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Continuous In-Plant Hot-Gas Blanching of Vegetables

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CONTINUOUS IN-PLANT HOT-GAS BLANCHING OF VEGETABLES

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ABSTRACT

An experimental hot-gas blancher was operated in two food processing plants using spinach, green beans, corn-on-cob, beets, and green peas. A side stream of commercially prepared vegetables was hot-gas blanched and returned to the production line. Wastewater samples were collected from the commercial blanchers and the hot-gas blancher; these were measured for volume and analyzed for pH, COD, BOD, and SS. Electrical, gas, and steam flow meters were used to obtain data for cost estimates of commercial scale hot-gas blanching. Comparisons were made of potential reductions in volume of wastewater, weight of BOD, and weight of SS generated when conventional steam or hot-water blanching was replaced by hot-gas blanching; in the case of spinach these reductions were 99.9, 99.8, and 99.5%, respectively. Preserved (canned or frozen) samples of blanched vegetables were analyzed for vitamin and mineral content. The retention of nutrients was the same for hot-gas blanching and commercial blanching except for retention of ascorbic acid in spinach and green peas where hot-gas blanched samples had higher retentions. Evaluation of flavor, texture and appearance of preserved samples demonstrated similar quality products from hot-gas blanching and commercial blanching. The overall quality of hot-gas blanched vegetables was well within the range of commercial acceptability. Estimated capital costs for a commercial scale hot-gas blancher for green beans are twice that of a hot-water blancher. The estimated operating costs for hot-gas blanching of green beans are 25% less than those for hot-water blanching of green beans.

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SECTION I

CONCLUSIONS

Hot-gas blanching of thin or small piece-size vegetables (such as spinach, cut green beans, or green peas) accomplishes the requisite enzyme deactivation and tissue gas removal at practical loading rates [10.7 to 14.6 kg/m^2 (2.2 to 3.0 lb/ft^2)] and residence times (77 to 240 sec).

Hot-gas blanching of large piece-size vegetables (such as corn-on-cob and whole beets) requires long residence times (14 to 25 min) and high steam usage [1.9 to 2.9 kg (4.2 to 6.3 lb)/min] to achieve adequate blanching.

Costs for hot-gas blanching of vegetables are higher than for steam or hot-water blanching. The fixed costs estimated for hot-gas blanchers are 1.6 to 10.7 times higher than for hot-water blanchers. The operating costs for hot-gas blanching are 0.75 to 5.8 times higher than for conventional steam or hot-water blanching.

The flavor, texture, appearance, nutritional content, and safety of hot-gas blanched vegetables are generally equivalent to hot-water or steam blanched vegetables.

SECTION II

RECOMMENDATIONS

Food processing equipment-supply companies should design hot-gas blanchers of optimal performance for each individual commodity.

The commercial scale hot-gas blanchers should incorporate vibratory conveyors to move vegetable pieces and to expose fresh surfaces for more efficient and uniform heating.

The commercial scale hot-gas blanchers should be designed to take advantage of natural convection currents above natural gas flames with minimal assistance from blowers.

A commercial scale hot-gas blancher for cut green beans should be installed in a food processing plant and should be compared to current or previous experience with hot-water blanching.

Hot-gas blanching should receive careful consideration in new plant installations where closed loop use of water is planned.

The overall consequence of accepting higher dehydration losses during hot-gas blanching of vegetables prior to canning or freezing should be more completely evaluated.

SECTION III

INTRODUCTION

The food processing industry is now evaluating the economic consequences of radical changes in processing equipment as one option available to assist the industry in meeting the national goal of zero discharge of pollutants by 1985. It is likely that new technology for raw product preparation, which substantially reduces waste generation, will cost less when old equipment is replaced than the cost of installation or expansion of treatment facilities. New equipment which produces little or no liquid waste would be advantageous if total recycle use of water in food processing is shown to be possible.

Vegetables which are preserved for long-term storage by freezing, dehydration, or canning, receive a treatment (known as blanching) with hot-water or steam. The purpose of blanching is to deactivate enzymes and to remove tissue gases. In addition, blanching frequently accomplishes or facilitates removal of juice, soil, insects and other debris from the vegetable pieces.

It has long been known that the blanching of vegetables is a source of strong liquid wastes with a potential for pollution of receiving water. For example, the blanching and peeling of beets, carrots, and potatoes account for 85, 65, and 89 percent, respectively, of the five-day biochemical oxygen demand (BOD) generated in the processing of these commodities, Weckel *et. al.*[1] It has been estimated, Weckel,[2] that the national (United States) amortized annual (1969) treatment facility cost for liquid wastes from selected vegetable blanching is $2,400,000 and the annual operating and maintenance cost is $3,000,000.

The blanching of vegetables, therefore, is a food processing unit operation having a high potential for substantial reduction in liquid waste generation. The volume of liquid waste produced from hot-water blanching of vegetables is 10-20 times that produced by steam blanching. Therefore, the greatest opportunity for significant reduction of waste water volume during vegetable processing is the replacement of hot-water blanching by a system generating little or no liquid waste.

A preliminary study of potential low-water volume methods of blanching was accomplished under U.S. Environmental Protection Agency's Grant 12060 PAV, Ralls and Mercer.[3] Comparison of the results of blanching seven vegetables with microwave, hot-gas, steam, and hot-water blancher simulators revealed exceptional promise for the new method of hot-gas blanching. The experimental unit used in the laboratory study of hot-gas blanching (also called hot-air blanching or dry-blanching) was the first of its kind known (to the authors) to be constructed and tested. The unit conveyed raw vegetables through an insulated rectangular chamber containing a natural gas furnace. Most of the thermal energy received by the vegetable was due to the heat content of combustion products and nitrogen. The hot gases were circulated in the chamber by means of a large blower and by convection currents. The cooled combustion gases were partially recirculated through the blower. Steam was injected at the top of the chamber to improve heat transfer from the hot gases to the vegetables and to reduce dehydration losses from the high-water content vegetables.

This preliminary study indicated that the volume of wastewater, the pounds (lb) of chemical oxygen demand (COD), and suspended solids (SS) per ton of vegetable blanched could be reduced 90 to 99 percent when hot-water blanching was replaced by hot-gas blanching. There were no significant differences in product quality, vitamin and mineral retention, or internal can corrosion, among samples of vegetables prepared with the four different blanching systems. An estimate for commercial blanching using the four systems studied led to the following total annual cost per ton of raw vegetable blanched: microwave, $18.47; hot-gas, $3.39; steam, $2.21; and hot-water, $2.36 or $20.30; $3.73; $2.43; and $2.60 per kilo-kilogram (kkg), respectively.

The initial study of hot-gas blanching was conducted in the National Canners Association (NCA) Laboratory in Berkeley, California. The laboratory study had several limitations; the most serious of which was the requirement of long transport distances [322 to 1609 kilometers (km) (200 to 1000 miles)]and excessive holding times (8 to

48 hours (hr)] before blanching the vegetables. The long holding times between commercial preparation of the vegetable samples for blanching and the actual laboratory blanching were particularly serious for green peas (shelled), cut green beans, and asparagus (trimmed). The changes which took place in these commodities during the holding period before blanching made the significance of some data uncertain. The changes in corn (shipped in husks), beets, pumpkin (shipped whole), and spinach (whole leaf) during the holding periods were not large enough to influence the significance of the data collected on these commodities. The laboratory study was limited to short-duration blanching runs due to raw vegetable cost; for long-duration blanching runs it would have been necessary to waste large quantities of wholesome food since the laboratory equipment for canning and freezing of vegetables could not handle the blancher's output. A third limitation of the laboratory study was the lack of direct measurement of electrical, gas, and steam usage for more precise cost estimates.

The next step in testing the commercial utility of hot-gas blanching was operation of the unit under conditions which would avoid the limitations of the laboratory study. The decision was made to test the commercial utility of the new processing system at a commercial processing plant. With an in-plant installation, raw vegetables prepared for commercial and experimental blanching would be identical and, thereby, eliminate the impact of blanching time differences on the significance of data collected. Assuming that the experimental unit could be operated to produce blanched vegetables having acceptable commercial quality, most of the blanched vegetables could be returned to the commercial production line to avoid wastage of food. The in-plant installation of a single experimental blancher would make possible, at reasonable cost, the installation of electrical, gas, and steam flow meters. Meter readings would supply information for operational cost estimates. The in-plant study also would provide the opportunity for the measurement of the volume and characteristics of waste waters from commercial blanchers and comparison of these values with the same wastewater values from the experimental blancher.

This report describes the results of a comprehensive study of hot-gas blanching of peas, corn, spinach, beets and green beans at two food processing plants. The study was designed to develop information on all the factors which would concern potential commercial users of hot-gas blanching. The major considerations treated in the study were operational costs; wastewater generation; wastewater characteristics; final product safety, quality, and nutritional content; and internal can corrosion.

One safety aspect of the final product was not recognized until after the study was underway. This was the potential for the occurrence of polynuclear hydrocarbons in vegetables blanched by the hot-gas unit. It is known that oxidation of any fuel can produce a mixture of polynuclear hydrocarbons during incomplete combustion, Mukai, et. al.[4]

Some of these compounds are known to produce cancer in experimental animals, Bryan and Lower.[5] Although there is no definitive evidence that oral ingestion of trace amounts of polynuclear hydrocarbons causes cancer in humans, any food shown to contain significant amounts of known animal carcinogens would be subject to question by the Federal Food and Drug Administration. Therefore, a study of the polynuclear hydrocarbon content of samples of hot-water and hot-gas blanched cut green beans was conducted to determine if the potential for this contamination existed.

SECTION IV

EXPERIMENTAL PLAN

GENERAL CONSIDERATIONS

The study of hot-gas blanching in commercial canning and/or freezing plants was designed to collect sufficient data to provide a basis for management decisions on the use of this new blanching system. To evaluate all possible options, a manager would need to know capital cost, operating cost, ease of sanitation and maintenance, product quality, effect on containers, and cost of waste management for each blanching system under consideration. Therefore, the hot-gas blancher was operated and sampled in a way which would provide the necessary data for comparison to the steam or hot-water blanchers which are now in use.

The in-plant location of the hot-gas blancher provided access to a readily available supply of vegetables prepared for blanching under commercial conditions. The option of returning hot-gas blanched vegetables to the commercial production line was available and, if used, demonstrated the immediate commercial utility of hot-gas blanching. The opportunity for extended operation of the hot-gas blancher made it possible to use material from all stages of the production season and provided assurance that raw product variation would not limit the utilization of hot-gas blanching to any specific time span of the operating season. A target of forty hr of operation for each of the five vegetables scheduled for study was established to provide the long term testing period.

The in-plant testing program provided the opportunity for sampling of commercial blanchers receiving lots of vegetables identical to those being hot-gas blanced. Volumetric measurement and analysis of samples of wastewater from commercial blanchers provided a basis for direct comparison of the waste generating characteristics of hot-gas, steam, and hot-water blanching. While it is well known that wide variations exist in the waste generating characteristics of blanchers in different plants processing the same commodity, Holdsworth[6], such comparisons should establish the approximate extent of waste reduction possible with hot-gas blanching. The waste generation comparison should also provide a model into which new data could be substituted for the reported data to allow a comparison to be made between a specific commercial blancher and the hot-gas blancher.

The in-plant study gave access to product samples which could be evaluated for quality on a direct comparison basis. The first quality measurement planned was the effect of the blanching treatment received on the level of nutrients in the blanched samples of vegetables. The retention of nutrients during food processing is receiving considerable attention at the present time due to intense public concern with nutrition and nutritional labeling. The nutrient retention in vegetables which are hot-gas blanched must be at least equivalent to that in vegetables from the blanching system being considered for replacement. The cost of preparing labels for food producers listing nutritional information is so large that changes in nutrient content due to hot-gas blanching would be the basis for rejecting its use. Therefore, for decision making reasons it was important to determine the percentage change in the nutrient content of raw vegetables due to hot-gas blanching. A comparison of nutrient retention between commercially blanched vegetables and hot-gas blanched vegetables is important as a basis for judgements on the degree of differences to be expected.

Assuming that no substantial differences in nutrient content are found due to hot-gas blanching, the next product quality factors of concern would be flavor, texture, and appearance. The ideal basis for comparison of the effect of blanching on these quality factors would be using preserved samples from all hot-gas blanched product compared with regular commercial production line samples from similar lots of vegetables prepared on the same day. The experimental plan was designed to provide these kinds of samples whenever possible. It was recognized that if the output of the hot-gas blancher was low, it would be necessary to blend hot-gas blanched product with commercially blanched product to avoid loss of commercial production capacity. In the event that blending of the two types of blanched materials was necessary, consumer reaction to lots of such product would be used for quality evaluation. For commodities where it was possible to preserve all hot-gas blanched material, direct testing against an equivalent commercial sample was possible.

The experimental plan called for evaluation of flavor and appearance by an organoleptic panel. These panels are used routinely in the food industry to establish differences in quality among food samples, Amerine, et. al.[7]. The laboratory study of hot-gas blanching had indicated a weight loss in blanched material due to dehydration. There was also an indication that steam injection could reduce dehydration losses. Loss in weight by dehydration is of direct consequence for preservation by freezing since the product value is usually based on weight. The only frozen product used in this study, corn-on-cob, was sold by count so weight losses due to blanching were not of critical concern. There is a possibility that spray cooling of hot-gas blanched vegetables destined for frozen preservation would cause replacement of a substantial part of the water lost by dehydration; investigation of this point was not part of the experimental plan. Some loss of moisture content during hot-gas blanching of vegetables could be accomodated in products to be preserved by canning. It would be expected that the partially dehydrated vegetables would regain water from the packing medium. The experimental plan called for control of the loss of water through dehydration by injection of steam. In those cases where some dehydration of vegetables took place, the experimental plan called for determination of the change in moisture content and evaluation of the degree of rehydration in the can.

The most important function of blanching for vegetables to be preserved by canning is removal of tissue gases. If not properly removed during blanching, gases released by the vegetable tissue can decrease the vacuum and contribute to the internal corrosion of the container by increasing the oxygen content in the headspace gases. Direct measurement of the gas composition of vegetables is very difficult due to sampling and gas displacement problems. It is possible to determine the degree of gas removal during blanching by an indirect method of headspace gas analysis. The experimental plan included analysis of cans from hot-gas blanched and commercially blanched material for composition of gases in the headspace as an indication of the effectiveness of hot-gas blanching in removing oxygen from vegetable tissues.

Another indicator of incomplete removal of gases from vegetables during blanching is accelerated internal can corrosion. Examination of opened cans containing samples of hot-gas blanched vegetables and commercially blanched vegetables were made as a second indirect estimation of tissue gas removal.

Vegetables are classified as low acid foods due to observed pH values above 4.6. The pH range of vegetables permits growth and toxin production from the mesophilic anaerobic bacterium Clostridium botulinum, if any spores survive in a can due to underprocessing.

The calculation of the thermal process is based on thermal death time data for anaerobic spores and heat penetration measurement for each product formulation. Blanching can influence the heat penetration characteristics of canned vegetables, such as in chopped spinach, and render an established thermal process inadequate. Blanching may have an effect on fill weights which are another factor which must be controlled for thermal processing adequacy. For these reasons, the experimental plan called for examination of the effect of hot-gas blanching on critical control points in the thermal processing of canned vegetables.

BLANCHING

The hot-gas blancher used for the in-plant studies was the experimental unit described previously by Ralls and Mercer.[3]

Figure 1 shows a photograph of the hot-gas blancher installed in one of the food processing plants used in this study.

The blancher was installed with three electrical meters: one for the large blower; one for the combustion air supply turbine; and one for the conveyor drive, gas furnace ignitor, and electronic controls. A gas meter was placed on the inlet side of the natural gas furnace. A Fisher and Porter Model 10A1152-55EM steam flow meter rated at 9.54 kg (21 lb)/ minute(min) at 100 percent of scale was installed on the steam inlet line. A FMC Syntron Model No. BF-2 electric vibratory feeder was used to control the rate of feeding of green beans and beets onto the conveyor belt of the hot-gas blancher. Corn-on-cob and spinach were loaded by hand by workers wearing food grade rubber gloves. Peas were delivered in a flume from storage hoppers with partial removal of water on the conveyor belt of the hot-gas blancher.

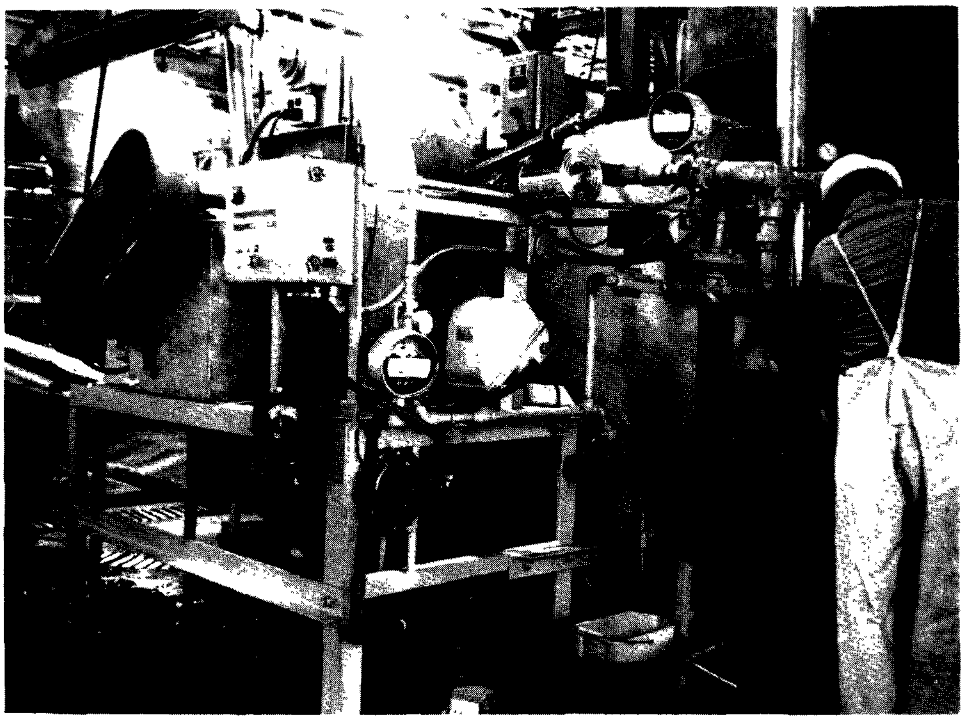

Figure 1. Hot-gas blancher installed in a food processing plant

Dry belt conveyors were used as much as possible to accomplish the transfer to both raw and blanched vegetables. Raw No. 4 sieve size cut green beans were delivered to the hot-gas blancher in 363 kg (800 lb) capacity tote boxes using fork-lift trucks. Spinach was transported to a feed conveyor in a 227 kg (500 lb) capacity wheeled cart. Corn-on-cob and beets were carried in 13.6 kg (30 lb) capacity plastic pails.

After the installation and testing of the hot-gas blancher had been completed, samples of commercially blanched vegetables were examined and the reduction in peroxidase level measured, Dietrich, et al.[8]

Beets, spinach and peas for canning are blanched until almost all peroxidase activity is destroyed. Therefore, the target peroxidase reduction level for hot-gas blanching of beets, spinach, and peas was 95-100 percent. Complete destruction of peroxidase activity is required to retain the quality of frozen corn-on-cob. The target peroxidase reduction level for both kernels and cob of hot-gas blanched corn-on-cob was 100 percent. The level of enzyme deactivation during blanching of cut green beans is a special case and requires careful control to avoid over-blanching. Cut green beans which are hot-water blanched to a level of 40 percent peroxidase reduction or greater, frequently show a separation of the skin from the bean pod in the final canned product. This condition is known as "sloughing" and when it occurs, the appearance of the product is much less attractive than material consisting wholely of intact bean pods. The target peroxidase reduction level for hot-gas blanched beans was 20 to 40 percent. A large number of short duration hot-gas blanching runs were necessary to establish consistent operating conditions yielding canned samples showing low levels of sloughing.

The appearance, texture and color changes in commercially blanched samples were used, along with the peroxidase reduction values, as targets for the performance of the hot-gas blancher. The operating conditions (loading rate, temperature, residence time, and steam flow) were varied systematically until a set of conditions were found which reproduced the commercial blanching effect as closely as possible. The hot-gas blancher was then operated for approximately one hr under the conditions found to duplicate the effect of the commercial blancher to confirm that extended operation would produce uniformly blanched material and to provide material for preparation of samples for quality evaluation using the commercial line equipment.

The canned or frozen samples prepared for quality evaluation were examined by routine quality control procedures used by the plant and by a group of company management and technical persons. The process of sample preparation and company evaluation was repeated until management was satisfied that material from the hot-gas blancher could be incorporated into commercial production and sold in the same way as conventional products.

The next stage of the in-plant study was extended operation of the hot-gas blancher up to the planned period of forty hr whenever possible.

WASTEWATER MEASUREMENTS

The measurements made on wastewaters from the hot-gas blancher and the commercial blanchers were designed to provide the basis for comparison of the waste generating characteristics of these blanching systems. The volume of wastewater produced during the blanching of a measured quantity of vegetables was determined. For the hot-gas blancher, the total volume of condensate collected from the single drain of the blancher, during each eight hr of operation was measured with a plastic graduated cylinder or a calibrated plastic pail. The collection of the eight hr total volume wastewater from the hot-gas blancher was accomplished with ice-water cooling whenever possible.

The method used for collection of wastewater samples from the hot-gas blancher, with ice-water cooling, is shown in Figure 2.

To determine the volume of wastewater generated per unit weight of vegetable blanched, it was necessary to measure the quantity of vegetables hot-gas blanched during every two hr period of operation.

Generally the weight of vegetables hot-gas blanched was calculated from the constant loading used and the determination of the number of flights of the conveyor belt loaded during different periods of operation. This method of determining the weight of material hot-gas blanched was used for corn-on-cob and beets. In the case of hot-gas blanching of cut green beans and spinach, gross and tare weights of tote boxes or wheeled carts containing beans or spinach were used for the determination of the weight of material blanched. Due to the variability in maturity of green peas, it was necessary to change the residence time frequently to get complete blanching. A constant loading rate was used. The variable residence time accounted for variable through put.

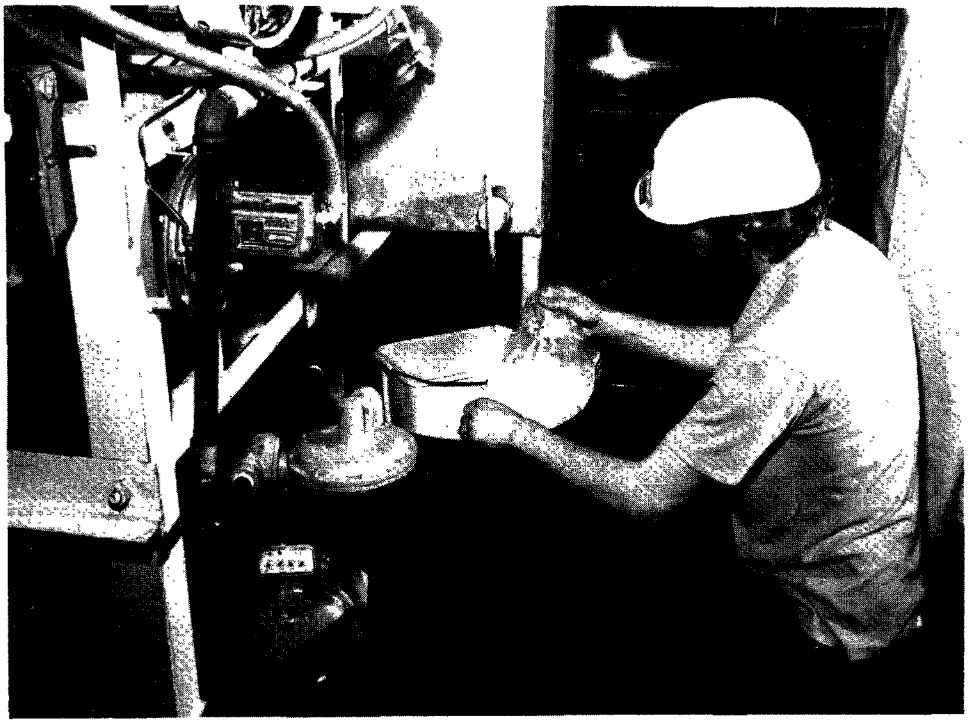

Figure 2. Collection of steam condensate sample from the hot-gas blancher

The sampling of wastewater from commercial blanchers was designed to determine the total wastewater generated during eight hr periods of commercial operation. The wastewater measured consisted of total steam condensate in the case of the corn-on-cob blancher which was collected at four drainage points, combined, and the volume measured in calibrated drums every two hr.

Combined make up water overflow and dump water for the green bean, beet, spinach, and green pea blanchers were measured. Rarely did the dumping of commercial hot-water blanchers occur at eight hr intervals; to put wastewater data on a comparable basis, the volume of dump water measured was divided by the number (no.) of eight hr periods comprising the hr of use of the blanchers between dumpings.

The method used to determine the weight of vegetables blanched in the commercial blancher being monitored varied with the commodity under study. The no. of cans packed in any given time period from material blanched during that time in a specific blancher was obtained from warehouse counts of cans after retorting. Knowing the fill weight for each can, the total weight of material after blanching (with the exception of material lost in hold-up and spillage) could be computed. This method was used for determining the weight of cut green beans and whole beets blanched commercially during specific time periods. No hot-gas blanched beans were mixed in with commercially blanched beans; the weight of beets hot-gas blanched and returned to production was subtracted from the computed weight. The weight of corn-on-cob blanched in the commercial steam blancher was determined from a count of the no. of ears entering the blancher/min and the weight of an average (ave.) ear. The ave. weight/ear was determined by weighing several containers each holding a known no. of unblanched ears and dividing the net weight of ears by the no. of ears.

The weight of spinach commercially blanched was determined from scalehouse weights (gross and tare) of trucks unloading spinach during the period of blancher wastewater monitoring. These weights were incorrect to the degree to which the raw spinach contained debris or unusable spinach leaves rejected during sorting or washing. It was estimated that the wet spinach presented to the blancher weighed about the same as the dry, raw, spinach containing small amounts of stones, dirt, weeds, and overmature leaves.

The volume of wastewater added to the commercial hot-water blanchers was determined by metering the make-up water line, or by measuring the blancher liquid discharge by collection in calibrated drums for specific time periods. Generally, the rate of wastewater from the commercial hot-water blanchers was determined by collection during a period of one to five min every two hr of operation of the hot-gas blancher. In the case of the pipe blancher for peas, the extensive foaming at the make-up water surge tank and drain made direct measurements of volume inaccurate. It was determined by observation of the complete pipe blanching system that the major source of make-up water was the rinse water at the dewatering screen which delivered commercially blanched peas to the conveyor belt feeding the can filler. A measurement of the rate at which rinse water was sprayed on the commercially blanched peas established the make-up water feed rate.

The estimate of the weight of peas blanched in the commercial blancher being monitored was made from can counts, can size, fill weights of each can size, and subtraction of the weight of peas contributed by the hot-gas blancher during the period monitored. A check list for recording measurements and sample collections during the operation of the hot-gas blancher is shown as Appendix T.

The eight hr total volume wastewater discharge from the hot-gas blancher, two hr grab samples, and a composite of equal volumes of four consecutive two hr grab samples from the commercial blancher wastewater were analysed for BOD, COD, SS, and pH by standard methods, Taras[9]. The wastewater samples were refrigerated from shortly after collection until laboratory analyses were started.

The wastewater samples were not screened prior to analysis and were shaken before aliquot removal to give uniform suspension of insoluble material. No preservatives were used to stabilize the refrigerated wastewater samples prior to analysis.

Wastewater samples from the blanching of cut green beans, corn-on-cob, and beets were analysed at a laboratory in Corvallis, Oregon. Wastewater samples from the blanching of spinach and green peas were analysed at a laboratory in Berkeley, California.

PRODUCT EVALUATION

The evaluation of the effect of hot-gas blanching on the quality of vegetables took place in several stages. The initial product evaluation was made subjectively, by blancher operators and company technical specialists who inspected freshly blanched material from short duration exploratory experiments. Experienced observers estimated the adequacy of blanching by noting changes in color, texture and flavor of freshly blanched material. For exploratory runs of the hot-gas blancher, where the blanched material passed subjective examination, a measurement of the extent of reduction in peroxidase was made. This objective test of peroxidase reduction was made hourly for the long duration (forty hr) runs.

The next product evaluation was made by examination of samples of hot-gas blanched material which had been prepared and preserved under commercial conditions. It was this examination which was the basis of approval by plant management for the long duration runs. The examination was made by running routine quality control examination and additional subjective testing for color, flavor, and texture using commercial line samples as a basis for comparison.

Samples of raw, hot-gas blanched and commercially blanched vegetables were frozen using solid carbon dioxide, shipped frozen, and stored frozen until vitamin and mineral analysis could be conducted in the Berkeley, California and St. Louis, Missouri laboratories. Samples were analysed for the vitamins and minerals expected, from published compositional data, to occur at significant levels in each of the five vegetables studied. The determinations of vitamin and mineral content were made according to the Eleventh Edition of the "Official Methods of Analysis of the Association of Official Analytical Chemist", Horwitz[10].

The selection of vitamins and minerals for analysis was based on three types of data:

a) Tabulations of vitamin and mineral content of raw and processed vegetables, Watt and Merrill[11], Orr[12].

b) Official tabulations of Recommended Daily Dietary Allowances, National Research Council[13].

c) Per capita consumption of processed vegetables, Judge[14].

In general, a vitamin or mineral was included in the analytical schedule if a 100 gram (g) portion of a specified vegetable contained 10 percent or more of the maximum recommended daily dietary allowance, (MRDA). In those cases where all vitamins and minerals were below the 10 percent figure, a combination of the percentage contribution to the MDRA and the per capita consumption were used to make the selection.

The vitamin and mineral testing schedule used in this study is tabulated in Table 1.

Table 1. SCHEDULE OF ANALYSIS FOR VITAMINS AND MINERALS

	Vitamins						Minerals			
Commodity	A	B_1	B_2	B_6	C	Niacin	Ca	Mg	P	Fe
Green Beans	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Beets	No	No	Yes	No	No	Yes	No	No	Yes	No
Corn	No	Yes	Yes	Yes	No	Yes	No	No	Yes	No
Peas	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spinach	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes

Headspace gas analysis (by gas chromatography) of canned samples of green beans, beets, spinach and peas was made as a measure of the removal of oxygen from the tissues of blanched vegetables, Ralls and Mercer[3]. The second type of estimation of the extent of tissue oxygen removal was subjective examination of cans of cut green beans after various storage times and temperatures. Canned samples of beets, spinach, and peas were not stored long enough to show differences in extent of internal can corrosion. Samples of green beans were stored at 38 degrees Centigrade (°C) [100 degrees Fahrenheit (°F)] (accelerated storage) for six months (mo), a condition which approximates the longest expected storage life (18 mo) of cans in commercial distribution at ambient temperatures. Results of examination of cans of green beans stored in a warehouse for five mo were also made available by the Research Director of the canning company in whose plant the cans were packed.

The complete description of the method used for measuring levels of polynuclear hydrocarbons is given in Appendix A. For this investigation, standards used were the polynuclear hydrocarbons: anthracene, fluoranthene, and pyrene. It was not possible to introduce potentially carcinogenic hydrocarbons such as benzo (a) pyrene into a food research laboratory due to the extensive monitoring and safety protocols which would have been required. The use of potentially carcinogenic hydrocarbons was unnecessary for this study since it had been demonstrated by Mukai, et. al.[4] that incomplete combustion of methane, propane or isobutylene always produces a mixture of anthracene, pyrene, fluoranthene, benzo (a) pyrene, benzo (e) pyrene, and perylene in relatively constant proportions. Therefore, detection of any significant differences in the level of anthracene, fluoranthene, and pyrene in hot-water and hot-gas blanched green bean samples would be presumptive evidence for the presence of benzo (a) pyrene.

A detailed evaluation of the quality of canned cut green bean samples was made in the Sensory Evaluation Program of the Department of Food Science and Technology at Oregon State University under the supervision of Professor Lois A. McGill. The samples were tested after storage at 38°C (100°F) for periods of one, three, and six mo. The procedure used for preparing samples for panel evaluation varied slightly for each storage period.

For samples stored one mo: The separate samples were brought to 71°C (160°F) and served in random numbered coded cups.

For samples stored three mo: One Number 10 can of each sample of canned green beans was removed from 38°C (100°F) storage at 10:00 a.m. and allowed to stand at room temperature until tested at 2:00 p.m. For testing, a vacuum reading was taken on each can, the cans opened, emptied into identical sized pans, heated to a rolling boil, removed from the heat then served hot to the judges.

For samples stored six mo: One Number 10 can of each sample of green beans was removed from 38°C (100°F) storage on March 12 and placed at ambient temperature until tested at 2:30 p.m., March 13, 1973. For testing, a vacuum reading was taken on each can, the cans opened, emptied into identical pans, heated to boiling at 100°C (212°F) and held at boiling temperature for ten min then removed from the heat and served hot to the judges. The ten min boil was a precautionary measure as the vacuum readings were 3.0 inches (in.) of mercury or less on all four samples.

The Oregon State University panel consisted of forty staff members who completed a ballot based on a nine point hedonic scale for appearance, texture, flavor and overall desirability.

The samples were served in paper cups coded with three-digit random no. The four coded cups, randomly placed on a tray along with a ballot and fork, were served to the judges seated in individual testing booths. The judges were asked to score the appearance by viewing one-cup samples in white bowls and finally score the overall desirability and indicate which sample they preferred.

It should be noted that a different scoring system was used at the one mo storage test than was employed on the three mo and six mo storage tests. At the initial storage period, sample A was used as a known reference and also included as a coded sample along with the other samples and the judges scored the four coded samples in direct relation to the reference (A) sample which was pegged at a score of five. However, even though the scoring system makes the absolute scores lower on the one mo storage test, the relative differences between samples are the main considerations.

The Oregon State University group also evaluated samples of hot-gas blanched and commercially blanched frozen corn-on-cob.

Laboratory taste panels were run in the NCA Berkeley Laboratory on samples of canned spinach. A set of three samples (two identical) of commercially-blanched and hot-gas blanched spinach was presented to a panel of sixteen persons on four occasions for determination of difference. A ranking test of three commercially-canned samples and one hot-gas blanched canned sample was also conducted in the NCA Berkeley Laboratory.

By following consumer reactions to samples, a less objective, but still highly significant, product evaluation was obtained on samples of green beans, beets, corn-on-cob, spinach and peas which contained all or partially hot-gas blanched material. For beets, and peas, this type of evaluation was the only source of information on product quality as influenced by the blanching treatment received.

The results of NCA product evaluations were subjected to analysis of variance to determine if there was a significant effect due to the blanching condition used in the preparation of samples on which the measurement was made. The analysis of variance was made using a randomized complete block design, Amerine, et. al.[7], with the vegetables involved in the analysis as blocks and the blanching conditions as treatments. When the variance ratio (F value) calculated exceeded the tabular F values at the one or five percent level of significance, multiple range tests could be used to determine significance due to individual blanching for specific vegetables.

The statistical evaluation of organoleptic evaluation of canned green bean samples was made by the investigators at Oregon State University who conducted the test. These data were analysed by analysis of variance and the Least Significant Difference (LSD) at the five percent probability level. A similar statistical evaluation was made of the results of organoleptic panel evaluation of samples of frozen corn-on-cob.

ECONOMICS

The cost of blanching using a new system such as hot-gas is a critical factor in any decision to replace currently used equipment. Therefore, a serious attempt was made in this study to gather information on which to base cost estimates of commercial scale equipment for hot-gas, steam, and hot-water blanching. The information on capital costs and space requirements was obtained from suppliers or potential suppliers of commercial scale equipment. The first cost ($) and space requirements (m^2) for commercial steam and hot-water blanchers were: 25,000, 46.65; 15,000, 46.40; 20,000, 45.13; 30,000, 55.14; and 8685, 15.50 for green beans, corn-on-cob, beets, spinach, and green peas, respectively.

The operating costs were estimated from power usage, steam usage, water consumption, and public utility fee schedules for a commodity being blanched in a unit of approximately five kkg or 5.5 ton/hr capacity. Actual measured energy use during hot-gas blanching was one basis for part of the estimate using appropriate scale-up factors.

Annual fixed costs were the sum of amortized first cost, space rent, taxes, insurance and maintenance. Amortization was defined as the capital recovery factor (crf) with 7 per-cent interest for a five year (yr) period and allowing no salvage value. Space rent was set at $129/m^2$. Boiler space requirements were ignored since all units require steam. Taxes were set at $5.00/$100 of assessed value based on 25 percent of first cost. Insurance cost was computed on the basis of 0.2 percent of assessed value. Maintenance cost was calculated as 1.0 percent of first cost/yr.

In calculating operational costs, actual energy usage for the experimental hot-gas blancher was multiplied by a scale-up factor (5 kkg divided by the ave. feed rate in kkg) and an energy cost factor. For commercial blanchers, part of the estimated operational costs were based on the no. of drive motors and their ratings, measured water consumption, and measured BOD and SS content of wastewaters. Cost of electrical power was based on $0.035/kilowatt hr (kwh). Steam costs were computed at a rate of $2.20/kkg. Water costs were computed based on $0.10/3785 liters (l) [1000 gallons (gal.)]. Waste disposal was based on $0.023/kg (0.05/lb) for BOD and SS removal during treatment. Cost of natural gas was computed on the basis of $0.76 /28.3m^3(1000 ft^3). Labor costs were based on $4.00/hr plus $1.20 in benefits. Each blancher was assigned a half-time worker for operation. Cost of operating the pipe blancher was based on water cost, heating cost, power cost for circulation pumps, and dewatering screen-drive motors.

The uncertainties of estimation made the cost estimate useful only as a rough screening of economic practicability of a new blanching system before more extensive collection of cost factors for specific application are made.

SECTION V

EXPERIMENTAL RESULTS

BLANCHING AND WASTEWATER MEASUREMENTS

Green Beans

The results of short duration hot-gas blanching runs for cut green beans are tabulated in Appendix B. The conditions used to prepare canned samples of hot-gas blanched green beans for evaluation by management prior to long duration runs are tabulated in Appendix C. The samples prepared in Runs No. GB-41, GB-42, GB-44 were judged to be of commercial quality and conditions used in these runs were established for the forty hr of long duration operation. The conditions used for the long duration hot-gas blanching of No. 4 sieve size, cut, green beans were: a loading of 14.6 kg/m^2 (3 lb/ft^2), a feed rate of 526-911 kg (1160-2000 lb)/hr, an 80-96°C (176-205°F) operating temperature, a 77 sec residence time, and a 3 percent gauge setting on the meter which gave 0.30 kg (0.66 lb)/min of steam flow. The results from long-term hot-gas blanching of cut green beans are tabulated in Table 2.

Table 2. LONG TERM HOT-GAS BLANCHING OF CUT GREEN BEANS

Date	Hour of operation[a]	Feed rate, kg/hr	Temp, °C	Peroxidase reduction, %
8-15-72	0	0	--	--
	1	737	85	17
	2	730	87	17
	3	--	92	28
	4	669	82	33
	5	--	91	20
	6	567	91	18
	7	--	93	55
	8	628	83	51
8-16-72	9	--	87	19
	10	671	84	27

Table 2 (Continued). LONG TERM HOT-GAS BLANCHING OF CUT GREEN BEANS

Date	Hour of operation[a]	Feed rate, kg/hr	Temp, °C	Peroxidase reduction, %
	11	--	95	54
	12	835	83	40
	13	--	80	83
	14	--	81	17
	15	725	86	43
	16	--	84	42
8-17-72	17	709	83	51
	18	709	96	44
	19	763	82	35
	20	--	83	23
	21	--	80	19
	22	758	83	26
	23	--	90	54
	24	780	83	45
8-18-72	25	--	83	37
	26	763	80	0
	27	--	92	40
	28	--	83	44
	29	--	87	32
	30	911	84	39
	31	763	83	30
8-19-72	32	--	80	27
	33	526	83	70
	34	--	86	42
	35	--	82	33
	36	763	83	37
	37	--	82	62
	38	--	89	23
	39	681	82	33
	40	--	84	27
	41	653	83	37

[a] Total volume wastewater samples collected from 0 to 8, 11 to 16, 24 to 32, and 32 to 40 hr of operation were 0.473, 0.113, 0.620, and 0.246 l. respectively, The 16 to 24 hr sample was spilled and lost.

The wastewater volume and characteristics for hot-gas blanching of cut green beans are tabulated in Table 3.

Table 3. WASTEWATER VOLUME AND CHARACTERISTICS FOR HOT-GAS BLANCHING OF GREEN BEANS

Sampling date	Wastewater volume, l	Weight blanched, kkg	BOD, mg/l	COD, mg/l	SS, mg/l	pH
8-15-72	0.473[a]	5.33	1170	2670	140	7.2
8-16-72	0.113[b]	3.90[b]	6380	15500	450	6.8
8-17-72	--[c]	5.95	--	--	--	--
8-18-72	0.620	6.49	3530	7260	180	--[d]
8-19-72	0.246	6.85	6840	17400	550	6.7

[a] Eight hr collection periods.
[b] For period of 11 to 16 hr of operation.
[c] Sample spilled
[d] Data not recorded.

The commercial green bean blancher was a cylindrical tank, partially filled with 1133 l (300 gal.) of hot water. The blancher water was drained about every eight hr. The wastewater volume and characteristics of the make-up water overflow from the commercial cut green bean hot-water blancher are tabulated in Table 4. The composite samples were prepared from equal volumes of each of four grab samples taken at 2 hr intervals.

The volume of make-up water overflow was highly variable as shown by the data in Table 4. The variability was due to the use of different settings of control valves for the make-up line and non-uniform practice in turning off valves when the complete canning line was not operating due to mechanical failures or rest periods. See Appendix D for additional data.

Table 4. WASTEWATER VOLUME AND CHARACTERISTICS FOR MAKE-UP WATER OVERFLOW COMPOSITE SAMPLES FROM COMMERCIAL BLANCHER FOR CUT GREEN BEANS

Sampling date	Total weight blanched, kkg	Total volume, l	BOD, mg/l	COD, mg/l	SS, mg/l	pH
8-15-72	12.9	882	8510	13900	1810	6.5
8-16-72	14.2	406	7070	11800	1520	--
8-17-72	17.6	339	3850	6600	530	--
8-18-72	9.8	303	2870	5280	470	--
8-19-72	11.3	272	4580	7720	810	--

Corn

The results of short duration experiments on hot-gas blanching of corn-on-cob are tabulated in Appendix E. Corn-on-cob was the only commodity studied in this project which was marketed as a frozen product.

A dozen ears of corn from Run Number COC-20 were tagged and frozen. The following day these ears were tested (with subjective examination) by a group of Agripac, Inc. quality control specialists and compared with commercially-blanched frozen ears of corn. The consensus of the evaluation group was that the hot-gas blanched corn would be commercially acceptable but had a distinctly different flavor. A decision was made by Agripac, Inc. management that the forty hr run of hot-gas blanching of corn-on-cob should proceed but that all product produced must be tagged and segregated after freezing for further quality evaluation after three mo of storage. A further condition was that the ears of hot-gas blanched corn be cooled to a temperature as low as the water-cooled corn on the commercial line before they were put into the freezer. This latter condition was met by installing a second cooling water spray manifold and using five min of spray cooling, five min of draining, and a second five min of spray cooling. The internal temperature in the cob of hot-gas blanched corn, under conditions of Runs 20-22, was 66-71°C (150-160°F). After the cooling sequence described above was used, the internal temperature of the cob ranged from 32-43°C (90-110°F); a commercial line sample taken at the end of the water spray cooling had a cob temperature of 51°C (124°F). In the initial tests, the bottom of the ears after the first five min of spray cooling were distinctly warmer than the tops. In the long duration runs the ears were rotated 180 degrees as they were held in the five min draining station to achieve more uniform cooling.

The conditions used for hot-gas blanching of corn-on-cob were: a loading rate of 22 kg/m^2 (4.5 lb/ft^2), a feed rate of 109 kg (240 lb)/hr, a temperature range of 99-110°C (210-230°F), a residence time of 14 min, and steam injection at a rate of 2.9 kg (6.4 lb)/min. No pH determinations were made on the corn-on-cob wastewater samples.

The results of observations recorded and analyses made on product samples collected during the long term hot-gas blanching of corn-on-cob are tabulated in Table 5.

Table 5. LONG TERM HOT-GAS BLANCHING OF CORN-ON-COB

Date	Hour of operation[a]	Temp, °C	Kernel peroxidase reduction, %
9-18-72 a.m.	0	---	--
	1	104	98
	2	104	100
	3	106	92
	4	99	100
	5	100	100
	6	102	98
	7	104	90
	8	102	97
9-18-72 p.m.	9	103	100
	10	102	100
	11	103	87
	12	104	97
	13	104	97

Table 5. (continued). LONG TERM HOT-GAS BLANCHING OF CORN-ON-COB

Date	Hour of operation[a]	Temp, °C	Kernel peroxidase reduction, %
	14	102	100
	15	104	97
	16	104	93
9-19-72 a.m.	17	104	98
	18	106	98
	19	103	99
	20	102	98
	21	107	92
	22	107	100
	23	105	100
	24	107	100
9-19-72 p.m.	25	110	100
	26	---	100
	27	---	100
	28	---	100
	29	---	100
	30	108	100
	31	106	91
	32	107	100
9-20-72 a.m.	33	104	100
	34	103	100
	35	107	100
	36	107	100
	37	105	100

[a] Total volume wastewater samples collected after 0 to 8, 8 to 16, 16 to 24, 24 to 32 and 32 to 37 hr of operation were, 26.4, 60.5, 52.9, 52.9 and 37.8 l respectively.

The wastewater volume and characteristic of samples collected during hot-gas blanching of corn-on-cob are tabulated in Table 6. The water used to cool the hot-gas blanched corn was not collected and, therefore, its contribution to wastewater volume and BOD content was unknown.

Table 6. WASTEWATER VOLUME AND CHARACTERISTICS FOR HOT-GAS BLANCHING OF CORN-ON-COB

Sampling date	Wastewater volume, l	Weight blanched, kkg	BOD, mg/l	COD, mg/l	SS, mg/l
9-18-72 a.m.	26.4[a]	0.872	13500	24900	2640
9-18-72 p.m.	60.5[a]	0.872	14200	23700	2920
9-19-72 a.m.	52.9[a]	0.872	15100	24500	2350
9-19-72 p.m.	52.9[a]	0.872	16500	26400	2680
9-20-74 a.m.	37.8[b]	0.545	14200	23000	1200

[a] Collected during eight hr of operation.
[b] Collected during five hr of operation.

The wastewater volume and characteristics for steam condensate from commercial corn-on-cob blancher are tabulated in Table 7; additional data are tabulated in Appendix F.

Table 7. WASTEWATER VOLUME AND CHARACTERISTICS FOR STEAM CONDENSATE COMPOSITE SAMPLES FROM COMMERCIAL BLANCHER FOR FROZEN CORN ON-COB

Sampling date	Average feed rate, ears[a]/min	Total weight blanched, kkg	Total volume, l	BOD, mg/l	COD, mg/l	SS, mg/l
9-18-72 a.m.	69	9.95	960	15600	21700	2000
9-18-72 p.m.	66	9.69	677	13800	20600	740
9-19-72 a.m.	66	9.56	919	13100	20100	1300
9-19-72 p.m.	76	11.0	1058	14200	22700	1880
9-20-72 a.m.	98	15.5	1150	13800	21800	3190

[a] Ave. weight of corn ear before blanching was 0.303 kg (0.667 lb).

Composite samples prepared from equal volumes of each of four grab samples taken at 2 hr intervals.

Beets

It was possible to develop hot-gas blanching conditions for beets which gave raw product which peeled satisfactorily and yielded canned product judged by cannery personnel as commercially acceptable. The results of short-term experiments on hot-gas blanching of beets are tabulated in Appendix G. Due to an unexpectedly short processing season for beets, it was possible to complete only nineteen hr of long-duration operation. The shortened operating season also limited collection of commercial blancher wastewater data by NCA personnel, in particular, the volume and composition of blancher discharge water.

The conditions used for the nineteen hr of hot-gas blanching of beets were: a loading rate of 29 kg/m^2 (6 lb/ft^2), a feed rate of 73-136 kg (160-300 lb)/hr, a 106-124°C (223-255°F) operating temperature, a 25 min residence time, and a steam injection of 1.9 kg (4.2 lb)/min. The data collected during the nineteen hr of hot-gas blanching of beets are tabulated in Table 8.

Table 8. LONG TERM HOT-GAS BLANCHING OF BEETS

Date	Hour of operation[a]	Feed rate, kg/hr	Temp, °C	Peroxidase reduction, %
10-5-72	0	0	---	---
	1	91	106	100
	2	--	122	98
	3	--	118	98
	4	--	116	100
	5	--	122	98
	6	--	124	98
	7	--	119	98
	8	136	117	96
10-6-72	9	136	116	97
	10	--	120	99
	11	136	118	98

Table 8. (Continued). LONG TERM HOT-GAS BLANCHING OF BEETS

Date	Hour of operation[a]	Feed rate, kg/hr	Temp, °C	Peroxidase reduction, %
	12	--	117	98
10-10-72	13	--	122	98
	14	73	119	98
	15	--	119	97
	16	--	123	98
10-11-72	17	91	120	98
	18	--	121	96
	19	--	116	100

[a] Total volume wastewater samples collected at 0 to 4, 4 to 8, 8 to 12, 12 to 16, and 16 to 19 hr of operation were 37.9, 18.9, 25.5, 35.2, and 35.0 l, respectively.

The wastewater volume and characteristics for hot-gas blanching of beets are tabulated in Table 9. No measurements of pH were made on wastewater samples from hot-gas blanching of beets. Additional data are tabulated in Appendix H.

Table 9. WASTEWATER VOLUME AND CHARACTERISTICS FOR HOT-GAS BLANCHING OF BEETS

Sampling date	Wastewater volume, l	Weight blanched, kkg	BOD, mg/l	COD, mg/l	SS, mg/l
10-5-72	56.8[a]	0.773	5360	8050	300
10-6-72	25.5[b]	0.544	--	--	--
10-10-72	35.2[b]	0.292	7140	10900	150
10-11-72	35.0[c]	0.271	d	d	d

[a] Eight hr of operation.
[b] Four hr of operation.
[c] Three hr of operation
[d] Sample lost.

The commercial beet blancher which was monitored was a rectangular tank 1.22 m (4 ft) by 0.71 m (2 ft 4 in.) by 9.18 m (30 ft), partially filled with approximately 7560 l (2000 gal.) of hot water. The blancher was drained weekly after five days of operation during which time 273-364 kkg (300-400 tons) of beets were blanched. The blancher was situated outdoors and it was observed that more steam was required on cold days than on hot days. The steam condensate formed the additional water which was discharged from the overflow pipe. No water was supplied to the blancher when it was in operation. The volume of overflow from the blancher receiving the smallest sized beets was measured on two days. The results of volumetric measurements and wastewater characterization of the make-up water overflow (steam condensate) of the commercial hot-water blancher for beets are tabulated in Table 10. Due to scheduling problems and the short processing season for beets, it was not possible for NCA to directly sample blancher dump water. For purposes of calculation, the values found for the eight hr composite sample of 10-5-72 (BOD=19,600 mg/l; and SS=340 mg/l) were used for the blancher dump water composition. The volume of water corresponding to eight hr of beet blanching on 10-5-72 was 21.8/(319) x 7560 or 517 l.

Table 10. WASTEWATER VOLUME AND CHARACTERISTICS FOR MAKE-UP OVERFLOW COMPOSITE SAMPLES FROM COMMERCIAL BLANCHER FOR BEETS

Sampling date	Weight blanched, kkg	Volume, l	BOD, mg/l	COD, mg/l	SS, mg/l
10-5-72	21.8	1999[a]	14000	19600	340
10-6-72	11.1	484[b]	11400	16500	230

[a] Composite sample prepared from equal volumes of each of the four grab samples.

[b] Composite sample made up of equal volumes of the 2 and 4 hr grab samples.

Spinach

A partial study of hot-gas blanching of spinach was made in March, 1972; a more detailed study was made during the 1973 canning season.

The results of short duration runs with washed spinach are tabulated in Appendix I. These runs were sufficient to prepare enough samples for quality evaluations and to receive approval of the cannery management to make long-duration runs and return hot-gas blanched spinach to commercial production.

The conditions used for the long-term hot-gas blanching of spinach were: a loading rate of 10.7 to 14.6 kg/m^2 (2.2 to 3.0 lb/ft^2), a feed rate of 113-202 kg (248-444 lb)/hr, operating temperatures of 99-118°C (210-245°F), a residence time of 108 sec and an average steam flow of 0.91 kg (2.0 lb)/min. The results of the long-duration hot-gas blanching of spinach are tabulated in Table 11.

Table 11. LONG TERM HOT-GAS BLANCHING OF WASHED SPINACH

Date	Hour of operation[a]	Feed rate, kg/hr	Temp, °C	Peroxidase reduction, %
3-28-72	0	--	--	--
	1	--	110	97
	2	--	118	97
	3	202	104	--
	4	--	106	99
	5	--	107	--
	6	--	110	99
	7	--	106	99
	8	120	113	--
3-29-72	9	--	110	99
	10	154	104	--
	11	--	99	99
	12	113	104	--
	13	--	104	99
	14	154	110	--

Table 11 (Continued). LONG TERM HOT-GAS BLANCHING OF WASHED SPINACH

Date	Hour of operation[a]	Feed rate, kg/hr	Temp, °C	Peroxidase reduction, %
	15	--	104	--
	16	173	110	--
4-12-73	17	--	104	--
	18	154	104	--
	19	--	99	99
	20	136	113	99
	21	--	110	99
	22	--	104	99
	23	132	102	99
4-13-73	24	--	107	99
	25	144	104	99
	26	--	107	99
	27	--	107	99
	28	158	104	99
	29	--	107	99
	30	132	104	99
	31	--	107	99
4-14-73	32	144	110	99
	33	158	107	99
	34	144	104	99
	35	122	107	99
	36	--	110	99
	37	144	107	99
	38	--	104	99
	39	144	102	99
	40	--	104	99
	41	156	107	99

[a] Total volume wastewater samples collected from 0 to 8, 8 to 16, 16 to 24, 24 to 32, and 32 to 40 hr of operation were 1.8, 0.74, 0.42, 0.58, and 0.51 l, respectively.

The presence of free water on the washed spinach loaded on the feed conveyor of the hot-gas blancher made direct weighings of samples of washed and blanched spinach of questionable significance in determining actual weight changes due to blanching. During the long-term runs in 1973, three samples each of raw and of hot-gas blanched spinach were taken and moisture determinations made; the results are tabulated in Table 12.

Table 12. MOISTURE CONTENT OF RAW AND HOT-GAS BLANCHED SPINACH

Sample	Moisture content,[a] %
Raw	
1	91.7
2	91.7
3	91.5
Ave.	91.6
Hot-gas blanched	
1	90.1
2	89.7
3	90.5
Ave.	90.1

[a] Calculated on a wet weight basis.

The volume and characteristics of wastewater collected from the hot-gas blancher during long term operation with washed spinach are tabulated in Table 13. Additional date collected during the 1972 season are tabulated in Appendix J.

The commercial spinach blancher monitored was a combination steam and hot-water unit. The blancher had a 1.52 m (5 ft) wide wire mesh belt which conveyed washed spinach through a steam section 3.05 m (10 ft) long and a hot-water section 12.2 m (40 ft) long and 0.914 m (3 ft) deep. The blancher had a rated capacity of 9.09 kkg (10 tons)/hr. For three 22.5 hr operating periods in 1972, the weight of spinach loaded into the blancher was 149, 174, and 164 kkg, respectively. The blancher had two continuous liquid waste discharge lines, one for steam condensate and one for water overflow. Single measurements of the flow rates of these lines in 1972 gave a volume of 227 l (60 gal.)/min for the overflow line and 113 l (30 gal.)/min for the steam condensate line. The volume of these lines were measured frequently in 1973 and the results are tabulated in Table 14.

Table 13. WASTEWATER VOLUME AND CHARACTERISTICS FOR HOT-GAS BLANCHING OF WASHED SPINACH

Sampling date	Wastewater[b] volume, l	Weight blanched, kkg	BOD, mg/l	COD, mg/l	SS, mg/l	pH
3-28-72	1.8	1.35	a	49900	3400	7.4
3-29-72	0.74	1.18	a	13200	2600	7.7
4-12-73	0.42	1.12	28600	41300	4700	7.0
4-13-73	0.58	1.14	15600	24100	1200	7.3
4-14-73	0.51	1.12	3700	5400	250	5.9

[a] BOD determinations were not made for wastewater samples collected in 1972.

[b] Total volume collected during eight hr of operation.

Table 14. STEAM CONDENSATE AND MAKE-UP WATER OVERFLOW RATES FOR COMMERCIAL SPINACH BLANCHER

Sampling dates and times		Weight blanched, kkg/hr	Steam condensate discharge rate, l/min	Water overflow discharge rate, l/min
4-9-73	1 pm	8.7	68	565
4-12-73	10 am	8.6	110	604
	12 pm	7.8	76	572
	2 pm	8.0	110	572
	4 pm	8.4	110	545
4-13-73	8 am	8.0	110	588

Table 14 (continued). STEAM CONDENSATE AND MAKE-UP WATER OVERFLOW RATES FOR COMMERCIAL SPINACH BLANCHER

Sampling dates and times		Weight blanched, kkg/hr	Steam condensate discharge rate, l/min	Water overflow discharge rate, l/min
4-16-73	1 pm	8.8	102	527
	3 pm	8.4	110	585
4-18-73	12 pm	8.2	117	545
	2 pm	7.8	76	604
	4 pm	8.6	102	545
4-19-73	10 am	8.4	102	481
	12 pm	8.2	110	572
	2 pm	8.8	114	604

The hot water in the blancher tank was drained three times each day; it had a volume of 16980 l (4480 gal.). The characteristics of the blanch water are tabulated in Table 15 along with the results from analysis of samples of steam condensate and water overflow discharge lines. Additional data collected during the 1972 season are tabulated in Appendix K.

Table 15. CHARACTERISTICS OF COMMERCIAL SPINACH BLANCHER DUMP WATER, STEAM CONDENSATE, AND MAKE-UP WATER OVERFLOW

Sampling date	Sample type	BOD, mg/l	COD, mg/l	SS, mg/l	pH
4-12-73	DW[a]	3860	4630	160	6.2
	SC-C[b]	2840	4030	170	6.0
	WO-C[c]	70	140	75	7.5
4-13-73	DW	3540	5050	190	5.8
	SC-C	3070	3740	230	5.9

Table 15 (continued). CHARACTERISTICS OF COMMERCIAL SPINACH BLANCHER DUMP WATER, STEAM CONDENSATE, AND MAKE-UP WATER OVERFLOW

Sampling date	Sample type	BOD, mg/l	COD, mg/l	SS, mg/l	pH
4-13-74	WO-C	80	140	12	7.7
4-19-73	DW	3390	4050	150	6.8
	SC-C	2740	3160	130	6.7
	WO-C	70	120	20	7.5

[a] DW Single sample of dump water

[b] SC-C Composite of equal volumes of steam condensate grab sample collected at 2,4,6 and 8 hr.

[c] WO-C Composite of equal volumes of make-up water overflow grab samples collected at 2,4,6 and 8 hr.

Green Peas

The results of short-duration hot-gas blanching runs for green peas are tabulated in Appendix L. The conditions used for the long-duration hot-gas blanching of peas were: a loading rate of 14.6 kg/m^2 (3 lb/ft^2), a feed rate of 182-490 kg (400-1080 lb)/hr. 99-132°C (210-270°F) operating temperature with an ave. steam flow rate of .94 kg (2.08 lb)/min. Due to the differences in size and maturity of peas available for hot-gas blanching, the residence time was varied between 108 and 240 sec. The variation in residence times accounts for the wide variation in feed rates. The results of 30 hr of hot-gas blanching of peas are tabulated in Table 16.

Table 16. LONG TERM HOT-GAS BLANCHING OF GREEN PEAS

Date	Hour of operation[a]	Feed rate, kg/hr	Temp, °C	Peroxidase reduction, %
5-11-73	0	--	--	--
	1	288	121	99

Table 16 (continued). LONG TERM HOT-GAS BLANCHING OF GREEN PEAS

Date	Hour of operation[a]	Feed rate, kg/hr	Temp, °C	Peroxidase reduction, %
	2	233	107	99
	3	288	107	99
	4	232	99	99
	5	259	107	99
	6	273	99	99
	7	268	99	99
	8	277	99	99
5-12-73	9	490	132	99
	10	286	116	99
	11	232	113	--
	12	182	107	99
	13	182	110	--
	14	182	107	99
	15	440	113	99
5-14-73	16	375	121	--
	17	280	101	99
	18	238	99	--
	19	263	104	--
	20	450	132	99
	21	186	107	--
	22	184	107	99
	23	273	110	--
	24	248	116	99
	25	408	113	--
	26	182	110	99
	27	477	132	99
	28	279	113	--
	29	284	110	99
	30[b]	277	107	99

[a] The total volume of waste water collected (corrected for the volume contributed by residual fluming water) at 0 to 8, 8 to 16, 16 to 24, and 24 to 29 hr of operation was 30.5, 33.1, 32.6, and 18.1 l, respectively.

b Ice supply exhausted, no sample collected.

The characteristics of wastewater collected from the steam condensate line of the hot-gas blancher during three eight-hr periods and one five-hr period are tabulated in Table 17.

Table 17. WASTEWATER VOLUME AND CHARACTERISTICS FOR HOT-GAS BLANCHING OF GREEN PEAS

Sampling date	Wastewater volume, l	Weight blanched, kkg	BOD, mg/l	COD, mg/l	SS, mg/l	pH
5-11-73	30.5	2.12	3100	4070	100	7.2
5-12-73	33.1	2.37	13800	31800	340	7.0
5-14-73 a.m.	32.6	2.12	10100	18100	440	6.0
5-14-73 p.m.	18.1	1.63	7330	14400	--	--

The commercial pea blanchers consisted of three pipes through which the peas were pumped in hot water. The rated capacity for the three pipe blanchers was 9.09 kkg (10 ton)/hr. The commercial pea blancher which was monitored was a stainless steel pipe 10 centimeters (cm) (4 in.) in diameter, approximately 34.1 m (112 ft) long, with a capacity of approximately 380 l (100 gal.). The source of make-up water for the pipe blancher was a water manifold (3 spray lines) used to rinse and partially cool peas after separation from the recirculated hot-water. The flow rate of the rinse water which returned to the pipe blancher surge tank was 9.5 l (2.5 gal.)/min based on the average of six measurements. The hot-water in the pipe blancher system was discharged about every 8 hr of operation. The results obtained on analysis of grab samples collected every 2 hr from the surge tank are tabulated in Appendix M. Characteristics of the commercial blancher's wastewater samples are summarized in Table 18.

PRODUCT EVALUATION

The results of analysis of single canned samples prepared from hot-gas or commercially-blanched material for headspace gas composition are tabulated in Table 19.

Table 18. CHARACTERISTICS OF COMMERCIAL GREEN PEA PIPE-BLANCHER DUMP WATER AND MAKE-UP WATER

Sampling date	Weight blanched, kkg	Sampling type[a]	BOD, mg/l	COD, mg/l	SS, mg/l	pH
5-8-73	20.4	DW	6920	9800	470	8.4
		WO-C	4820	7040	210	8.4
5-9-73	21.2	DW	8250	11800	410	7.1
		WO-C	5800	7040	290	8.2
5-10-73	20.1	DW	8890	13100	390	6.8
		WO-C	4650	7710	230	7.2
5-11-73	20.5	DW	4650	8170	220	7.4
		WO-C	6180	10700	210	7.0
5-12-73	20.6	DW	4060	5000	210	8.8
		WO-C	6500	10400	310	8.1
5-14-73	20.7	WO-C	7410	13600	190	8.1

[a] See footnotes a, c of Table 15.

Table 19. HEADSPACE GAS COMPOSITION OF CANNED VEGETABLE SAMPLES

Commodity (blancher)	Headspace volume, ml	Percent of			
		N_2	CO_2	Argon+O_2	H_2
Green beans					
(commercial)	119	90.3	1.1	8.6	0.0
(hot-gas)	117	86.4	5.0	5.2	3.4
Beets					
(commercial)	a	87.4	7.6	1.9	3.1
(hot-gas)	a	93.8	5.0	1.2	0.0

Table 19 (continued). HEADSPACE GAS COMPOSITION OF CANNED VEGETABLE SAMPLES

Commodity (blancher)	Headspace volume, ml	Percent of N_2	CO_2	Argon+O_2	H_2
Spinach					
(commercial)	40	88.5	4.3	5.3	1.9
(hot-gas)	146	87.6	10.7	1.7	0.0
Peas					
(commercial)	10.9	89.8	7.4	2.8	0.0
(hot-gas)	13.4	92.5	5.1	2.4	0.0

[a] Data not recorded.

The results of replicate analyses for vitamin content of raw, hot-gas blanched, and commercially blanched vegetable samples are tabulated in Appendix N.

The results of replicate analyses for mineral content of raw, hot-gas blanched, and commercially-blanched vegetable samples are tabulated in Appendix O. The average values found for nutrient content of vegetable samples are tabulated in Table 20.

Table 20. NUTRIENT CONTENT OF RAW, HOT-GAS BLANCHED, AND COMMERCIALLY BLANCHED VEGETABLES (mg/100 g wet weight)

Commodity	Nutrient	Raw	Hot-gas blanched	Commercially blanched
Green beans	Vitamin A[a]	--	0.34	0.32
	Vitamin B_1	0.08	0.06	0.07
	Vitamin B_2	0.07	0.06	0.06
	Vitamin B_6	0.03	0.03	0.05
	Vitamin C	7.3	2.2	1.3

Table 20 (Continued). NUTRIENT CONTENT OF RAW, HOT-GAS BLANCHED, AND COMMERCIALLY BLANCHED VEGETABLES (mg/100 g wet weight)

Commodity	Nutrient	Raw	Hot-gas blanched	Commercially blanched
	Niacin	0.46	0.36	0.51
	Calcium	32	31	38
	Magnesium	19	17	23
	Phosphorus	20	18	21
Corn	Vitamin B_1	0.12	0.18	0.16
	Vitamin B_2	0.04	0.04	0.04
	Vitamin B_6	0.20	0.20	0.20
	Niacin	1.9	1.9	1.9
	Phosphorus	92	90	86
Beets	Vitamin B_2[a]	--	0.03	0.05
	Vitamin C [a]	--	2.7	3.0
	Niacin[a]	--	0.06	0.09
	Phosphorus	--	110	97
Spinach	Vitamin A	2.41	4.41	4.14
	Vitamin B_2	0.15	0.13	0.10
	Vitamin C	0	12.2	7.0
	Calcium	47	66	66
	Magnesium	55	66	45
	Phosphorus	33	33	40
	Iron	2.6	3.1	2.5
Peas	Vitamin B_1	0.31	0.39	0.40
	Vitamin B_2	0.12	0.13	0.09
	Vitamin B_6	0.19	0.23	0.16
	Vitamin C	15.4	22.5	11.4
	Niacin	2.13	2.27	1.94
	Calcium	25	23	20
	Magnesium	34	36	29
	Phosphorus	89	93	79
	Iron	2.0	3.0	1.9

[a] Analysis conducted on canned samples.

The results of analyses for polynuclear hydrocarbon content of canned green bean samples are tabulated in Table 21.

Table 21. LEVELS OF POLYNUCLEAR HYDROCARBONS IN CANNED GREEN BEAN SAMPLES

Sample	Fortification level, ppb	Polynuclear hydrocarbon content, ppb
Hot-water blanched	100	87
Hot-gas	0	12
Hot-water	0	8.7
Hot-water	0	8.7
Hot-gas	0	5.6
Hot-gas	0	4.3
Hot-water	0	3.7
Hot-gas	0	2.4
Hot-water	10	6.3
Hot-water	10	7.2
Hot-gas	0	2.0

The sequence of results are tabulated in the order in which each analysis was made. The same set of glassware was used to saponify and extract each sample. See Appendix A. The downward trend in results indicated contamination of the glassware by the high-level fortified [100 parts per billion (ppb)] sample. As subsequent analyses were run, material was slowly released from adsorption on glass surfaces to give values higher than actually present. The glassware was rinsed with hot nitric acid prior to the last analysis and the result was below the sensitivity level of 2 ppb.

A maturity determination was made with canned pea samples. A large part of the score (50 of 100 maximum points) in the quality grading of canned peas is the maturity and tenderness factor. The maturity factor is derived from a flotation test of peas in sodium chloride brines of 11, 13, and 15 percent concentration. Eleven cans from the commercial line packed on 5-12-73, one can packed from all hot-gas blanched peas on 5-12-73, and 12 cans from all hot-gas blanched peas packed on

5-12-73 were measured for vacuum, headspace, net weight, total count, and no. of peas which sank in three different concentrations of brine. These tests were made on 5-16-73. The results of the examination of 24 cans of peas are tabulated in Appendix P.

The evaluation of hot-gas blanched bean samples for consumer acceptance was an important part of this project. It was possible to arrange for the evaluation, by food appraisal specialists at Oregon State University, of samples of canned, cut green beans after various periods of accelerated storage at 38°C (100°F).

The results obtained on samples one mo after canning are tabulated in Table 22.

Table 22. RESULTS OF ORGANOLEPTIC EVALUATION OF CANNED GREEN BEANS ONE MONTH AFTER CANNING

	Mean Score				
Factor evaluated	Sample A (hot-water)	Sample B (hot-water)	Sample C (hot-gas)	Sample D (hot-gas	LSD[a] (0.05)
Appearance	4.82	4.07	4.70	4.55	0.53
Texture	4.75	5.05	4.60	5.15	0.49
Flavor	4.95	4.77	4.32	4.77	0.60
Overall Desirability	4.85	4.80	4.35	4.80	0.52

[a] Least significant difference at 5 percent probability level. When the difference in mean scores of two samples exceeds the LSD the difference in scores is significant.

The results of testing samples of canned beans stored at 38°C (100°F) for periods of 3 and 6 mo are tabulated in Table 23.

Samples of frozen corn-on-cob prepared with hot-gas blanching and steam blanching (commercial) were evaluated by a 50-member panel at Oregon State University after storage for one mo. The results from this examination are tabulated in Table 24.

Table 23. RESULTS OF ORGANOLEPTIC EVALUATION OF CANNED GREEN BEANS AFTER STORAGE AT 38° FOR THREE AND SIX MONTHS

Factor evaluated	Mean Score: Sample A (hot-water) 3[b]	6[b]	Sample B (hot-water) 3[b]	6[b]	Sample C (hot-gas) 3[b]	6[b]	Sample D (hot-gas) 3[b]	6[b]	LSD[a] (0.05) 3[b]	6[b]
Appearance	6.40	6.45	5.92	5.82	6.40	6.90	7.45	7.12	.46	.43
Texture	6.22	6.25	7.02	6.82	6.77	6.37	7.00	6.72	.49	.56
Flavor	5.65	6.10	6.75	6.35	6.30	5.71	6.05	5.92	.54	.56
Overall Desirability	5.65	6.27	6.52	6.12	6.30	6.00	6.40	6.50	.49	.51

[a]See footnote a of Table 22.
[b]Storage times in mo.

Table 24. ORGANOLEPTIC PANEL EVALUATION OF FROZEN CORN-ON-COB AFTER STORAGE FOR ONE MONTH AT -18°C

Factor evaluated	Sample A (steam)	Sample B[a] (hot-gas)	Sample C (hot-gas)	Sample D (steam)	LSD (0.05)[b]
Appearance	7.18	6.40	6.50	7.08	0.55
Texture	5.80	5.26	5.80	6.12	0.53
Flavor	6.40	5.52	6.32	5.78	0.60
Overall Desirability	6.08	5.12	6.02	5.72	0.55

[a] It was noted that Sample B was a more mature, starchy corn than the other three samples and this is reflected in the lower texture and overall desirability score.
[b] See footnote a of Table 22.

A triangular set of commercially-blanched and hot-gas blanched spinach from the 1972 season was presented to a panel of sixteen persons (four replicates) after the cans had been stored for 10 weeks at room temperature. In a total of 57 judgments obtained in four sessions (using a randomized presentation of the samples), 29 were correct (significant at the p=0.01 level) matchings of two identical samples.

In a second type of evaluation, a ranking test of flavor preference using three commercially-canned samples and hot-gas blanched spinach (canned under commercial conditions) gave the results tabulated in Table 25.

Table 25. TASTE PANEL RANKING OF THREE COMMERCIAL AND ONE HOT-GAS BLANCHED SAMPLE OF CANNED SPINACH

Sample	Brine salt content, %	Taste panel ranking[a]
Commercial A	1.16	3.04
Commercial B	0.85	2.62
Commercial C	0.94	2.04
Hot-gas	0.96	2.38

[a] 1 = Best flavor; 4 = Worst flavor; 56 judgments.

In addition to the laboratory organoleptic evaluations, very substantial quantities of commercial production of green beans, corn, beets, spinach, and green peas containing material from hot-gas blanching were sold. No adverse consumer reaction was recorded,up to the time of this report about any of these production lots, which could be attributed to the blanching used.

ENERGY REQUIREMENTS

Electrical, gas and steam flow meters on the hot-gas blancher were used to develop information on power requirements. The energy consumption values obtained during hot-gas blanching of green beans, corn-on-cob, beets, spinach and peas are tabulated in Table 26.

Table 26. ENERGY CONSUMPTION DURING HOT-GAS BLANCHING OF VEGETABLES

Cumulative operational hr	Cumulative electrical energy used, kwh: blower	turbine	conveyor controls	Cumulative steam use, kkg	Cumulative gas use, m^3
Green Beans					
8.6	33	6	3	0.15	4.25
16.6	59	12	5	0.29	7.65
24.4	90	17	7	0.42	11.3
32.2	120	22	10	0.56	14.7
41.1	150	28	13	0.71	17.8
Corn					
8.5	12	4	1	1.5	7.09
16.0	29	8	2	2.7	8.21
23.3	40	13	3	4.0	11.3
32.1	57	17	4	5.5	18.5
37.0	64	21	4	6.4	20.4
Beets					
7.9	14	6	1	0.9	11.3
14.4	25	11	2	1.6	13.6
19.0	23	18	5	2.2	15.9
Spinach					
7.0	88	19	4	0.38	3.96
15.0	180	33	7	0.82	4.82
22.0	280	43	15	1.2	6.23
Peas					
8.0	40	29	2	0.46	4.53
16.0	81	58	3	0.73	8.78
24.0	120	87	4	1.2	12.8
30.0	140	110	4	1.7	16.4

SECTION VI

DISCUSSION

BLANCHING, WASTEWATER, AND PRODUCT EVALUATION

Any modification in food processing equipment must be rigorously evaluated in terms of reliability, safety, ease of sanitation, maintenance, and cost per unit of material processed. In recent years, the rate of generation of gaseous, liquid, and solid by-products as potential contributors to air, water, and soil pollution has become an important food processing equipment design criteria. The final product which results from use of modified processing equipment must be at least equivalent in wholesomeness, texture, flavor, appearance, and nutritive value to the product prepared with current equipment. During the course of this investigation of in-plant, hot-gas blanching of vegetables, all of the above outlined criteria were evaluated albeit at various degrees of completeness.

The prime motivation of this study was the attempt to demonstrate commercial feasibility of a new blanching system which would substantially reduce the volume of liquid wastes now produced during steam or hot-water blanching of vegetables. Therefore, much attention was devoted to measurement of wastewater generation from both the hot-gas blancher and the commercial blanchers. As the critical evaluation centered on reduction of waste treatment costs possible with the new blanching system, wastewater measurements were made for volume, BOD, COD, SS, and pH. Table 27 gives a summary of the comparisons of wastewater volume, BOD, COD, and SS for hot-gas and commercial blanching of five vegetables. The values tabulated in Table 27 are expressed in percentages in Table 28.

It must be emphasized that the percentage reductions shown, apply to only one location and it is well known that water usage and waste generation vary over a wide range for different plants processing the same commodity, (Holdsworth[6]). In any consideration of the commercial application of hot-gas blanching, it would be necessary to use data on wastewater generation from each individual operation to calculate expected percentage reductions.

It was not possible to evaluate completely the factors of equipment reliability, maintenance, ease of sanitation, and safety because the

Table 27. COMPARISON OF WASTEWATER VOLUME, BOD, COD, AND SS FROM HOT-GAS AND COMMERCIAL BLANCHING OF VEGETABLES

Commodity (sampling date)	Wastewater volume, 1/kkg[a]		BOD, kg/kkg[b]		COD, kg/kkg[b]		SS, kg/kkg[b]	
	hot-gas	comm[c]	hot-gas	comm[c]	hot-gas	comm[c]	hot-gas	comm[c]
Green Beans								
8-15-72	0.089	156	0.00010	1.34	0.00024	2.2	0.000013	0.28
8-16-72	0.029	108	0.00019	0.76	0.00045	1.3	0.000013	0.16
8-17-72	---	84	---	0.33	---	0.55	---	0.05
8-18-72	0.095	147	0.00034	0.42	0.00069	0.78	0.000017	0.07
8-19-72	0.035	124	0.00024	0.58	0.00061	0.96	0.000019	0.10
Ave.	0.062	124	0.00022	0.69	0.00050	1.2	0.000016	0.13
Corn-on-cob								
9-18-72 a.m.	30	97	0.41	1.5	0.75	2.1	0.079	0.19
9-18-72 p.m.	69	70	0.98	0.97	1.6	1.4	0.20	0.052
9-19-72 a.m.	61	96	0.92	1.3	1.5	1.9	0.14	0.13
9-19-72 p.m.	61	96	0.98	1.4	1.6	2.2	0.163	0.18
9-20-72 a.m.	69	74	1.0	1.0	1.7	1.6	0.083	0.24
Ave.	58	87	0.86	1.2	1.4	1.8	0.13	0.16
Beets								
10-5-72	74	115	0.40	1.6	0.60	2.3	0.022	0.039
10-6-72	47	67	---	0.77	---	1.1	---	0.015
10-10-72	121	--	0.86	---	0.88	--	0.012	---

Table 27 (continued). COMPARISON OF WASTEWATER VOLUME, BOD, COD, AND SS FROM HOT-GAS AND COMMERCIAL BLANCHING OF VEGETABLES

Commodity (sampling date)	Wastewater volume, l/kkg[a]		BOD, kg/kkg[b]		COD, kg/kkg[b]		SS, kg/kkg[b]	
	hot-gas	comm[c]	hot-gas	comm[c]	hot-gas	comm[c]	hot-gas	comm[c]
10-11-72	129	--	---	---	---	---	---	---
Ave.	93	91	0.63	1.2	0.74	1.7	0.017	0.027
Spinach								
3-28-72	1.3	2900	---	--	0.065	--	0.0044	---
3-29-72	0.63	3100	---	--	0.0083	--	0.0016	---
4-12-73	0.38	5200	0.011	3.4	0.016	4.8	0.0018	0.48
4-13-73	0.51	5500	0.0079	3.8	0.012	5.0	0.00061	0.29
4-14-73	0.46	---	0.0017	--	0.0025	--	0.00011	---
4-19-73	---	4900	---	3.2	---	3.9	---	0.22
Ave.	0.66	4300	0.0069	3.5	0.021	4.6	0.0017	0.33
Green Peas								
5-8-73	---	240	---	1.2	---	1.8	---	0.056
5-9-73	---	230	---	1.4	---	1.7	---	0.070
5-10-73	---	250	---	1.2	---	2.0	---	0.059
5-11-73	14	240	0.043	1.5	0.057	2.5	0.0014	0.051
5-12-73	14	240	0.19	1.5	0.45	2.4	0.0048	0.073
5-14-73 a.m.	15	--	0.15	1.6	0.27	3.0	0.0066	---
5-14-73 p.m.	11	--	0.081	--	0.16	--	---	---
Ave.	14	240	0.12	1.4	0.23	2.2	0.0043	0.062

[a] Dividing by 4.17 will convert l/kkg to gal./ton.
[b] Dividing by 0.5 will convert kg/kkg to lb/ton.
[c] Values for commercial blanchers included water overflow, steam condensate, and dump water.
See Appendix Q for example of calculation.

Table 28. PERCENTAGE REDUCTION OF WASTEWATER VOLUME, BOD, COD, AND SS DUE TO HOT-GAS BLANCHING OF VEGETABLES

	Percentage reduction			
Commodity	Wastewater volume	BOD	COD	SS
Green beans	99.9	99.9	99.9	99.9
Corn	33.3	28.3	22.2	18.7
Beets	(2.2)[a]	47.5	56.5	37.0
Spinach	99.9	99.8	99.2	99.5
Green peas	94.2	91.4	90.0	93.0

[a] Value in parenthesis is percentage increase.

hot-gas blancher used was an experimental design possibly quite different from any future commercial unit.

The experimental hot-gas blancher was operated safely during a total of approximately 300 hr of in-plant work. The natural gas furnace had elaborate safety controls and the accumulation of gas, which would represent the major hazard, was highly improbable. The combustion of the natural gas was complete so the formation of carbon monoxide in toxic amounts was highly unlikely.

There was no overt evidence of difficulty in sanitizing the hot-gas blancher. The blancher was operated at a temperature above those tolerant to the growth of microorganisms. There was some sticking to the conveyor belt surface of small pieces of vegetables or their parts (beet-hair roots, beet stems, corn silk, etc.). These sticking pieces tended to stay on the belt and gradually dry out and caramelize as the belt recycled through the heated zone. The sticking pieces did not fall off the belt to contaminate freshly blanched vegetables. There was no difficulty experienced in cleaning the wire mesh conveyor belt with small volumes of water after several hr of continuous operation. The hot-gas blancher did not present any unusual maintenance problems during the period of operation.

The quality of final products from hot-gas blanched vegetables was a major concern in this study. The quality evaluation of products from hot-gas blanching was made at three stages. The first stage was subjective examination of freshly blanched material by experienced industry persons. A combination of appearance, feel, taste, and color change was used to decide if a sample was adequately blanched. After passing this first screening test, blanched samples were preserved, by use of commercial equipment, as canned or frozen final products. The preserved samples were given a complete quality control examination using objective tests and were also evaluated subjectively for color, flavor, and texture differences by a group of technical and management persons employed by the cannery. This evaluation was the basis for approval to conduct long term runs with hot-gas material returning to the production line. The third stage of evaluation was controlled laboratory organoleptic panel comparison of samples and/or the sale of products through ordinary commercial channels. This latter form of evaluation was the only possible method for spinach, beets, and peas where hot-gas blanched material was mixed with commercially blanched material. For frozen corn-on-cob and canned green beans, the hot-gas blanched portion was kept separate and identified.

The very fact that every commodity studied was accepted for return to production after hot-gas blanching demonstrated the utility of this method with a considerable degree of confidence. The sale of beets, spinach, and peas containing mixtures of hot-gas blanched and commercially blanched material has resulted in no adverse consumer response.

The organoleptic evaluation of green beans made by Oregon State University, and tabulated in Table 23, indicates that there is no significant difference in overall desirability between hot-gas and hot-water blanched samples. Similar evaluation of frozen corn-on-cob (Table 24) was complicated by maturity difference in the samples. The significantly lower preference for hot-gas blanched corn-on-cob due to difference in appearance may be a deterrent to use of hot-gas blanching of this commodity.

The results of the taste panel ranking of canned spinach samples (Table 25) demonstrated no significant preferences among three commercial and one hot-gas blanched samples. However, a triangle test in differences in canned spinach samples from the 1972 season did demonstrate a significant flavor difference between hot-water blanched and hot-gas blanched spinach.

One of the expectations for hot-gas blanching, when it was first considered, was improved retention of water soluble vitamins and minerals due to reduced water leaching of soluble components. The production of a more nutritious food with hot-gas blanching would justify part of the expense of shifting to this new method. For this reason, and due to the need for information on nutrient retention, considerable effort has been devoted to measuring vitamin and mineral content as a function of the type of blanching used.

The results of nutrient retention measurements were tested for significance in those cases where results were available for three or more commodities. The results of nutrient analysis of thiamin (Vitamin B_1), riboflavin, (Vitamin B_2), ascorbic acid (Vitamin C), Vitamin B_6, niacin, phosphorus, calcium, and magnesium were subject to randomized complete-block tests using the commodities as blocks and the blanching conditions as treatments. None of the computations produced F-values larger than the tabulated F-values for the appropriate degrees of freedom of the variance ratios. The over-all data available to date, with the exception of ascorbic acid retention in canned spinach (see Appendix N), strongly suggests that there is no significant difference in vitamin and mineral retention when hot-gas blanching is compared to steam or hot-water blanching. The higher level of retention of ascorbic acid in canned spinach from hot-gas blanching is significant and is supported by a higher level in blanched samples compared to raw and hot-water blanched samples.

An observation made by technicians at Oregon State University, who were preparing taste-panel samples of canned green beans held at 38°C (100°F) for three mo, has led to a more detailed study of the extent of internal can corrosion by Agripac, Inc. and their container supply company. Sets of ten No. 10 cans each of hot-water and hot-gas blanched green beans were opened at 12°C (54°F) after five mo of warehouse storage. The extent of corrosion was rated from visual inspection by experienced persons from a container supply company on a scale of 1 = no corrosion and 10 = detined completely. The set of hot-water blanched bean cans showed an average corrosion number of 4.5 compared to a corrosion number of 2.3 for cans used for hot-gas blanched beans.

If the extent of corrosion continues to be lower in hot-gas blanched green bean cans, a considerable saving in container costs could help to justify commercial use of hot-gas blanching.

Examination of cans used to store hot-gas and hot-water blanched green beans for six mo at 38°C (100°F) was made by Oregon State University with the following results:

> "When examined immediately after opening, there appeared to be very little difference in the black film on the insides of the cans. Some people thought that the hot-gas cans were not quite so black, but the difference was so small as to be questionable. Close examination of the surface of the cans showed that the control cans appeared to be quite extensively detined. After setting in the laboratory for a few days, the control cans showed quite extensive internal rusting, and the hot-gas cans only a small amount of rusting, indicating that there was more detinning on on the controls than in the hot-gas cans." (Beavers[15])

COMPARISON OF COSTS OF BLANCHING SYSTEMS

In any consideration of new processing technology, the cost of operation per unit of production is one of the most important factors in decision-making. It was possible to get exact operating costs for the experimental hot-gas blancher by metering power and steam use.

Table 29 tabulates the dollar cost per kkg (2200 lb) of vegetable blanched for hot-gas, steam, and hot-water blanching of five vegetables. Examples of detailed calculations are tabulated in Appendices Q, R, and S.

Table 29. ESTIMATED COST OF BLANCHING VEGETABLES ($/kkg blanched)

	Blanching System		
Commodity	Hot-gas	Steam	Hot-water
Green Beans			
Fixed costs	2.19	--	1.41
Operating cost	0.75	--	0.99
Total cost	2.94	--	2.40
Corn-on-cob			
Fixed cost	11.70	1.11	--
Operating cost	5.20	1.40	--
Total cost	16.90	2.51	--
Beets			
Fixed cost	13.28	--	1.24
Operating cost	5.90	--	1.01
Total cost	19.18	--	2.26
Spinach			
Fixed cost	8.26	--	1.68
Operating cost	2.30	--	1.21
Total cost	10.56	--	2.89
Green Peas			
Fixed cost	4.35	--	0.88
Operating cost =	1.83	--	1.51
Total cost	6.18	--	2.39

This estimate for steam and hot-water blanching was made using published steam requirements for blanchers (Lopez[16]), cost of operation of conveyor-drive motors, cost of make-up water, and estimates of wastewater disposal costs.

The estimates of first cost for commercial scale blanchers was obtained from commercial suppliers or potential suppliers. The first-cost of hot-gas blanchers was based on cost of modules which could be arranged in series to provide blanching conditions for each commodity. The required number of modules was computed from feed rates observed during experimental hot-gas blanching. Table 30 summarizes the basis of computing first-cost of hot-gas blanchers for various commodities.

Table 30. BASIS FOR ESTIMATING FIRST COST OF COMMERCIAL SCALE HOT-GAS BLANCHERS

Commodity	Average feed rate[a], kkg/hr	Scale-up factor[b]	Relative scale-up factor	No. of modules[c]	First cost, $
Green beans	0.720	7	1	2	50,000
Corn-on-cob	0.109	46	6	12	255,000
Beets	0.105	48	7	14	285,000
Spinach	0.158	31	4	8	185,000
Green peas	0.336	15	2	4	100,000

[a] For experimental data, see Tables for long term blanching of each commodity.

[b] See Experimental Plan (Economics) for basis of calculating scale-up factors.

[c] Estimated cost/module: 1 to 5 @ $25,000/each; 5 - 10 @ $20,000/each; 10 - 20 @ $15,000/each.

Only in the case of green bean blanching is the operation cost of hot-gas blanching competitive with commercial blanching costs. The high operational costs for corn-on-cob and beet blanching are due to the light loading, long residence time, and high steam-injection requirements. The operational cost for hot-gas blanching of spinach is a factor of two higher than hot-water blanching and the increased cost could only be justified by offsetting savings in waste disposal costs. It is expected that some reduction of cost for hot-gas blanching would result from increased efficiency of a commercial-scale unit compared to the experimental unit.

The most significantly different cost factor in comparing hot-gas blanching with steam and hot-water blanching is in waste management Hot-gas blanching may be more attractive economically in the next few years as waste treatment costs increase as the national goal of zero discharge of pollutants by 1985 is approached. The very small volume of liquid effluent produced during the hot-gas blanching makes it an excellent choice as part of closed-loop technology if this is proven possible.

The cost of treatment will increase as the percent removal of BOD and SS increases. For those processors discharging into municipal treatment systems, an increase in treatment level will increase the surcharges paid by the industrial discharger. It is likely that waste management costs will increase substantially; this will make hot-gas blanching economically more competitive with steam or hot-water blanching for additional vegetable commodities.

There has been much publicity recently about the "energy crisis". There seems to be little doubt that fossil fuel energy sources will be in short supply for the period of 1974 to 1980. The reasons for the potential shortage of such fossil fuels as natural gas are the high-rate growth of energy consumption (4 percent per year) and reduction in the U.S. reserves-to-production ratio. The reasons for the latter fact are complex, but deliverable supplies of natural gas are shrinking and in a number of areas potential customers have been unable to obtain supply commitments.

The predicted shortage of natural gas may cause potential users of hot-gas blanching to postpone use of this new blanching system. Fortunately, the hot-gas blancher operates with liquified propane as a fuel. Under the allocation program in effect since May, 1974, food processing is one of the categories listed as "priority customers" (some others are residential uses, agricultural production and mass transit vehicles). Therefore, it is highly likely that vegetable processors using hot-gas blanching could get adequate supplies of propane. For the longer term future, use of liquified natural gas and new sources such as the Siberian production area and gasification of coal should provide ample supplies up to the end of this century.

DEHYDRATION DURING HOT-GAS BLANCHING

A major reduction in operational cost would result if dehydration of the hot-gas blanched material were accepted, as this would lower steam cost. It is likely that partially dehydrated beets would recover their water content after canning. Partially dehydrated corn-on-cob may recover water during spray cooling. Neither of these possibilities have been examined as yet. If it were possible to accept partial dehydration of vegetables during hot-gas blanching, both operational costs and cost of wastewater treatment would be substantially reduced.

The 1.5 percent difference in moisture content between raw and hot-gas blanched spinach represents an 18 percent increase in solids content or approximately 2 percent actual weight loss due to the dehydrating effect of hot-gas blanching. This level of dehydration would be of concern to a freezer of spinach, but for canned spinach a 2 percent reduction in fill weight would provide the proper fill of container for processing and standard of identity specifications. It is expected that spray cooling of hot-gas blanched spinach prior to preservation by freezing would accomplish a partial rehydration and lead to reasonable weight recovery.

The data shown in Appendix P confirm the observations made about weight loss and cooling of hot-gas peas as they were conveyed approximately 34 m (110 ft) from the blancher to the filler. The lower vacuum found is due to a lower temperature of can contents at the time of closing of the cans. There is no significant difference in headspace. The net weight of hot-gas blanched peas was 5.6 g [0.2 ounces (oz)] higher due to filling of more peas having a higher average solids content. The count of peas from hot-gas blanched samples was 2.8 percent higher than the hot-water (commercial) blanched samples. The observed count difference indicates about a 3 percent weight loss due to hot-gas blanching of peas. The short duration runs TLFP-5 and TLFP-15 (see Appendix L) were made under conditions similar to the long duration runs and 14-15 percent weight losses were recorded. The weighing of partially dewatered peas and losses in collecting blanched peas from the conveyor belt made these values uncertain.

The higher no. of peas sinking in each of the three different salt solutions from hot-gas blanched peas indicates that rehydration was not complete even after 9 days of storage. Peas were quality graded within a few hr of retorting and the data clearly confirm the cannery quality control records showing lower grading of samples containing hot-gas blanched peas. If hot-gas blanching of peas ever becomes a common commercial practice, it will be necessary to amend the maturity test ranges in the USDA Standards of Quality regulations to more accurately reflect the storage equilibrium conditions rather than apparent maturity immediately after retorting.

Hot-gas blanching of peas for frozen preparation would require a water application during cooling. The peas could recover most of the 3 percent dehydration loss.

OVERALL CONSIDERATIONS

The experiences with in-plant hot-gas blanching of vegetables has demonstrated that this new system is technologically feasible for certain vegetables (such as cut green beans, peas, and spinach). The hot-gas blanching of larger piece size vegetables (such as corn-on-cob and beets) is not feasible due to the long residence times necessary for achieving requisite blanching temperature in the center of the vegetable. The reduction in wastewater generation during hot-gas blanching of corn-on-cob and beets is not large enough to justify the high estimated capital costs of commercial scale blanchers. The use of hot-gas blanching looks most promising for canned or frozen cut green beans. Although not demonstrated as yet, the use of hot-gas blanching of vegetables (such as diced carrots) destined for preservation in a dehydrated state appears to have considerable promise. It is likely that hot-gas blanching will first be used on a commercial scale in unique situations. The factors which will promote commercial use of hot-gas blanching are: (1) shortage of potable water, (2) good supply of natural gas or propane, (3) high costs of liquid waste disposal and, (4) a commodity which regains dehydration losses readily.

For the long term future, as food processing operations move toward total in-plant recycle of reconditioned water, the use of hot-gas blanching will increase due to its potential for adequate blanching with minimum generation of liquid waste.

SECTION VII

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SECTION VIII

GLOSSARY

Acceptance - (1) An experience or feature of experience, characterized by a positive (approach in a pleasant) attitude. (2) Actual utilization (purchase, eating). May be measured by preferences or liking for specific food item.

Analysis of Variance - A method of determining the significance of differences in a group of averages of experimental observations by partitioning of the total sum of squares and degrees of freedom, and estimation of the standard deviation of the population by two or more methods and a comparison of these estimates.

Appearance - The visual properties of a food, including size, shape, color and conformation.

BOD - Abbreviation for biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

COD - Abbreviation for chemical oxygen demand. A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater.

Blanching - Heating a food to a temperature high enough to inactivate enzymes present and to remove undesirable occluded gases and contaminants.

Coding - Assignment of symbols, usually letters and/or numbers, to test samples so that they may be presented to a subject without identification.

Consumer - An individual who obtains or uses a commodity.

Enzyme - A catalyst produced by living cells which is protein in nature.

Flavor - An attribute of foods, beverages, and seasonings resulting from stimulation of the sense ends that are grouped together at the entrance of the alimentary and respiratory tracts -- especially odor and taste.

Make-up water - Water added to circulating water in a system to replace water lost by evaporation, leakage, or blowdown.

Panel - A group of people (observers, subjects, judges) comprising a test population which has been especially selected or designated in some manner.

Peroxidase - A class of enzymes which catalyze the reaction of molecular oxygen with a substrate to produce a peroxide link in the altered molecule.

Protein - Any of the complex nitrogeneous compounds formed in living organisms which consist of amino acids bound together by peptide linkages.

Quality - The composite of the characteristics that differentiate among individual units of the product and have significance in determining the degree of acceptability of the unit by the user.

Ranking - A procedure of arranging food products in order according to some criterion and assigning consecutive integers (ranks) corresponding to the order.

Sample - A specimen or aliquot presented for inspection.

Score - A value assigned to a specific response made to a test item.

Suspended Solids (SS) - Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids.

Taste - One of the senses usually limited to four qualities: saline, sweet, sour, and bitter.

SECTION IX

APPENDICES

APPENDIX A

PROCEDURE FOR DETERMINATION OF POLYNUCLEAR HYDROCARBONS IN CANNED GREEN BEANS

Introduction

The following procedure for extraction and determination of polycyclic aromatic hydrocarbons was adapted from the publications of J. W. Howard et. al. (17, 18) of the Division of Food Chemistry, Federal Food and Drug Administration, Washington, D. C. Using an alcoholic potassium hydroxide solution, the vegetable sample was digested by refluxing for 2.5 hr. The hydrocarbons were extracted into iso-octane, loaded onto a Florisil column, and eluted with benzene. The eluate was concentrated and chromatographed using reverse phase partition thin-layer chromatography. The hydrocarbons were then extracted from the plate absorbent, and the fluorescence measured quantitatively.

Extraction

To a one l round-botomed flask were added 200 g of homogenized sample, 400 ml of 95 percent ethanol, 50 g of KOH pellets, and boiling chips. The flask was fitted with a condenser in the reflux position, and the digestion was allowed to continue for 2.5 hr, refluxing at a rapid rate.

At the end of the digestion, the contents of the flask were filtered, while still hot, through glass wool into a one l separatory funnel. The flask was then rinsed with two 50 ml portions of warm, distilled water (about 120°F), followed by two 50 ml portions of 95 percent ethanol, and finally with 50 ml of iso-octane. Each washing was poured through the glass wool into the separatory funnel.

The funnel was shaken for three min, the layers allowed to separate, and the lower aqueous layer drawn off into a second sepatatory funnel. This aqueous layer was then extracted a second time with 100 ml of iso-octane, and the aqueous layer drawn off as before into a third separatory funnel. Following a third extraction with 100 ml of iso-octane, the aqueous layer was discarded.

Each of the three iso-octane extracts was then washed with four 100 ml portions of warm, distilled water by pouring through the water, followed by gentle swirling action. The aqueous layer was drawn off and discarded after each washing.

Column Chromatography

A chromatographic column was prepared by packing with a 60 g of Florisil which had been washed three times with methanol and activated for 16 hr in an oven at 100°C. The column should also contain about 50 g of anhydrous sodium sulfate packed above the Florisil, and the entire column should be prewetted with about 100 ml of iso-octane. The iso-octane was passed in the first separatory funnel through the column and the eluate was collected in a 500 ml beaker. The first separatory funnel was then rinsed with the contents of the second separatory funnel, and the iso-octane poured into the column. The first and second separatory funnels were then rinsed consecutively with the third iso-octane extract, and then poured into the column. All of the eluate was collected in the same beaker. The drip rate for the column should be about 20-25 drops/min.

The three separatory funnels were then washed consecutively with 50 ml of benzene, which was then poured into the column and the eluate was collected in a separate beaker. The column was then eluted with three 100 ml portions of benzene.

Both the iso-octane and benzene eluate were evaporated down to a volume of 2-3 ml using warm air steam to increase the evaporation rate. These solutions should not be allowed to evaporate to dryness as this results in significant losses of hydrocarbons.

Thin Layer Chromatography (TLC)

Prepare five 20 x 20 cm TLC plates as follows: Homogenize 20 g cellulose and about 100 ml water in a Waring Blender at high speed for about three minutes. Using Kensco applicator, apply to plates (500 u thickness) and allow to air-dry completely. Before use, plates should be washed in a TLC tank with iso-octane and stored in a desiccator.

Two TLC tanks should be prepared and allowed to equilibrate for about one hr before use, one with iso-octane (mobile phase solvent), and another with 20 percent dimethyl formamide (DMF) in ethyl ether (immobile phase solvent).

The two concentrated extracts were now applied to the cellulose plate in a streak (about 0. 5 cm x 10 cm) about 1. 5 cm from the bottom of the plate. Both extracts were applied to the same streak, and the beakers rinsed with three small portions of benzene, which were also applied to the same streak. A standard solution of pyrene and fluoranthene in iso-octane was also applied in a streak adjacent to the extract.

The plate was inverted and placed in immobile solvent tank, allowing solvent to wet to within 0. 5 cm of applied streaks. The plate was removed from tank and excess solvent was allowed to drain from plate (about 15-20 sec). Then plate was re-inverted and placed in iso-octane tank and allowed to develop in dark until solvent reached top of plate (about 1 hr).

When development was complete, plate was removed from tank and viewed under short-wave UV light, outlining pyrene-fluoranthene band. It was scraped and collected in a small Erlenmyer flask. Hydrocarbons were extracted with three 5-10 ml portions of hot methanol, and filtered through Whatman No. 1 filter paper into a small beaker. Methanol was evaporated down to less than 10 ml and transferred to a 10 ml volumetric flask. Beaker was rinsed with methanol and flask made up to 10 ml.

Quantitative Analysis

Fluorescence of the extract was measured in a fluorometer at the 10-times sensitivity setting using a 7-60 primary and 2A-12 secondary filter. This filter combination was experimentally found to yield the most satisfactory results with pyrene and fluoranthese. A methanol blank should always be run. The standard solution used contained 1 ug/ml each of fluoranthene and anthracene in iso-octane, giving a 2 ug hydrocarbon/ml solution. An equal ratio of pyrene to fluoranthene was used arbitrarily as they ratio in the green bean samples could not be determined. Pyrene and fluoranthese being isomers, they cannot be readily separated by thin-layer chromatography. One ml of this standard solution was diluted to 10 ml and used as the fluorometer standard.

APPENDIX B

SHORT DURATION HOT-GAS BLANCHING OF CUT GREEN BEANS

Run no.	Kg/flight / total feed wt, kg	Product wt/kg	Temp, °C	Residence time, sec	Peroxidase reduction, %	Steam meter, %
GB 1	0.9 / 5.0	4.1	121	183	66	0[a]
GB 2	0.9 / 5.3	4.1	121	183	80	25[a]
GB 3	0.9 / 5.3	2.7	121	330	96	50[a]
GB 4	0.9 / 5.5	4.9	114-119	144	100	(70 psig)[b]
GB 5	0.9 / 8.8	9.3	110-117	82	96	(70 psig)[b]
GB 6	0.9 / 9.5	9.5	116-118	82	98	(70 psig)[b]
GB 7	0.9 / 8.6	8.5	113-121	82	99	(70 psig)[b]
GB 8	0.9 / 5.9	5.7	113-121	92	96	(70 psig)[b]

APPENDIX B (continued).

SHORT DURATION HOT-GAS BLANCHING OF CUT GREEN BEANS

Run no.	Kg/flight / total feed wt, kg	Product wt/kg	Temp °C	Residence time, sec	Peroxidase reduction, %	Steam meter, %
GB 9	0.9 / 9.6	9.4	103-107	82	98	(85 psig)[b]
GB 10	0.45 / 8.5	8.4	110-116	73	99	(80 psig)[b]
GB 11	0.9 / 8.9	8.6	110-118	73	98	(80 psig)[b]
GB 12	1.4 / 9.0	8.9	110-116	73	98	(80 psig)[b]
GB 13	1.8 / 9.5	9.5	110-116	73	96	(80 psig)[b]
GB 14	1.8 / 12.3	11.3	107-113	73	97	(60 psig)[b]
GB 15	1.8 / 9.1	9.0	116-118	73	96	(50 psig)[b]
GB 16	1.8 / 10.2	10.0	113-116	73	99	(70 psig)[b]
GB 17	1.8 / 9.3	9.2	110-116	73	98	(40 psig)[b]
GB 18	1.4 / 10.5	10.5	110-116	73	99	(40 psig)[b]

APPENDIX B (continued).

SHORT DURATION HOT-GAS BLANCHING OF CUT GREEN BEANS

Run no.	Kg/flight / total feed wt/kg	Product wt/kg	Temp, °C	Residence time, sec	Peroxidase reduction, %	Steam meter, %
GB 19	1.8 / 10.5	10.5	107	73	98	(40 psig)[b]
GB 20	1.8 / 10.3	10.4	110	77	95	(40 psig)[b]
GB 21	1.8 / 9.7	10.2	110	77	--	(40 psig)[b]
GB 22	1.8 / 10.5	10.4	104-110	77	80	(40 psig)[b]
GB 23	1.8 / 9.9	10.7	116-121	77	87	(40 psig)[b]
GB 24	1.8 / 8.3	8.4	116-127	77	86	(40 psig)[b]
GB 25	2.8 / 9.7	10.2	104-107	77	87	(30 psig)[b]
GB 26	2.8 / 10.2	10.1	104-107	77	--	(30 psig)[b]
GB 27	2.8 / 9.9	10.0	104-107	77	63	(20 psig)[b]
GB 28	2.8 / 9.1	9.6	107	77	0	(10 psig)[b]

APPENDIX B (continued).

SHORT DURATION HOT-GAS BLANCHING OF CUT GREEN BEANS

Run no.	Kg/flight / total feed wt/kg	Product wt/kg	Temp, °C	Residence time, s c	Peroxidase reduction, %	Steam meter, %
GB 29	1.8 / 10.0	11.1	107-110	77	61	(20 psig)[b]
GB 30	1.8 / 9.1	9.3	107-110	77	--	(20 psig)[b]
GB 31	1.8 / 9.0	9.3	107	77	--	(10 psig)[b]
GB 32	2.1 / 9.1	9.5	110	77	0	4[c]
GB 33	2.1 / 9.5	9.6	121	77	9	4[c]
GB 34	2.1 / 9.3	9.5	110	77	19	4[c]
GB 35	1.4 / 10.3	10.0	106-107	77	59	4[c]
GB 36	1.4 / 10.0	10.1	93-94	77	21	4[c]
GB 37	1.4 / 10.5	10.6	80-82	77	0	4[c]
GB 38	1.4 / 8.4	8.5	74-77	77	0	4[c]

APPENDIX B (continued).

SHORT DURATION HOT-GAS BLANCHING OF CUT GREEN BEANS

Run no.	Kg/flight total feed wt/kg	Product wt, kg	Temp °C	Residence time, sec	Peroxidase reduction, %	Steam meter, %
GB 39	1.6 / 11.7	12.0	85	77	22	3[c]
GB 40	1.5 / 12.0	12.1	90-91	77	--	3[c]
GB 41	1.4 / 13.2	13.0	83-91	77	34	3[c]
GB 42	1.4 / 12.5	12.9	84-88	77	0	3[c]
GB 43	1.4 / 12.0	12.2	85-88	77	7	3[c]
GB 44	1.4 / 12.6	12.7	87-91	77	12	3[c]

a Steam flow meter rated at 0.95 kg (2.1 lb)/min at 100 percent of scale.

b Steam pressure gauge reading made during temporary closing of inlet steam valve.

c Steam flow meter rated at 9.5 kg (21 lb)/min at 100 percent of scale.

APPENDIX C

PREPARATION CONDITIONS AND QUALITY EVALUATION OF CANNED SAMPLES OF HOT-GAS BLANCHED GREEN BEANS

Run no.	Can size	Brine temp, °C	Exhaust box temp, °C	Headspace vacuum, cm, Hg	Quality evaluation
GB 18	303[a]	88	85	17.8	Excessive sloughing
GB 26	303	82	80	15.3	Excessive sloughing
GB 29	303	88	--	12.7	Moderate sloughing
GB 30	303	88	--	12.7	Moderate sloughing
GB 31	303	86	--	15.3	Moderate sloughing
GB 34	303	85	--	12.7	Good flavor, little sloughing
GB 36	303	82	74	12.7	No sloughing
GB 39	10[b]	77	74	12.7	Too long hold before retorting
GB 40	10	60	74	10.2	Good flavor but under-blanched

APPENDIX C (continued)

PREPARATION CONDITIONS AND QUALITY EVALUATION OF CANNED SAMPLES OF HOT-GAS BLANCHED GREEN BEANS

Run no.	Can size	Brine temp, °C	Exhaust box temp, °C	Headspace vacuum, cm, Hg	Quality evaluation
GB 41	10	88	74	12.7	Overblanched, soft texture
GB 42	10	88	74	17.8	Good flavor, no sloughing
GB 43	10	85	71	12.7	Good flavor, no sloughing
GB 44	10	88	74	15.3	Good flavor, no sloughing

[a] Can 8.09 cm in diameter and 11.02 cm high (3 3/16 x 4 3/8 in.).
[b] Can 15.71 cm in diameter and 17.76 cm high (6 3/16 x 7 in.).

APPENDIX D

WASTEWATER VOLUME AND CHARACTERISTICS FOR MAKE-UP WATER OVERFLOW GRAB SAMPLES FROM COMMERCIAL BLANCHER FOR CUT GREEN BEANS

Sampling date (operating time)	Volume, l	BOD, mg/l	COD, mg/l	SS, mg/l	pH
8-15-72					
(0-2 hr)	458	6790	11600	1490	5.9

APPENDIX D (continued)

WASTEWATER VOLUME AND CHARACTERISTICS FOR MAKE-UP WATER OVERFLOW GRAB SAMPLES FROM COMMERCIAL BLANCHER FOR CUT GREEN BEANS

Sampling date (operating time)	Volume, l	BOD, mg/l	COD, mg/l	SS, mg/l	pH
(2-4 hr)	227	7760	15500	1560	5.6
(4-6 hr)	133	7610	15500	1820	5.0
(6-8 hr)	64	10500	13400	1870	5.3
8-16-72					
(0-2 hr)	133	7500	13000	1640	5.1
(2-4 hr)	72	7820	13300	1680	5.4
(4-6 hr)	57	7660	13100	1840	5.2
(6-8 hr)	144	4940	8320	910	5.4
8-17-72					
(0-2 hr)	91	1820	3120	140	6.4
(2-4 hr)	104	2610	4780	550	6.5
(4-6 hr)	76	2040	3720	870	6.2
(6-8 hr)	68	6630	11000	610	6.1
8-18-72					
(0-2 hr)	91	2390	4470	390	6.2
(2-4 hr)	64	4530	8380	670	6.0
(4-6 hr)	68	1300	2500	210	6.2
(6-8 hr)	80	---	----	--	--
8-19-72					
(0-2 hr)	83	4430	7390	650	6.0
(2-4 hr)	64	4020	6780	800	6.1
(4-6 hr)	49	4790	8080	1020	5.9
(6-8 hr)	76	4300	7000	820	6.1

APPENDIX E

SHORT DURATION HOT-GAS BLANCHING OF CORN-ON-COB

Run no.	Kg/flight total feed wt/kg	Product wt, kg	Temp, °C	Residence time, min	Peroxidase reduction, %	Steam meter, %
COC-1	2.1 / 8.9	8.8	129	8	--	3[a]
COC-2	2.1 / 9.5	9.3	138	8	53	3
COC-3	2.1 / 9.2	9.0	154	10	--	5
COC-4	2.1 / 9.0	8.5	121	19	--	10
COC-5	2.1 / 9.4	9.0	113	19	100	10
COC-6	2.1 / 9.8	8.9	99	37	96	4
COC-7	2.1 / 9.6	9.4	104	13	90	10
COC-8	2.1 / 9.2	9.3	97	13	96	10
COC-9	2.1 / 9.0	8.9	99	16.5	92	8
COC-10	2.1 / 9.2	9.1	107	16.5	100	10

APPENDIX E (continued)

SHORT DURATION HOT-GAS BLANCHING OF CORN-ON-COB

Run no.	Kg/flight / total feed wt, kg	Product wt, kg	Temp, °C	Residence time, min	Peroxidase reduction, %	Steam meter, %
COC-11	2.1 / 9.2	9.0	102	16.5	83	13
COC-12	2.1 / 10.0	9.6	104	16.5	95	10
COC-13	2.1 / 9.7	9.3	104	16.5	95	10
COC-14	2.1 / 9.8	9.5	107	15	97	15
COC-15	2.1 / 10.0	9.9	107	15	96[b]	25
COC-16	2.1 / 9.8	9.5	110	17	[b]	23
COC-17	2.1 / 8.1	9.5[c]	102	12.8	92[b]	30
COC-18	2.1 / 9.0	9.3[c]	102	10	82[b]	30
COC-19	2.1 / 9.1	9.7[c]	102	11.3	95[b]	30
COC-20	2.1 / 9.5	10.0[c]	102	12.5	78	30

APPENDIX E (continued)

SHORT DURATION HOT-GAS BLANCHING OF CORN-ON-COB

Run no.	Kg/flight total feed wt,kg	Product wt, kg	Temp, °C	Residence time, min	Peroxidase reduction, %	Steam meter, %
COC-21	2.1 / 9.5	10.1[c]	104	12.5	97	30
COC-22	2.1 / 8.8	9.4[c]	104	12.5	93	30

[a] Steam flow meter rated at 9.5 kg (21 lb)/min at 100 percent of scale.
[b] Catalase test negative.
[c] After cooling with water sprays.

APPENDIX F

WASTEWATER VOLUME AND CHARACTERISTICS FOR STEAM CONSENSATE GRAB SAMPLES FROM COMMERCIAL BLANCHER FOR FROZEN CORN-ON-COB

Sampling date	Feed rate ears/min	Weight blanched, kkg	Volume, l	BOD, mg/l	COD, mg/l	SS, mg/l
9-18-72 a.m.						
(0-2 hr)	65	2.32	210	12500	19000	370
(2-4 hr)	78	2.83	190	14400	22100	733
(4-6 hr)	92	3.31	290	16800	24700	533
(6-8 hr)	41	1.49	270	14200	20100	620
9-18-72 p.m.						
(0-2 hr)	69	2.51	201	12800	19000	610
(2-4 hr)	62	2.35	213	14800	21100	630

APPENDIX F (continued)

WASTEWATER VOLUME AND CHARACTERISTICS FOR STEAM CONSENSATE GRAB SAMPLES FROM COMMERCIAL BLANCHER FOR FROZEN CORN-ON-COB

Sampling date	Feed rate ears/min	Weight blanched, kkg	Volume, l	BOD, mg/l	COD, mg/l	SS, mg/l
(4-6 hr)	79	2.87	129	13600	20700	980
(6-8 hr)	54	1.96	134	16600	24800	980
9-19-72 a.m.						
(0-2 hr)	61	2.22	166	10500	15700	490
(2-4 hr)	48	1.74	254	10700	14000	590
(4-6 hr)	91	3.31	247	15400	23100	1500
(6-8 hr)	63	2.29	252	16200	24200	1700
9-19-72 p.m.						
(0-2 hr)	85	3.08	312	12800	20900	1450
(2-4 hr)	77	2.80	306	14800	23400	1780
(4-6 hr)	64	2.32	213	12500	19600	1980
(6-8 hr)	78	2.83	227	15500	24600	2120
9-20-72 a.m.						
(0-2 hr)	93	3.38	242	14500	23100	770
(2-4 hr)	141	5.12	321	13400	21400	830
(4-6 hr)	79	4.14	312	13100	20800	890
(6-8 hr)	79	2.87	275	13800	21700	940

APPENDIX G

SHORT DURATION HOT-GAS BLANCHING OF BEETS

Run no.	Feed wt, kg	Product wt, kg	Temp, °C	Residence time, min	Steam flow, kg/min	Peroxidase reduction, %
B-1	9.1	8.4	121-132	5.5	70[b]	Underblanched
B-2	9.1	7.5	124-138	6.5	40[b]	Underblanched
B-3	9.1	8.9	124-132	2.4	40[b]	Underblanched
B-4	9.1	8.1	124-132	6.5	100[b]	Good peel, loosening
B-5	9.1[a]	8.4	121-128	18.5	80[b]	Underblanched, soft peel
B-6	6.4	5.0	118-123	14	1.0	Good peel, loosening
B-7	10.0	8.0	113-122	14	1.8	99.9
B-8	9.2	7.8	110-117	14	4.5	----
B-9	9.4	7.5	102-112	14	4.4	----
B-10	22.3	19.3	79-87	21	1.0	100
B-11	21.4	21.1	133-138	1	1.0	0
B-12	20.0	17.9	83-88	30	0.5	95
B-13	22.5	21.4	81-82	20	0.5	----
B-14	18.4	17.5	80-82	20	0.5	95
B-15	9.6	8.9	110-115	8	0.4	73
B-16	11.0	10.0	111-118	14	0.4	99
B-17	8.4	18.0	113-115	14	1.0	Underblanched
B-18	9.7	8.6	118-121	16	2.2	91
B-19	9.2	8.2	121	20	2.2	96
B-20	10.1	8.9	114-122	23	2.2	100
B-21	10.7	9.5	113-121	26	1.9	99
B-22	9.2	8.2	118-124	25	1.9	99
B-23[c]	20.0	18.6	113-121	26	1.9	----

a Large beets used.

b Steam pressure gauge reading made during temporary closing of inlet steam valve in lb/in.^{2}.

c Beets put through peeling line during plant lunch break, canned for evaluation.

APPENDIX H

WASTEWATER VOLUME AND CHARACTERISTICS FOR MAKE-UP OVERFLOW GRAB SAMPLES FROM COMMERCIAL BLANCHER FOR BEETS

Sampling date (operating time)	Weight blanched, kkg	Volume, l	BOD, mg/l	COD, mg/l	SS, mg/l
10-5-72					
(0-2 hr)	5.55	489	13800	20000	520
(2-4 hr)	5.36	511	13500	19400	220
(4-6 hr)	5.42	515	13200	19000	170
(6-8 hr)	5.45	484	14500	21800	270
10-6-72					
(0-2 hr)	5.47	257	12100	16900	290
(2-4 hr)	5.58	227	11700	16300	240

APPENDIX I

SHORT DURATION HOT-GAS BLANCHING OF SPINACH (1972)

Run no.	Feed wt, kg	Product wt, kg	Temp, °C	Residence time, sec	Perosidase inactivation, %
TLSP-1	4.5	2.7	116-121	154	99
TLSP-2	4.1	2.3	116-121	183	99
TLSP-3	3.9	2.0	113-118	210	99
TLSP-4	4.0	2.2	116-121	330	99
TLSP-5	4.8	3.0	118-121	144	99
TLSP-6	4.8	3.0	113-121	83	94
TLSP-7	3.9	2.3	116-121	108	99
TLSP-8	90.9	81.8	104-121	108	99

APPENDIX J

VOLUME AND CHARACTERISTICS OF WASTEWATER SAMPLES COLLECTED FROM HOT-GAS BLANCHER FOR SPINACH (1972)

Date/time	Volume l	COD, mg/l	SS, mg/l	pH
3-27-72				
11:40	---	---	---	---
12:40 p.m.	0.472	30500	5990	7.6
1:40	0.238	31800	2090	7.7
2:40	0.238	52400	7920	7.4
3:55	0.238	69000	6340	7.6
4:35	0.238	68500	5590	7.4
5:10	0.238	67000	870	7.2
3-28-72				
10:00	---	---	---	---
11:00	0.026	194200	12340	7.7
12:50	0.15	201000	4360	7.6
1:35	0.02	146900	5860	7.9
2:35	0.005	275800	10440	7.8
3:35	0.472	104000	1430	7.6
3-19-72				
8:30	---	6200	360	7.4
9:30	0.011	3300	810	7.4
10:30	0.026	179500	10620	7.6
12:00	0.034	26900	1700	7.4
1:00	0.12	226900	6230	7.6
2:00	0.053	42400	2530	7.7
3:00	0.083	259500	6670	7.5

APPENDIX K

CHARACTERISTICS OF WASTEWATER FROM COMMERCIAL SPINACH BLANCHER (1972)

Date	Sample type	COD, mg/l	SS, mg/l	pH
3-27-72	WO-OH[a]	260	50	7.8
	WO-1H	160	70	7.7
	WO-2H	270	50	7.7
	WO-3H	230	40	7.7
	WO-4H	240	30	7.7
	SC-OH	4040	140	7.0
	SC-1H[b]	4120	120	7.0
	SC-2H	4370	120	7.0
	SC-3H	4330	130	7.0
	SC-4H	4450	80	7.0
3-28-72	WO-OH	510	70	7.5
	WO-1.5H	300	70	7.6
	WO-2H	480	170	7.6
	WO-4H	330	140	7.6
	WO-5.6H	250	90	7.7
	WO-6H	300	90	7.7
	SC-OH	4120	110	7.1
	SC-1.54H	4080	70	7.0
	SC-2H	4080	120	7.1
	SC-4H	3880	100	7.1
	SC-5.6H	3960	60	7.7
	SC-6H	3960	80	7.7
3-29-72	WO-OH	270	60	7.0
	WO-1H	290	70	6.9
	WO-3.5H	340	130	6.9
	WO-4.5H	270	60	6.9
	WO-5.5H	430	170	6.8
	WO-6.5H	340	100	6.8
	SC-OH	4410	140	7.1
	SC-1H	4690	110	7.1

APPENDIX K (continued)

CHARACTERISTICS OF WASTEWATER FROM COMMERCIAL SPINACH BLANCHER (1972)

Date	Sample type	COD, mg/l	SS, mg/l	pH
	SC-3.5H	3550	140	7.1
	SC-4.5H	4450	140	7.1
	SC-5.5H	4120	120	7.1
	SC-6.5H	4330	160	7.1

a WO-OH = water overflow at zero hr.
b SC-1H = steam condensate at one hr.

APPENDIX L

SHORT DURATION HOT-GAS BLANCHING OF GREEN PEAS

Run no.	Feed wt, kg	Product wt, kg	Temp, °C	Residence time, sec	Steam flow kg/min	Peroxidase reduction, %
TLFP-1	15.1	15.1	127-138	90	1.0	17
TLFP-2	9.6	8.8	121-132	90	1.0	25
TLFP-3	9.1	8.0	136-143	90	1.0	92
TLFP-4	9.1	7.9	136-154	110	2.0	99
TLFP-5	9.1	7.8	108-116	150	2.0	99
TLFP-6	9.1	8.0	119-143	102	2.0	99
TLFP-7	22.7	20.4	118-127	110	2.0	99
TLFP-8	9.1	8.0	127-143	105	1.0	99
TLFP-9	13.6	12.6	138-152	105	1.0	100
TLFP-10	9.1	8.6	143-149	107	1.0	99
TLFP-11	22.7	22.2	138-146	106	1.0	99
TLFP-12	9.1	8.7	143-149	107	1.4	99
TLFP-13[a]	product canned		110-132	106	0.6	18

APPENDIX L

SHORT DURATION HOT-GAS BLANCHING OF GREEN PEAS

Run no.	Feed wt, kg	Product wt, kg	Temp, °C	Residence time, sec	Steam flow kg/min	Peroxidase reduction, %
TLFP-14[b]	--	--	121-166	--	2.0	99
TLFP-15	9.8	8.3	129-138	144	1.0	99
TLFP-16	--	--	138-143	190	1.0	--

a 10 min operation.
b 15 min operation.

APPENDIX M

GRAB SAMPLE CHARACTERISTICS FOR MAKE-UP WATER FROM COMMERCIAL BLANCHER FOR GREEN PEAS (Volume = 570 l/hr)

Sampling date (operating time)	Weight blanched, kkg	Sample type[a]	BOD, mg/l	COD, mg/l	SS, mg/l	pH
5-8-73						
(0-2 hr)	4.8	2 hr	5980	12200	320	7.5
(2-4 hr)	5.4	4 hr	3440	5820	200	8.5
(4-6 hr)	5.0	6 hr	4300	5790	240	8.8
(6-8 hr)	5.2	8 hr	5010	7630	230	8.5
5-9-73						
(0-2 hr)	5.1	2 hr	6130	8550	450	8.3
(2-4 hr)	5.6	4 hr	5640	9410	260	8.0
(4-6 hr)	5.4	6 hr	5250	9800	220	8.0
(6-8 hr)	5.1	8 hr	4200	8160	390	8.0

APPENDIX M (continued)

GRAB SAMPLE CHARACTERISTICS FOR MAKE-UP WATER FROM COMMERCIAL BLANCHER FOR GREEN PEAS (Volume = 570 l/hr)

Sampling date (operating time)	Weight blanched, kkg	Sample type	BOD, mg/l	COD, mg/l	SS, mg/l	pH
5-10-73						
(0-2 hr)	4.8	2 hr	3990	7180	360	8.0
(2-4 hr)	4.9	4 hr	3970	8170	220	7.5
(4-6 hr)	5.2	6 hr	8330	13800	290	7.1
(6-8 hr)	5.2	8 hr	4930	6390	280	8.0
5-11-73						
(0-2 hr)	5.1	2 hr	3590	5320	210	8.6
(2-4 hr)	5.2	4 hr	4970	7100	180	8.1
(4-6 hr)	5.0	6 hr	7030	12100	190	7.5
(6-8 hr)	5.2	8 hr	5860	9770	210	7.6
5-12-73						
(0-2 hr)	5.3	2 hr	7750	11800	490	7.8
(2-4 hr)	5.1	4 hr	7330	9540	370	8.0
(4-6 hr)	5.2	6 hr	3950	5850	200	8.6
(6-8 hr)	5.0	8 hr	6920	10600	380	8.2
5-14-73						
(0-2 hr)	5.1	2 hr	8010	11500	270	7.9
(2-4 hr)	5.3	4 hr	9280	12400	200	7.8
(4-6 hr)	5.2	6 hr	7210	8620	230	8.0
(6-8 hr)	5.1	8 hr	8230	13000	190	8.0

a Grab sample taken from blancher return surge tank after each 2 hr of operation.

APPENDIX N

VITAMIN CONTENT OF RAW, HOT-GAS BLANCHED, AND COMMERCIALLY BLANCHED VEGETABLES (mg/100 g wet wt)

Commodity	Vitamin	Raw	Hot-gas blanched	Commercially blanched
Green beans	A[a]	--	0.32, 0.34, 0.39, 0.32, 0.35, 0.30, 0.37, 0.37, 0.34 (0.03)[b]	0.40, 0.34, 0.35, 0.33, 0.32, 0.35, 0.27, 0.25, 0.26, (0.05)[b]
	B_1	0.08, 0.08, 0.07, (0.007)	0.06, 0.06, 0.06, (0)	0.07, 0.08, 0.07, (0.007)
	B_2	0.07, 0.07, 0.08, (0.007)	0.06, 0.07, 0.06, 0.05, (0.01)	0.06, 0.06, 0.06, (0)
	B_6	0.03, 0.03, (0)	0.03, 0.03, (0)	0.05, 0.05, (0)
	C	7.3, 7.9, 6.7, 7.4, (0.6)	2.2, 2.6, 3.2, 1.0 (1.1)	1.3, 0.7, 1.6, 1.6 (0.6)
	Niacin	0.46, 0.45, 0.47, (0.01)	0.36, 0.36, 0.36, 0.36 (0)	0.51, 0.50, 0.51, (0.007)
Corn	B	0.12, 0.13, 0.10, 0.13, (0.02)	0.18, 0.18, 0.19 (0.007)	0.15, 0.14, 0.18, (0.02)

APPENDIX N (continued)

VITAMIN CONTENT OF RAW, HOT-GAS BLANCHED, AND COMMERCIALLY BLANCHED VEGETABLES (mg/100 g wet wt)

Commodity	Vitamin	Raw	Hot-gas blanched	Commercially blanched
	B_2	0.04, 0.03, 0.04 (0.007)	0.04, 0.04, 0.04, (0)	0.04, 0.04, 0.03, (0.007)
	B_6	0.20, 0.20 (0)[b]	0.20, 0.20 (0)[b]	0.20, 0.20 (0)[b]
	Niacin	1.9, 1.8, 2.0, 1.8, (0.17)	1.9, 1.9, 1.9, (0)	1.9, 1.8, 1.9, 1.9, (6.07)
Beets	B_2[a]	--	0.03, 0.04, 0.03, (0.01)	0.04, 0.05, 0.05 (0.01)
	C[a]	--	3.1, 2.4, 2.5, (0.38)	3.2, 3.1, 2.8, (0.21)
	Niacin[a]	--	0.08, 0.04, 0.07, (0.021)	0.09, 0.10, 0.08, (0.016)
Spinach	A	2.13, 2.40, 2.71, (0.85)	4.29, 4.99, 3.97, (0.53)	4.27, 4.29, 3.87, (0.24)
	A[a]	--	4.0, 3.4, (0.4)	5.4, 5.3

APPENDIX N (continued)

VITAMIN CONTENT OF RAW, HOT-GAS BLANCHED, AND COMMERCIALLY BLANCHED VEGETABLES (mg/100 g wet wt)

Commodity	Vitamin	Raw	Hot-gas blanched	Commercially blanched
	B_2	0.16, 0.14, 0.16, (0.01)	0.14, 0.12, 0.13, (0.01)	0.10, 0.11, 0.10, (0.007)
	B_2[a]	--	0.11, 0.10, (0.007)[b]	0.12, 0.12, (0)[b]
	C	0, 0, 0	12.0, 11.1, 12.5, (1.0)	5.6, 6.5, 8.8, (1.7)
	C[a]	--	42.6, 32.9, 32.2, 25.9, 23.2, 34.1, 33.4, 46.3, 46.8, 26.2, 22.7, (9.1)	16.9, 18.5, 20.8, 28.7 28.7, 22.2, 21.5, 11.6, 13.0, 22.7, 25.5, (5.6)
Peas	B_1	0.35, 0.34, 0.25, (0.055)	0.35, 0.42, 0.41, (0.038)	0.41, 0.44, 0.34, (0.052)
	B_2	0.12, 0.12, 0.11, (0.005)	0.13, 0.12, 0.13, (0.009)	0.09, 0.09, 0.10, (0.004)
	B_6	0.19, 0.19, (0)	0.23, 0.23, (0)	0.16, 0.16, (0)

APPENDIX N (continued)

VITAMIN CONTENT OF RAW, HOT-GAS BLANCHED, AND COMMERCIALLY BLANCHED VEGETABLES (mg/100 g wet wt)

Commodity	Vitamin	Raw	Hot-gas blanched	Commercially blanched
	C	14.4, 16.9, 14.8, (1.3)	23.2, 20.4, 23.9, (1.9)	11.6, 11.3, 11.4, (0.02)
	Niacin	1.90, 2.45, 2.03, (0.29)	2.42, 2.21, 2.19, (0.13)	1.86, 2.00, 1.97, (0.07)

a Canned sample.

b Standard deviation shown in parentheses.

APPENDIX O

MINERAL CONTENT OF RAW, HOT-GAS BLANCHED, AND COMMERCIALLY BLANCHED VEGETABLES (mg/100 g wet wt)

Commodity	Mineral	Raw	Hot-gas blanched	Commercially blanched
Green beans	Ca	36, 31, 28 (4.2)[b]	30, 31, 31 (0.2)[b]	30, 39, 46 (8.1)[b]
	Mg	19, 15, 22 (3.6)	18, 18, 14 (2.3)	22, 26, 20 (3.1)
	P	18, 21, 20 (1.6)	18, 18, 18 (0)	22, 22, 19 (3.0)
Corn	P	87, 95, 93 (4.2)	90, 88, 93 (2.6)	87, 84, 86 (1.6)
Beets	P[a]	--	129, 112, 90 (19.5)	89, 104, 98 (7.5)
Spinach	Ca[a]	--	74, 70 (2.0)	88, 86 (1.0)
	Mg[a]	--	99, 99 (0)	95, 92 (1.6)
	Ca	39, 48, 53 (7.2)	65, 73, 60 (6.5)	69, 63, 65 (3.1)
	Mg	62, 62, 40 (12.7)	65, 75, 59 (8.1)	56, 43, 36 (10.1)
	P	36, 34, 29 (3.6)	35, 31, 34 (3.0)	41, 41, 39 (2.4)
	Fe	2.3, 2.2, 3.2 (0.6)	2.5, 3.0, 3.7 (0.6)	2.5, 1.9, 3.0 (0.6)
Peas	Ca	24, 27, 23 (2.1)	23, 23, 22 (0.3)	20, 21, 19 (0.8)
	Mg	34, 36, 33 (1.0)	36, 36, 35 (0.5)	29, 30, 28 (1.3)
	P	93, 92, 81 (6.7)	95, 95, 90 (2.7)	82, 73, 81 (5.4)
	Fe	1.8, 2.1 (1.0)	3.3, 2.7 (0.5)	2.2, 1.8, 1.6 (1.3)

a Canned sample

b Standard deviations shown in parentheses.

APPENDIX P

VACUUM, HEADSPACE, NET WEIGHT, COUNT, AND MATURITY OF CANNED GREEN PEAS

Vacuum, in. of Hg	Headspace, in./32	Net wt, oz	Count	No. of 50 sinking in NaCl brines 11%	13%	15%
		Commercial line samples				
8	13	16.9	700	19	7	0
11	13	16.9	680	20	6	1
8	13	16.9	701	15	4	0
10	14	16.7	657	15	4	0
10	15	16.6	641	24	5	0
11	13	16.8	660	20	4	0
10	16	16.4	716	14	4	0
11	13	16.7	648	22	6	2
10	10	17.1	681	19	5	0
11	14	16.8	676	17	5	0
6	13	16.6	622	16	6	1
			Ave.			
10	13	16.8	671	17	5	0
		Special hot-gas blanched				
7	9	16.9	641	11	1	0
		Hot-gas blanched				
5	13	16.8	687	23	7	0
5	16	16.7	710	13	8	0
6	12	16.8	667	20	5	2
5	12	16.9	684	16	8	2
6	14	16.8	667	22	8	3
5	8	17.7	688	17	4	1
5	13	16.7	706	19	5	1
5	12	17.7	689	21	10	0

APPENDIX P (continued)

VACUUM, HEADSPACE, NET WEIGHT, COUNT, AND MATURITY OF CANNED GREEN PEAS

Vacuum, in. of Hg	Headspace, in. /32	Net wt, oz	Count	No. of 50 sinking in NaCl brines 11%	13%	15%
		Hot-gas blanched				
6	11	17.1	718	17	12	0
6	10	17.1	702	17	2	0
5	13	16.9	687	29	10	3
8	11	17.0	678	26	8	1
			Ave.			
6	12	17.0	690	20	7	1

APPENDIX Q

CALCULATIONS FOR COMMERCIAL SPINACH BLANCHER WASTEWATER

3-28-72

Steam condensate =	6800 l/hr x 8 =	54,400 l
Water overflow =	13600 l/hr x 8 =	109,000 l
Dump water =		16,980 l
Total wastewater/8 hr =		180,380 l
Weight of spinach blanched =	$\left(\frac{174}{22.5}\right) \times 8 =$	62 kkg
(Volume/8 hr)/(kkg/8 hr) =	$\frac{180,380}{62} =$	2900 l/kkg

APPENDIX Q (continued)

CALCULATIONS FOR COMMERCIAL SPINACH BLANCHER WASTEWATER

3-29-72

Total wastewater/8 hr = 180,380

Weight of spinach blanched = $\left(\frac{164}{22.5}\right) \times 8 =$ 58 kkg

(Volume/8 hr)/(kkg/8 hr) = $\frac{180,380}{58} =$ 3,100 l/kkg

4-12-73

Steam condensate = $\left(\frac{110 + 76 + 110 + 110}{4}\right) \times 60 \times 8 =$ 48,720 l

Water overflow = $\left(\frac{604 + 572 + 572 + 545}{4}\right) \times 60 \times 8 =$ 275,160 l

Dump water = 16,980 l

Total wastewater/8 hr = 340,860 l

Weight of spinach blanched = $\left(\frac{8.6 + 7.8 + 8.0 + 8.4}{4}\right) \times 8 =$ 65.6 kkg

(Volume/8 hr)/(kkg/8 hr) = $\frac{340,860}{65.6} =$ 5,200 l/kkg

4-13-73

Steam condensate =	110 x 60 x 8 =	52,800 l
Water overflow =	588 x 60 x 8 =	282,200 l
Dump water =	16,980 l =	16,980 l
Total wastewater/8 hr =		352,000 l
Weight of spinach blanched =	8.0 x 8 =	64 kkg

(Volume/8 hr)/(kkg/8 hr) = $\frac{352,000}{64} =$ 5,500 l/kkg

APPENDIX Q (continued).

CALCULATIONS FOR COMMERCIAL SPINACH BLANCHER WASTEWATER

4-19-73

Steam condensate = $\left(\frac{102 + 110 + 114}{3}\right) \times 60 \times 8 =$ 52,160 l

Water overflow = $\left(\frac{481 + 572 + 604}{3}\right) \times 60 \times 8 =$ 265,120 l

Dump water = 16,980 l = 16,980 l

Total wastewater/8 hr = 334,000 l

Weight of spinach blanched = $\left(\frac{8.4 + 8.2 + 8.8}{3}\right) \times 8 =$ 67.8 kkg

(Volume/8 hr)/(kkg/8 hr) = $\frac{334,000}{67.8} =$ 4,900 l/kkg

4-12-73

BOD

Steam condensate = $\left(\frac{2840}{10^6}\right) \times \left(\frac{48,720}{65.6}\right) =$ 2.1 kg

Water overflow = $\left(\frac{70}{10^6}\right) \times \left(\frac{275,160}{65.6}\right) =$ 0.29 kg

Dump water = $\left(\frac{3860}{10^6}\right) \times \left(\frac{16,980}{65.6}\right) =$ 1.0 kg

Total BOD = 3.4 kg/kkg

COD

Steam condensate = $\left(\frac{4030}{10^6}\right) \times \left(\frac{48,720}{65.6}\right) =$ 3.0 kg

Water overflow = $\left(\frac{140}{10^6}\right) \times \left(\frac{275,160}{65.6}\right) =$ 0.59 kg

APPENDIX Q (continued).

CALCULATIONS FOR COMMERCIAL SPINACH BLANCHER WASTEWATER

Dump water =	$\frac{(4630)}{(10^6)} \times \frac{(16,980)}{(65.6)} =$	1.2 kg
Total COD =		4.8 kg/kkg

SS

Steam condensate =	$\frac{(170)}{(10^6)} \times \frac{(48,720)}{(65.6)} =$	0.12 kg
Water overflow =	$\frac{(75)}{(10^6)} \times \frac{(275,160)}{(65.6)} =$	.32 kg
Dump water =	$\frac{(160)}{(10^6)} \times \frac{(16,980)}{(65.6)} =$	0.04 kg
Total SS =		0.48 kg/kkg

4-13-73

BOD

Steam condensate =	$\frac{(3070)}{(10^6)} \times \frac{(52,800)}{(64)} =$	2.5 kg
Water overflow =	$\frac{(80)}{(10^6)} \times \frac{(282,200)}{(64)} =$	0.35 kg
Dump water =	$\frac{(3540)}{(10^6)} \times \frac{(16,980)}{(64)} =$	0.94 kg
Total BOD =		3.8 kg/kkg

COD

Steam condensate =	$\frac{(3740)}{(10^6)} \times \frac{(52,800)}{(64)} =$	3.1 kg
Water overflow =	$\frac{(140)}{(10^6)} \times \frac{(282,200)}{(64)} =$	0.62 kg

APPENDIX Q (continued).

CALCULATIONS FOR COMMERCIAL SPINACH BLANCHER WASTEWATER

Dump water =	$\frac{(5050)}{(10^6)} \times \frac{(16,980)}{(64)} =$	1.3 kg
Total COD =		5.0 kg/kkg

SS

Steam condensate =	$\frac{(230)}{(10^6)} \times \frac{(52,800)}{(64)} =$	0.19 kg
Water overflow =	$\frac{(12)}{(10^6)} \times \frac{(282,200)}{(64)} =$	0.05 kg
Dump water =	$\frac{(190)}{(10^6)} \times \frac{(16,980)}{(64)} =$	0.05 kg
Total SS =		0.29 kg/kkg

4-19-73

BOD

Steam condensate =	$\frac{(2740)}{(10^6)} \times \frac{(52,160)}{(67.8)} =$	2.1 kg
Water overflow =	$\frac{(70)}{(10^6)} \times \frac{(265,120)}{(67.8)} =$	0.27 kg
Dump water =	$\frac{(3390)}{(10^6)} \times \frac{(16,980)}{(67.8)} =$	0.85 kg
Total BOD =		3.2 kg/kkg

COD

Steam condensate =	$\frac{(3160)}{(10^6)} \times \frac{(52,160)}{(67.8)} =$	2.4 kg
Water overflow =	$\frac{(120)}{(10^6)} \times \frac{(265,120)}{(67.8)} =$	0.47 kg

APPENDIX Q (continued).

CALCULATIONS FOR COMMERCIAL SPINACH BLANCHER WASTEWATER

Dump water =	$\frac{(4050)}{(10^6)} \times \frac{(16,980)}{(67.8)} =$	1.0 kg
Total COD =		3.9 kg/kkg

SS

Steam condensate =	$\frac{(130)}{(10^6)} \times \frac{(52,160)}{(67.8)} =$	0.10 kg
Water overflow =	$\frac{(20)}{(10^6)} \times \frac{(265,120)}{(67.8)} =$	0.08 kg
Dump water =	$\frac{(150)}{(10^6)} \times \frac{(16,980)}{(67.8)} =$	0.04 kg
Total SS =		0.22 kg/kkg

Use of above values in partial calculation of the cost of commercial blanching of spinach [5 kkg (5.5 tons)/hr].

Water cost = $\frac{2900 + 3100 + 5200 + 5500 + 4900}{5} \times 5$ = 4320 l/5kkg

4320 l x \$0.10/3785 l = \$0.11

BOD disposal cost = $\frac{3.4 + 3.8 + 3.9}{3} \times 5$ = 18.5 kg/5kkg

18.5 kg x \$0.023/kg = \$0.43

SS disposal cost = $\frac{0.48 + 0.29 + 0.22}{3} \times 5$ = 1.65 kg/5kkg

= 1.65/kg x \$0.023/kg = \$0.038

Total waste disposal cost = \$0.47/5kkg spinach blanched.

APPENDIX R

COST ESTIMATE FOR COMMERCIAL PIPE BLANCHER AND HOT-GAS BLANCHER FOR GREEN PEAS

Cost Estimate for Commercial Pipe Blancher
[2.73 kkg (3 tons)/hr capacity]

First cost (FC) = $8685.00

Annual fixed cost		
Amortization = FC x crf (7%, 5 yr = 0.24389)	= $	2118.18
Space rent	=	2000.00
Taxes [$5.00/$100 assessed value (25% of FC)]	=	108.50
Insurance (0.2% of assessed value)	=	4.34
Maintenance (1% of FC/yr)	=	86.85
Total	= $	4317.87/yr
Hourly fixed cost (1800 hr/yr)	= $	2.40/hr
Hourly operating costs		
Electrical power	= $	0.220
Steam	=	1.200
Water	=	0.016
Waste disposal	=	0.092
Labor	=	2.600
	$	4.13/hr
Hourly fixed cost	= $	2.40
Hourly operating cost	=	4.13
Total hourly cost	=	6.53
Cost per kkg blanched	=	2.39/kkg

Cost Estimate for Commercial Hot-Gas Blancher
[5 kkg (5.5 tons)/hr]

First cost (FC) = $100,000.00

APPENDIX R (continued).

COST ESTIMATE FOR COMMERCIAL PIPE BLANCHER AND HOT-GAS BLANCHER FOR GREEN PEAS

Cost Estimate for Commercial Hot-Gas Blancher
[5 kkg (5.5 tons)/hr]

Annual fixed cost		
Amortization = FC x crf (7%, 5 yr = 0.24389)	= $	24389.00
Space rent	=	12000.00
Taxes [$5.00/$100 assessed value (25% of FC)]	=	1250.00
Insurance (0.2% of assessed value)	=	50.00
Maintenance (1.5% of FC/yr)	=	1500.00
Total	= $	39189.00/yr
Hourly fixed cost (1800 hr/yr)	=	21.77/hr
Hourly operating costs		
Electrical power	= $	4.45
Steam	=	1.87
Water	=	0.00
Gas	=	0.22
Waste disposal	=	0.01
Labor (half-time worked at $5.20/hr)	=	2.60
Total	= $	9.15/hr
Hourly fixed cost	= $	21.77
Hourly operating cost	=	9.15
Total hourly cost	=	30.92
Cost per kkg blanched	= $	6.18/kkg

APPENDIX S

CALCULATION OF COST OF HOT-GAS BLANCHING OF PEAS

Electrical power:

$$\frac{140 + 110 + 4}{30} = \frac{254}{30} = 8.46 \text{ kw/hr}$$

Scale-up factor = 15
8.46 x 15 = 127 kw/5 kkg
127 x \$0.035/kw = $1.27 \times 10^2 \times 3.5 \times 10^{-2} = 4.45 \times 10^0$ = \$4.45/5 kkg/hr

Steam:

1.7 kkg/30 hr = 0.0567 kkg/hr

Scale-up factor = 15
15 x 0.0567 = 0.85 kkg/hr
\$2.20 x .85 = \$1.87/hr

Gas:

16.4 m^3/30 hr = 0.546 m^3/hr

Scale-up factor = 15
15 x 0.546 = 8.2 m^3/hr
$\left(\frac{8.2}{28.3}\right)$ x \$0.76 = \$0.22/hr

Waste disposal: (80 percent removal)

0.124 kg/kkg BOD + SS = .620 kg/5 kkg
0.620 x \$0.023/kg = \$0.0143/5 kkg

APPENDIX T

CHECKLIST FOR MEASUREMENTS NECESSARY FOR HOT-GAS BLANCHING OPERATION

(Data to be recorded in bound notebook as taken)

Commodity__________________
Location__________________
Date__________________
Starting time__________________

Product feed

Rate__________ (every 2 hr)

Conveyor drive

Setting______________
Setting______________

Temperature, °F (hourly)
(or when significant change)

____

Electrical meter #1
Start______________
Finish______________

Electrical meter #2
Start______________
Finish______________

Electrical meter #3
Start______________
Finish______________

Gas meter
Start______________
Finish______________

Steam flow meter
Start______________
Finish______________

Blanched product weight
(every 2 hr)__________________________

2 hr grab sample volume + COD sample

Commercial_________(refrigerate)

8 hr wastewater volume + COD sample

Commercial_________hot-gas_________
(ice-cooled)

Peroxidase sample, hourly__________
(hot-gas only)

Vitamin, mineral samples (1 run)

Raw______Commercial blanched______
hot-gas__________

Finishing time________________________

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

An experimental hot-gas blancher was operated in two food processing plants using green beans, corn-on-cob, beets, spinach, and green peas. A side stream of commercially prepared vegetables was hot-gas blanched and returned to the production line. Electrical, gas, and steam flow meters were used with the hot-gas blancher to obtain data for operational cost estimates.

Wastewater samples were collected from the commercial blancher and the hot-gas blancher for each commodity studied; these were measured for volume and analyzed for BOD, COD, SS and pH. Comparisons were made of reductions in wastewater volume, BOD, COD and SS when steam or hot-water blanching were replaced by hot-gas blanching. For beans, spinach and peas these reductions were 91 to 99 percent. Operational costs were higher for hot-gas blanching than for steam or hot-water blanching for all vegetables studied except for green beans which were slightly lower. The flavor, texture, appearance, nutritional content and safety of hot-gas blanched vegetables are generally equivalent to hot-water or steam blanched vegetables.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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