or spreading may be practiced. The relatively high sodium ion content may cause subsequent soil texture problems, and a change from NaOH to KOH for the peeling has been proposed (Muneta and Shen, 1972) to avoid this.

Recovery of materials from wastes eliminates treatment costs of the recovered material. The cost of biological oxidation waste treatment in its different forms varies over a wide range for reasons not discussed here. Typical costs or charges range from about 1.5 to 8 ¢/lb of BOD; incentive to reduce waste to be treated will vary accordingly.

In considering among the various options for dealing with fruit and vegetable processing wastes, one can be misled by the numbers involved. Generalizations about amounts of possible by-products available as related to total amounts of wastes or volumes of product packed may lead to enthusiasm for impractical solutions. Economics of proposed processes must be examined as soon as possible in a development; however, in some cases a considerable amount of laboratory study will be required before reliable cost estimates can be made.

Processing of perishable wastes for by-products has a number of limitations other than the cost considerations. It diverts attention and effort from the principal business of the fruit or vegetable processing operation at the time it is least available: attention to distribution or marketing of by-products is also diverted. The seasonal nature of processing operations and the perishability of wastes would require a capacity in recovery operations which may remain idle much of the year. For these reasons it may be more reasonable to process the waste simply to stabilize it and let others handle any use. Such minimal processing is usually dehydration, though for some wastes the cost of dehydration is limiting. Transportation costs will limit the area of use in relation to availability and price of conventional feeds.

Wilson and Borger (1969) have calculated feed values of several fruit and vegetable processing wastes, both wet as a silage component and dehydrated. The value of the wet wastes as silage components at various distances from the cannery was calculated. Tomato waste had the second lowest value and was worth 91 ¢/ton at a distance of 50 miles from the source.

Solid tomato wastes have been dried for feed in this country, though the low feed value limits its use. Feeding of wet waste to swine at a large Eastern cannery was recently discontinued because new State Regulations require cooking. This company now sends tomato wastes to landfill. Return of processing wastes to the tomato fields is common. A proposal was made about 20 years ago (Edwards. et al., 1952) to recover about 83% of the waste from a tomato juice processing plant. Waste liquors were concentrated and dried together with recovered solids, to produce a feed product. The cost of the process exceeded the product value by $41/ton. Drying the waste of a plant with a seasonal capacity of 26,000 tons of tomatoes would produce 263 tons of dried feeds, and cost $10,800/year, a figure to be compared with the cost of other means of disposal.

In Italy where many tomato processing operations are in close proximity, pomace (seeds and skins) has been collected at various plants and shipped to central locations where oil is extracted from the seeds and the residue used for feed or fertilizer (Campbell, 1937). Such operations have not been practical in the United States because of higher labor, transportation, and equipment costs. Tomato wastes have been tried for feed use, but in general they are returned to the fields or to landfill.

A recent Russian publication (Klemenko & Kaganskii, 1969) describes a pilot scale drying plant for tomato seeds, so that they could be shipped to idle oilseed extraction facilities. After a successful operation of a drying plant producing one ton/hour, the commercial recovery and drying of tomato seeds from the Moldavian tomato processing industry was proposed. From the capacity of 187,000 tons of tomatoes processed, about 3,700 tons of seeds would be available, containing about 940 tons of oil. For perspective, this is about the amount of oil contained in 5,700 acres of soybeans. Although no mention was made of the extracted seed meal in the article, it should contain around 40% protein and amount to 2,760 tons. It is not clear if this proposal was actually put into operation.

Tables 1 and 2 provide some general information on the potential of this type of operation in this country. No data are available on the economic aspects. Refined tomato seed oil is an edible oil.

Some years ago the H. J. Heinz Company examined a system to carry out initial processing step at a station adjacent to the tomato fields. They did not adopt the system generally and are not now using it. More recently workers at the Western Regional Research Laboratory have proposed (Schultz et al., 1971; Wagner, 1970) and field-tested a system in which tomatoes are processed to juice in the field, with juice the only material taken to the plant. Wastes are returned to the nearby land. This is the Acidified-Field Break process, and a descriptive film is available for loan.

Disposal of wastes is thus facilitated and it is claimed that yields are improved because of reduced delay from field washing station to centralized processing.

In considering the processing of a given waste to recover useful materials, the instability of the waste frequently (but not always) requires a one-to-one relation between the fruit or vegetable processing plant and the recovery operation. Thus those impressive numbers like 30,000 tons of protein from tomato waste, or 14 billion pounds of discarded cheese whey containing 910 million pounds of nutritive solids might provide order at magnitude data for a potential recovery plant, but obviously will never be attained. The individual recovery proposal must stand or fall at the local plant level in terms of economies of scale and markets for by-products.

I will now give a case history of a project that appeared attrative in terms of the urgency of pollution alleviation, the value of the products, and the availability of technology. After the laboratory work needed for detailed costing was completed, the concept was grounded on the twin rocks of high cost and excessive technology level in relation to the primary processing operation.

Potato starch factories provide a much needed outlet for low grade potatoes, in recent years making about 50,000 tons of starch from about 415,000 tons of potatoes. By the nature of their input, they may be considered a disposal operation, and had survived competition from other starches only by paying a low price ($0.25-0.30/cwt) for their potatoes and essentially nothing for disposal of wastes. These wastes consist of everything in the potato except the starch, and are among the strongest (10,000-15,000 ppm BOD) and heaviest wastes (10,000-15,000 lb BOD per day for a 30T starch plant) in agricultural processing.

Most of this BOD arises from the grinding of the potatoes and centrifugal separation of starch from the "fruitwater". The washed solids are separated and may be fed wet or dry to cattle, though they have relatively low value. The protein-containing fruit water is, or can be made, available at 2 to 2-1/2% solids and about 108,000 gal is available daily with a BOD about 10,100 lb.

During the past several years, research has been carried out at the Eastern Regional Research Laboratory to develop methods to recover these components. The amounts recoverable are shown in Table 3. The 20,000 lb of salts includes those from the protein water as well as neutralization of ammonia and sulfuric acid used in the process. Processes for protein recovery by heat coagulation (Strolle et al., 1971), protein, amino acids, and potassium salts by ion exchange (Heisler et al., 1972) and organic acids by ion exchange (Schwartz et al., 1972) were developed and have been described. Details of the technology are available elsewhere.

At that point sufficient data were available for a fairly detailed cost estimate of the various processes, in comparison with several alternatives, including conventional biological oxidation treatment of the wastes. These estimates have been published (Stabile et al., 1972) and will not be detailed here. It is sufficient to state that the processes noted above have a fixed capital requirement for a 30-ton starch plant of over 2.5 million dollars, five times that of an activated sludge installation. Even after sale of the products, losses are estimated to be nearly 3-1/2 times the annual cost of the biological oxidation.

Since the cost estimate was made, the ion exchange process has been modified to eliminate the need for removal of protein before the ion exchange processing. Protein is coagulated in the column by acid released when potassium ions are adsorbed from the liquor; rapid upflow operation avoids clogging. This modification, though it eliminates the protein coagulation step and much of its $382,000 fixed capital outlay, would not reduce overall costs enough to attain parity with biological oxidation.

Several other options were also cost-evaluated. One of these, evaporation of the entire effluent, was calculated to be economically feasible and dried wastes are under evaluation as a poultry feed component, since the protein of potatoes is of good quality.

Reflecting on these cost studies, it is evident that the ion exchange processes studied, though straightforward and technically quite feasible, are on the whole considerably more complex operations than that of the starch plant itself. The possibility of selling the products at the prices required to break even is quite remote; marketing efforts greater than those involved in selling the primary product, starch, would in any case be required.

This brings up an important consideration in undertaking to process fruit and vegetable wastes. This is the disposition of the recovered materials, hopefully returning a profit or at least enough to cover recovery costs. There are three ways that this is being done: by recycling or internal use, by selling on an existing market, or by developing a market. The last is, of course, the most expensive and uncertain, and it diverts efforts from the main products.

I will introduce some examples of proposals or accomplishments in these areas. First, recycling or re-use.

Processing brines are difficult to dispose of because of their high BOD combined with high inorganic ion contents. Two recent examples of renovation of brine have been proposed, in processing of maraschino cherries and in olive processing. The recovered brine or brine salts are reused in processing and in both cases cost estimates have been made and indicate a moderate degree of financial return.

Roughly half of the sweet cherry production in the United States is processed into maraschino cherries, producing about 53,700 tons of the product annually.

The brine in which cherries are bleached and preserved for several months, contains about 1.5% each of sulfur dioxide, calcium chloride, and 1% of calcium hydroxide; this brine is disposed of when the cherries are further processed. At that time it contains, in addition to reduced levels of salts, between 6-12% solubles extracted from the cherries. A packer who makes 5000 tons of maraschino cherries annually must dispose of about 1,250,000 gal of this highly corrosive effluent. Researchers at Oregon State University have developed a process for renovating this brine so that it is suitable for reuse. Details of the laboratory work have been published by Beavers et al (1970) and of pilot scale tests and a cost study by Soderquist (1971). Activated carbon treatment decolorizes the brine without significant effect on levels of other soluble solids. Cherries treated with reclaimed brine are firmer, with less defects than from those from fresh brine, and are equivalent in yield. A summary of the cost study is shown in Table 4. It is concluded that the economic feasibility of any specific system will probably be determined by the BOD sewerage charge factor, which may vary greatly with the locality. The calculation in Table 4 was made using a charge of 1.3¢/lb BOD.

Sodium chloride brines are widely used in food processing - in manufacture of kraut, pickles, olives, for example. Not only are they difficult to dispose of but re-use would require dilution, since starting brines are lower in salt than finishing brines.

Evaporation is a necessity if there is to be no waste stream. Lowe and Durkee (1971) of the Western Regional Research Laboratory have developed a process for recovery of solid salt from spent processing brines. As seen in the figure, the brine is evaporated by submerged combustion to a slurry of about 57% solids, of which about 6% is combustible organic matter. This is destroyed by a 5-min incineration at 1200°F, leaving a mixture of salt and carbon, which is stored for the next season.

For the next use, the salt is dissolved in water to the desired concentration, hydrochloric acid is added to neutralize it, and the carbon is either allowed to settle or is filtered off.

Preliminary cost estimates indicated a cost of about $2000 per year for an average olive processing plant handling 2500 tons of olives in 250,000 gal of brine per year. The process is presently being evaluated by H. J. Heinz at a California pickle brining station. A ton of recovered salt will be used experimentally in the 1972-73 pickling season.

Processing of a waste for reuse in the plant is often considered and new technology is not needed, though cost-reducing processes may be decisive. Part of the sugar used in canned pineapples is recovered from wastes (Ben-Gera and Kramer, 1969). A process for recovering pear sugars for similar use is, however, not in use (Ben-Gera and Kramer, 1969). Condensation and return of solubles resulting from cooking pumpkins to a purée with a resulting yield increase has been proposed (Aceto, 1971), and commercially evaluated.

Processing of fruit and vegetable wastes to a product which has an existing market is desirable in that market development is not critical and a more stable economic situation exists.

An old example of this is the production of apple juice concentrate, apple essence, and vinegar from apple peels and cores. The existence of this return makes mechanical apple peeling more attractive than it might otherwise be, with its rather large peel waste.

Another example of this approach is the recovery of food grade starch in the processing of potatoes to chips. A British company was reported to produce 20 tons of high grade potato starch per week from the cold cutting operation. A completely automated plant for this purpose is described. The price received for the starch does not cover the cost of the entire effluent plant, which also includes processing of other wastes to reduce their strength to less than 300 ppm, but "nevertheless goes a considerable way towards offsetting the cost of the effluent disposal" (Anon, 1966).

As far as is known, no recovery of purified starch from potato chip manufacture is done in this country. Douglass (1960) has shown that cutting of potatoes into 1/16 in. slices for chips releases 53.6 lb of starch per ton. He noted that "the potato chip industry is badly in need of a simple, relatively inexpensive starch recovery unit." The average U. S. chipper processes 200 tons of potatoes per week and thus wastes 10,700 lbs of recoverable potato starch. Solids that are recovered are used for stock feed only. Solubles go to municipal treatment plants (Willard et al., 1967).

The problems encountered by potato starch factories already discussed above have reduced the numbers of such plants in operation. A need still exists for outlets for off-grade tubers. Feeding of raw tubers is not efficient because of their high moisture content; 450 lb of potatoes are equivalent to 100 lb corn in feed value. Dried, they have 96% of the feed value of corn but drying costs at least $28-30 per ton, without including payment for raw stock. An existing large-scale drying operation in New England can ship the dried potato product several hundred miles (Maine to Massachusetts) in competition with corn only without payment for the input potatoes. Thus the operation provides a "free dump" for the potato grower, but no other return.

Recently, Shaw and Shuey (1972) have applied dry milling and air classification technology to the disposal of low-grade potatoes. They described a process wherein potatoes are dehydrated, finely milled, and subjected to screening and air classification using conventional wheat flour processing equipment. Two principal fractions result - an animal feed and a starch fraction. Counter-current washing of the starch reduces its impurities to less than 0.4% ash and protein and provides wash water of 11% solids and greatly reduced volume in comparision with the wet process. The wash water is dried and added to the feed fraction. Table 5 compares this process with the conventional wet process. Table 6 shows the composition of the two products of the dry milling process.

This process has not been completely evaluated and several areas remain for further examination. A preliminary cost estimate, with several assumptions, was made and indicated overall economic feasibility providing the assumptions were verified by further work. Potato drying conditions in relation to product quality and cost are chief among the areas remaining to be examined.

Mercer (1969) has described the processing of peach pits to charcoal briquets in a plant producing 35 tons of charcoal per day from 120-140 tons of aged peach pits, without apparent emission of smoke or other particles. The magnitude of this disposal problem is indicated by the annual production of 50 to 60 thousand tons of peach pits in the San Francisco Bay region alone.

Another aspect of the fruit and vegetable waste problem is the disposal of culls or pick-outs from fresh market. When these commodities were harvested by hand, culls were not picked and largely disposed of by natural processes or returned to the land. Once-over non-discriminatory machine harvesting has increased the need for disposal of culls, either from a preliminary field sorting, where they could be disposed on the land, or at the processing plant, where a form of processing is available to offset the transportation cost.

Where fresh market varieties are concerned, processing may be a marginal operation because of lower yields or low product quality in comparison with products from processing varieties. Examples are certain Western apple products, Southern tomato products, and freestone peach products in the South. In this latter case an extended effort was made in the sixties to broaden the processing options available for Southern peaches.

A symposium (Anon, 1967) covered quality improvement in canned freestone peaches and preserves, and preparation of peach pickles, baby foods, juices, purées, dehydrated products, refrigerated slices.

To summarize, economic factors dictate the direction taken in handling fruit and vegetable processing wastes. Wet wastes suitable for feed must compete with local feeds and rapidly become worthless if much transportation is required. Preservation as silage by the farmer is feasible only within economic hauling range, and by drying at the production site is costly.

Process modification to reduce waste by increasing yield of primary product is probably the most attractive option: no outlay for sales promotion of a by-product is needed. Usually the primary product produces the best return available, and disposal costs are proportionately reduced.

Recovery of a by-product with an existing market is to be preferred in most cases over recovery of materials for which markets must be developed.

The costs of proposals for recovery of values from waste streams should be examined as early as possible in their development. Costs of conventional waste disposal vary widely and provide a basis against which decisions can be made.

Realistic examination of by-product values and costs must be made; wishful thinking and overoptimistic market projections must be as carefully avoided in waste processing as in any other processing operation.

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Table 1

RECOVERABLE PRODUCTS FROM TOMATO PROCESSING

Input 1000 Tons per Day

Seeds	20 tons at 65% H_2O
Dry Seeds	7.86 tons at 11% H_2O
Recoverable Oil	1.98 Tons
Seed Meal	5.02 Tons

Table 2

COMPOSITION OF TOMATO BY-PRODUCTS

OIL		EXTRACTED SEED MEAL	
Saponification No.	188-190	Moisture	7.1%
Iodine No.	115-125	Protein	37.0
Glycerides of		Fiber	22.1
Oleic Acid	45%	Ash	4.6
Linoleic Acid	34	Nitrogen-free Extract	29.1
Palmitic and Stearic Acids	18		

Source: Winton & Winton, 1935.

Table 3

BY-PRODUCT RECOVERY FROM PROTEIN WATER

OF A POTATO STARCH PLANT

Potatoes Used	250 tons/day
Starch Produced	30 tons
Crude Protein	4100 lb
Amino Acids	4680
Organic Acids	7130
Inorganic Salts	20,400

Table 4

ECONOMIC ANALYSIS OF CHERRY BRINE RECLAMATION

	Production Level (ton/yr)		
	1,000	5,000	10,000
Capital Costs 1/ ($)	7,500	18,000	22,400
Operating Costs 2/ ($/yr)	6,830	20,870	34,590
Cost Savings 3/ ($/yr)	6,240	30,979	61,959
Net Annual Saving ($)	-574	10,109	27,369
Unit Cost Saving ($/ton)	-0.06	2.02	3.05

Data of Soderquist (1971)

1/ After tax saving.

2/ With carbon wastage.

3/ Including savings in water, sewerage charges, and brine chemicals.

Table 5

PRODUCTS OF POTATO STARCH PROCESSES

Daily Input 250 Tons Potatoes

Conventional Wet Process	Dry Process 1/
30 tons starch	30 tons starch
6.8 tons pulp	22.1 tons animal feed
11.9 tons soluble waste solids containing 5.35 tons soluble BOD	0 tons BOD

1/ Projected from pilot-scale data.

Table 6

SHAW-SHUEY DRY STARCH PROCESS

	Composition of Products	
	Starch	Feed
Nitrogen	0.044%	3.9%
Protein (N x 6.25)	0.37	25.7
Ash	0.37	5.0
Starch	99.2	61.8