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DISCLAIMER

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ABSTRACT

The research was designed to test and/or develop new systems of washing, peeling and blanching, develop methods of utilization of solid wastes, and find ways to reduce wastestrength of effluent without affecting quality of vegetables for processing. The highest wastestrength of effluent from vegetable processing in the region was found in plants that were canning Irish potatoes, dry beans and hominy. The high volumes of water used for washing spinach and leafy greens and the physical damage to the washed product is one of the major problems. Repetitive washing of spinach in the same water did not affect quality as long as there was sufficient rinsing after the second wash. The levels of COD, TSS, TS, SS, PO_4 and NO_3 did not build up to prohibitive levels by the reuse of water as long as adequate make-up water was added. Steam blanching, which leaches out much less soluble constituents, can be substituted for water blanching by using appropriate times and temperature for different vegetables. The greater retention of nutrients in steam blanched vegetables was demonstrated in different vegetables grown and processed under different conditions. Data from research on the canning of dry beans indicated that the high wastestrength can be reduced by shortening the soaking time, controlling the temperature of soaking and processing without blanching without changing the quality appreciably. It appears that the present method of hominy preparation and processing can be altered to reduce pollution. By dipping corn in 10% lye solution, followed by heating and scrubbing, corn can be peeled and bleached efficiently. Most of the heavy solid waste can be isolated before the final rinse of the peeled corn. The prototype leafy greens washing system decreased the use of water by 70% on spinach, turnip greens and mustard. Water quality data showed that wastestrength of the effluent from washing was reduced over 50%, as compared to industrial washers, primarily due to less physical breakage. Less nutrients were leached out in greens washed by the experimental washer than the industrial washer. High alkalinity solid wastes from peeling Irish and sweet potatoes can be fermented and stored as long as 9 months without any great change in carbohydrates and total dry matter. There was an increase in sugar content and a decrease in starch content during fermentation. The quality of the sweet potato waste appeared to be excellent after storage when mold inhibitor was sprayed on vats. Irish potato waste storage created more odor problems unless the fermentation temperature was controlled at 25 to 30°C.

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INTRODUCTION

One of the major users of fresh water in the United States is the food processing industry. Cleaning, washing, peeling and blanching of vegetables by the present methods requires large volumes of water which carry soil, solid materials, sugars and other soluble constituents that have to be removed by screening, settling tanks, aerated ponds, activated sludge, landfills and other methods. The National Canners Association estimated that by 1980 there would be 100 billion gallons of wastewater discharged from food processing plants carrying with it 500 million tons of Biochemical Oxygen Demand (BOD) 250 million tons of Suspended Solids (SS) and 10 million tons of solid residuals (24). Changes in processing methodology (washing, blanching, cooling) and reuse of water to meet the EPA guidelines probably will reduce these original estimates significantly. Nevertheless, disposal of liquid and solid wastes will continue to be costly to the food industry and thus the consumer.

The effluent limitation guidelines require that food industries apply the best available control technology economically feasible by 1983 (12). The act strives to accomplish zero discharge, the complete elimination of all discharge of pollutants to navigable waterways as a national goal by 1985. A number of methods for reducing wastes have been established such as improved processes for degrading liquid waste, better screening of suspended solids, conservation of water, recycling of water, development of useful by-products from liquid and solid wastes, etc. (13).

Bough (7) found the composite load of water, BOD, and SS from a commercial leafy greens canning operation to be 17%, 28% and 14%, respectively of the total waste strength. Certain methods of washing snap beans can reduce water use as much as 100% (10). Variations in water use for peeling and washing potatoes have been recorded from 468 to 2500 gal/ton (2,10,35). Peas required from 432 to 1200 gal/ton of water for cleaning, washing and fluming (35).

Peeling of root crops has been accomplished by a number of methods such as hot lye solutions, steam, mechanical abrasion, exposure to flame and infrared radiation. Dry caustic peeling has been shown to remove peel with less product loss and lower volumes of water and lower BOD than conventional methods (9,13,23) In sweet potatoes, a 50% reduction in water use and BOD was reported by the dry caustic method (33).

In a comparison of four blancher designs including water, steam hydrostatic, vibratory spiral and hot-gas, the hot-gas method produced the lowest wasteload (3). The energy efficiency of hot-gas was an improvement over steam (3,26,27). However, the low capital investment of water blanchers has continued to be an attractive feature (3). Using air as a means of heat transfer for blanching reduces water use and loss of solids by leaching (17). The use of microwave blanching for vegetables retained equal or greater chlorophyll and ascorbic acid than conventional methods but it was not practical because of large capital investment and low energy efficiency (26).

Large volumes of water are required to cool vegetables after blanching. However, Bomben (5) demonstrated that either forced air plus spray cooling or forced air alone reduced solids loss when compared to water cooling. Cooling of vegetables for canning is not always necessary nor is it economically feasible. Forced air cooling was found to be as effective as air in combination with water spray although a limited amount of water prevented dehydration of the product. Blanching and cooling have been combined in recent years in a vibratory blancher-cooler (6,8).

There were four objectives of the present research as follows:

1. To develop and test systems of dry and wet cleaning of raw vegetables for processing.
2. To evaluate and/or develop new techniques of peeling and blanching for vegetables.

3. To determine the most efficient methods of (1) utilization of solid wastes and (2) reduction of BOD in liquid wastes.
4. To determine the effect of these techniques on quality of water and quality of processed product.

MATERIALS AND METHODS

Initially, a survey was made in the spring of 1975 of the processing plants in the Ozark region to evaluate the methods of cleaning, peeling and blanching of vegetables. Also, the effluent from different processing plants was monitored to determine normal waste loads during operation. From the evaluations and from discussions with management the following operations appeared to be the most critical, contributing significantly to the wastestrength of the effluent and control of solid wastes: 1) Washing and cleaning; 2) blanching and cooling; 3) high alkalinity peeling wastes from peeling Irish and Sweet potatoes, and corn for hominy; 4) removal of suspended solids from effluent; and 5) excessive use of fresh water.

Six major areas of research were pursued during the four years of the project:

I. Monitoring of water quality of effluent (BOD, COD, SS, TS and settleable solids) periodically in different plants to aid in the solution of problems that developed on different products during the application of new technology to reduce wastestrength of the effluent.

II. Research on (a) steam and water blanching (b) cooling vs no cooling of product after blanching and (c) wash water volumes with and without detergent on canned green beans, spinach, turnip greens, mustard greens and kale greens.

III. Research on bean types, including soaking times, soaking temperatures and chemical treatment to evaluate ways of reducing wastestrength of effluent from canning dry beans.

IV. Research on new methodology for peeling and bleaching corn for the manufacture of hominy to reduce wastestrength of effluent.

V. Evaluation of a new washing system for spinach and leafy greens.

VI. Research on fermentation, handling and storage of Irish and Sweet potato high alkalinity peeling wastes for animal feed.

Raw product, sampling and methods of analysis

I. The water samples were taken from different steps of operation in the processing plants to determine not only where the greatest wastestrength was produced, but effectiveness of new screening technology, chemical treatment and mechanical separators. It was from this cooperative effort with plant management and control personnel that the greatest feedback on waste management was obtained. Water samples were taken of effluent from processing spinach, leafy greens, fried shoestring potatoes, canned Irish potatoes, green beans, dry beans and hominy. The grab samples were taken from the different steps in the operation and analyzed by Standard Methods for the examination of water and wastewater (1) for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Settleable Solids (SS) and Total Solids (TS).

II. The raw material for the processing methodology was obtained from three different processing plants and from plots on the Main Experiment Station, Fayetteville, AR. The raw product was prepared by sorting, washing, blanching, cooling and freezing or canning. Detailed procedures are recorded in the separate published articles (appendix A-1,A-2,A-3). For this study a small reel-type washer was adapted for use as a washer and steam blancher. Five spray nozzles were interchanged between lots to obtain 3 rates of water flow and the reel could be enclosed to serve as a rotary steam blancher. Separate studies were conducted on spinach, turnip greens, green beans and kale to study the effect of volume of water, detergent, blanch temperature, type of blancher, blanch time and cooling on water and product quality.

Water samples were analyzed by Standard procedures (1) for COD, TSS, SS, and TS. The canned and frozen samples were rated by a 6 member sensory panel for color, texture and general appearance. Other determinations were drained weight, liquor color, ascorbic acid, nitrates, shearpress, grit and sand, and color by the Gardner Color Difference Meter. On frozen spinach and greens the analyses were confined to ascorbic acid and color.

The drained weight of canned products was obtained by draining the contents on an 8-mesh screen for 2 minutes and weighing. Liquor color was obtained by centrifuging samples of liquor and reading the optical density (OD) at 475 nm. Nitrates and phosphates were determined on a aliquot of the liquor of canned product by standard procedures (1, appendix A-2) Ascorbic acid was determined by weighing a 25g sample of product and blending in 100 ml of 1% oxalic acid, then filtering and following the procedure of Morell (22). Color was determined on both the whole processed product and a 1:1 blend of product and water by a Gardner Color Difference Meter using standard plaques to standardize the instrument. Grit and sand were determined by washing away the pulp of a 150g sample of blended canned spinach by a gentle stream of water in a 600ml beaker. The water was decanted and the grit and sand transferred to a tared pan, dried at 100°C, and weighed to obtain the dry residue. Resistance to shear was determined on 150g of the drained product using a Food Tech. Corp. Model Tp-1A shearpress.

III. The dry bean research was conducted on 3 bean types (Navy, Pinto and Red Kidney), 3 soaking times (3, 6 and 14 hours), 3 soaking temperatures (15, 25, and 35°C), 11 soaking treatments including citric and malic acids, and ethylenediaminetetracetic acid (Na salt) at 3 concentrations with tap and deionized water as controls and 3 storage times of canned product.

Detailed procedures of the research,method of processing and methods for wastewater and canned product analyses,are given in the appendix B-1).

IV. The corn was obtained from one of the local processing plants. The corn was weighed out in 200g lots and peeled by 2 methods, the standard commercial method which involves cooking the corn in a solution of approximately 1.5% caustic soda for 30 minutes and a dip method in which lots of corn were dipped in 10% lye solution for different times followed by heating in steam for different time periods. Peeling was accomplished by stirring in a perforated stainless steel basket under a spray of water. Bleaching was accomplished either by heating the peeled corn in a solution of $NaHSO_3$ or HCl. After further cooking of the peeled corn (30-45 minutes) the hominy was canned according to NCA recommendations.

Water samples were analyzed for SS, COD and TSS as described above. The canned product was rated by a 6 member sensory panel and colorand firmness were determined as described in Section II.

V. The research on washing of spinach and leafy greens using the prototype washing system obtained on a license agreement from EPA, Cincinnati, OH was conducted in the spring of 1978 and 1979. The washing system was developed by the Agricultural Engineering Department of Virginia Polytechnic Institute and was loaned to the University of Arkansas and Steele Canning Co. for testing and demonstration. The equipment was transported to Springdale, AR and installed adjacent to one of their processing lines at their expense. The capacity of the washing system is 4-5 tons/hour. Details of the design of the system have been previously described (18,36,37).

The commercial processing line normally runs 10 to 12 tons/hour of spinach and leafy greens. During the experimental runs 1/3 of the product 3-4 tons/hour was diverted to the experimental washer. Water samples and raw product samples were taken at 30 minute intervals from 4 sites from both commercial and experimental washers. Water samples were sealed in polypropylene sterile bottles and preserved until analyses were made. The raw product samples were collected at the discharge end of the washers and transported to the Horticultural Food Science pilot plant (6 mi distance) for water blanching, cooling and canning and/or freezing. Standard commercial procedures were used for these operations. Separate samples of canned product washed by the two methods could not be obtained from the processing plant since all washed product was combined before proceeding to the water blancher.

The methods for wastewater analysis have been described under section I above. The types of determinations and methods of analysis on the canned and frozen product are described under section II above. Total plate counts were conducted on water samples by standard methods (1).

VI. This research has been conducted over a 4-year period; that is , various phases of the work. Initially, studies were conducted on time and temperature of fermentation with and without aeration by an air pump. A major study during 1976-77 involved time and temperature of fermentation of Irish potato wastes under aerobic and anaerobic conditions. Bacteria were isolated and identified during the stages of fermentation at different pH levels. Part of the results of this study are recorded in a Master's thesis, Appendix D-3, and two published articles (Appendix C-1, C-2).

RESULTS AND DISCUSSION

I. Monitoring of water quality of effluent.

The effluent from vegetable processing plants in the region was monitored for water quality, samples being taken from the major steps in production. An average of these analyses taken at different times is shown in Tables I-1 to I-8. In

1975, practically no recycling of water was carried out in the region. However, since 1975 different plants have drastically reduced consumption and more and more recycling of water is the general practice. Most of the plants discharge water into municipal systems and thus volume of water as well as SS and BOD are important in calculating surcharge rates.

From the data in Tables I-1 and I-2 it can be seen that peeling and preparation of potatoes produced high wastestrength effluent that is high in SS. This necessitated an efficient screening operation and starch recovery in order to reduce wastestrength. The highest wastestrength in green beans was produced by blanching (Table I-3), and much of the research on this project has been directed toward alternate blanch methods (Section II). Preliminary tests showed that soaking and blanching of dry beans were the two major operations that contribute to wastestrength of the effluent from canning dry beans (Tables I-4 and I-5). Research findings have demonstrated that a high percentage of the wastestrength can be eliminated by reduced soaking times and eliminating blanching without affecting product quality (Section III).

The present method of peeling and preparation of hominy produces the highest wastestrength of any process studied (Table I-6). We have discussed alternate methods with processors based on research results on this project that would drastically reduce this pollution (Section IV). Most of the wastestrength from canning spinach and leafy greens continues to be produced by washing and blanching (Tables I-7), I-8). Because of the research on this project (Section II and V), much of it in cooperation directly with industry, the washing and blanching systems will be altered. The present washing system breaks up the leaves and stems badly, thus releasing more soluble constituents to the effluent. This also produces more loss of soluble constituents as well as nutrients during blanching and cooling (Section II, V).

Other monitoring of water quality of effluent from processing plants has been in conjunction with new screening equipment, recycling of water and cyclone separators for suspended solids. Also, preliminary research has been conducted on flocculants for removal of suspended solids from effluent from dry beans, hominy and potato processing with subsequent testing of the water (data not shown).

Table I-1. Water quality of effluent at different stages of preparation of Irish potatoes for fried potato sticks.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids ml/l	COD mg/l
Washer	780	200	30	200
Abrasive peel	4410	1780	60	4050
Slicing	1600	140	6	1250
Washer (slices)	2760	360	12	2500
Total flow				

[z] Production capacity - 8500-9000 lb/hr.
Water usage - 8,040 gal/hr.

Table I-2. Water quality of effluent at different stages of preparation of Irish potatoes for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids ml/l	COD mg/l
Washer	675	184	26	410
Scrubbers	3100	1128	140	1756
Flume	784	104	12	608
Total flow	2376	264	76	1262

[z] Production capacity - 400 cs/hr, 6/10 cans.
Water usage - 12,950 gal/hr.

Table I-3. Water quality of effluent at different stages of preparation of green beans for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids ml/l	COD mg/l
Washer	120	0.6	8	80
Blancher	4205	15	26	3150
Cooling	214	0.8	12	165
Total flow	1425	1.8	17	384

[z] Production capacity - 18 tons/hr
Water usage - 17,500 gal/hr.

Table I-4. Water quality of effluent at different stages of preparation of Red Kidney dry beans for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids ml/l	COD mg/l
Soaking	2640	310	9	2124
Fluming	3104	270	11	2396
Blancher	11040	890	21	9927
Total flow	4284	360	14	3310

[z] Production capacity - 450 cs/hr-24/300 cans.
Water usage - 11,900 gal/hr.

Table I-5. Water quality of effluent at different stages of preparation of pork and beans for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids mg/l	COD mg/l
Soaking	4978	420	16	4540
Fluming	5214	490	17	2824
Blanching	10800	1080	41	9386
Total flow	4380	460	14	3760

[z] Production capacity - 440 cs/hr-24/300 cans.
Water usage - 11,500 gal/hr.

Table I-6. Water quality of effluent at different stages of preparation of hominy for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids mg/l	COD mg/l
Peeling	64200	44080	1240	59800
Bleaching	12400	10140	245	9876
Cooking	7940	3570	87	5766
Fluming	4160	2194	68	3570
Total flow	24800	17840	292	18960

[z] Production capacity - 410 cs/hr-24/300 cans.
Water usage - 10,600 gal/hr.

Table I-7. Water quality of effluent at different stages of preparation of spinach for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Setteable solids mg/l	COD mg/l
Washing	792	480	3.2	386
Blanching	1770	848	10.8	1134
Cooling	247	122	0.6	81
Total flow	591	487	2.8	284

[z] Production capacity - 10 ton/hr.
Water usage - 18,200 gal/hr.

Table I-8. Water quality of effluent at different stages of preparation of turnip greens for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids mg/l	COD mg/l
Washing	473	124	0.9	248
Blanching	804	486	1.7	671
Cooling	148	73	0.2	72
Total flow	446	314	0.4	269

[z] Production capacity - 10 ton/hr.
Water usage - 17,900 gal/hr.

II. Washing, blanching and cooling.

Most of the research data conducted on wash water volumes, detergent, blanch method, blanch time and cooling has been published (Appendix A-1, A-2, A-3, A-4).

One additional study on turnip greens indicated that steam blanching could be substituted for water blanching without greatly affecting quality of canned turnip greens (Table II-1). Shearpress values, ascorbic acid and liquor color were higher on steam blanched spinach and stemminess was rated lower by a sensory panel as compared to water blanched samples.

The use of detergent resulted in slightly darker canned product as shown by the 'L' values. This was reflected in lower color scores by the sensory panel. Also, the product was slightly tougher as measured by the shearpress and higher in ascorbic acid. Higher water volumes decreased 'a' value indicating less greenness, and the product was less firm as shown by lower shearpress values. Furthermore, the canned product that was washed in greater volumes of water was rated lower in color. Greater physical damage to the raw product by the use of larger volumes of water during washing apparently did significantly affect quality of canned turnip greens.

An additional series of experiments were conducted to measure the change in water quality with repetitive washing,blanching and cooling lots of spinach. Rinse water after the 2nd wash was added to the 2nd recycle tank and water levels maintained in the other tanks by movement of a constant volume from d to a tanks. During the first washing experiment (Table II-2) there was a gradual increase in TS, TSS and SS. The recycle tanks built up more slowly in these constituents. There was a steady increase in nitrates in all tanks with no indication of leveling off. The COD build up in the washing tanks was fast initially, but after a few wash cycles it appeared to level off or increase at a very slow rate around 300 mg/l.

The first blanching and cooling experiment (Table II-3) showed a steady increase in TS but there appeared to be a leveling off after 22 batches. The rate of increase for TS was slower in the cooling water. There was a slow build up of TSS and SS with the rate being slower in the cooling water. This particular experiment was conducted in two parts. The first part included samples 1-10 on the first day. The following day samples 11-22 were completed. The tanks of blanch water and cool water were left to stand overnight and the same waters used on the second day of the experiment. For this reason, the bacteria had a chance to reduce the organic compounds overnight thereby causing a sharp decrease in nitrates and COD. There was a steady rate of increase in both nitrates and COD on each day with the blanching water increasing in greater amounts than the cooling water.

The second washing experiment showed basically the same trends as in Table II-2. TS, TSS and SS increased slowly with little accumulation (Table II-4). Nitrates steadily increased with some indication of leveling off. The settling tank remained low in nitrates. COD levels were relatively high initially, but there was no great increase after the first 5 batches.

The second blanching and cooling experiment (Table II-5) showed basically the same results as in Table II-3. TS steadily increased with a slight leveling off after 7 batches. TSS and SS increased slowly with little build up. Nitrates and COD showed a steady rate of increase with no sign of leveling off.

The results of the steam blanching and cooling experiment using different blanch times showed an irregular pattern in TS TSS, COD and nitrates. There was a decrease in nitrates and COD up to 2 minutes of blanching in steam, then very little change to 4 minutes (Table II-6). Values for cooling water did not relate to blanch time.

In canned spinach from the same lots, there were no differences indicated with regard to either drained wt, shearpress, nitrates, organoleptic panel ratings or OD of liquor (Tables II-7 and II-8). The CDM 'a' value indicated a slight decrease in greenness with each blanch cycle for the first blanching experiment (Table II-7). No difference was detected between cooling and not cooling. However, the CDM 'a' value in the second blanching experiment (Table II-8) indicated an increase in greenness in blanch cycles 7 to 10. In any event there did not appear to be any great change in quality with repetitive washing, blanching and cooling.

Neither steam blanching time nor cooling had any effect on drained wt, shearpress, or OD of liquor of canned spinach (Table II-9). Blanched samples that were not cooled contained slightly more nitrates than did blanched, cooled samples (Table II-9). This indicates that the cooling water leached out additional nitrates from the spinach. The taste panel ratings seemed to indicate better color, texture and flavor with shorter blanch times. No difference was detected due to cooling. The CDM 'a' value also showed slightly more greenness in the samples with shorter blanching times.

Table II-1. Effect of detergent wash, volume of wash water and blanch method on quality of canned turnip greens.

	Hunter CDM			Drained	Shearpress	Sensory Panel			Ascorbic acid	Liquor color
Main effect	L	a	b	wt(g)	lb/150g	Color	Stemminess	Texture	mg/100g	O.D. 475nm
Blanch										
Water	22.99	.74	12.15	301.7	770	6.84	6.19	6.70	20.18	.183
Steam	22.85	.65	12.07	306.9	786	6.76	5.82	6.67	28.03	.241
F Value	1.90NS	3.78NS	2.21NS	2.61NS	4.33*	1.21NS	11.52**	0.06NS	367.45**	65.78**
Detergent Wash										
Control (H_2O)	23.02	.72	12.16	302.7	771	6.89	611	6.73	24.55	.211
0.5% Metzo	22.88	.67	12.05	305.9	786	6.71	5.90	6.64	23.67	.214
F Value	4.91*	.86NS	3.73NS	1.03NS	3.84*	5.54*	3.89NS	0.41NS	4.65*	0.11NS
Volume of Wash Water l/min										
1	22.80	.86	12.03	302.5	805	6.95	6.05	6.69	24.07	.205
3	23.01	.71	12.14	302.9	766	6.79	5.96	6.69	24.13	.213
10	22.94	.51	12.16	307.5	763	6.66	6.00	6.68	24.13	.220
F Value	0.99NS	16.36**	1.92NS	1.01NS	12.73**	4.95*	0.22	0.001	0.01NS	1.38NS

* Significant at 5% level.

** Significant at 1% level.

NS Not significant.

Table II-2.Effect of washing on water quality in spinach processing.

Wash Cycle	TS[1] (g/l)	TSS (g/l)	SS (ml/l)	NO_3 (mg/l)	COD (mg/l)
1-a[2]	.320	.050	0.20	7.7	128
b	.232	.018	0.08	5.4	200
c	.252	.018	T	4.4	74
d	.252	.016	T	4.2	120
2-a	.480	.252	0.8	7.8	213
b	.280	.044	T	6.4	87
c	.224	.040	T	4.3	89
d	.184	.010	T	4.3	102
3-a	.628	.350	0.4	9.6	124
b	.276	.098	T	9.0	108
c	.168	.012	T	4.8	77
d	.224	.008	T	4.2	90
4-a	1.016	.528	0.16	11.0	130
b	.436	.184	0.12	12.0	94
c	.260	.028	T	5.2	92
d	.340	.074	T	4.6	92
5-a	.828	.616	1.8	16.0	146
b	.360	.164	1.4	14.0	172
c	.332	.048	0.4	5.8	73
d	.184	.020	T	5.4	120
6-a	.580	.356	1.2	17.0	137
b	.380	.026	2.0	17.0	118
c	.220	.026	T	16.2	94
d	.196	.020	T	5.0	90
7-a	.996	.518	2.0	17.5	296
b	.740	.198	1.2	19.4	152
c	.396	.174	T	9.2	96
d	.260	.022	T	5.1	60
8-a	.772	.436	2.0	16.4	249
b	.500	.182	1.6	14.6	246
c	.196	.032	T	8.4	166
d	.228	.020	T	5.2	130
9-a	.796	.514	2.0	18.8	252
b	.568	.210	1.2	11.0	194
c	.328	.040	T	8.8	143
d	.136	.018	T	5.4	128
10-a	.788	.568	1.6	15.8	240
b	.516	.166	1.2	14.0	222
c	.308	.044	T	9.8	158
d	.108	.022	T	5.7	136
11-a	1.028	.480	2.0	19.9	369
b	.796	.268	1.2	21.8	298
c	.144	.020	T	11.0	142
d	.204	.040	T	6.2	141
12-a	1.136	.608	1.2	20.5	316
b	.564	.322	0.8	24.6	358
c	.260	.032	T	11.6	290
d	.164	.060	T	6.8	164
13-a	1.184	.704	1.6	23.5	365
b	.828	.414	2.0	28.1	383
c	.264	.072	T	14.8	232
d	.528	.050	T	7.6	219

[1] TS-Total Solids, TSS-Total Suspended Solids, SS-Settleable Solids, NO_3-Nitrates, C)D-Chemical Oxygen Demand.

[2] a-first wash
b-second wash
c-1st recycled tank
d-2nd recycled tank

Table II-3. Effect of sequence of water blanching and cooling on water quality in spinach processing.[1]

	Water Blanching					Cooling				
Sample No.	TS[1] (g/l)	TSS (g/l)	SS (ml/l)	NO_3 (mg/l)	COD (mg/l)	TS (g/l)	TSS (g/l)	SS (ml/l)	NO3 (mg/l)	COD (mg/l)
1	.472	.056	0.2	19	40	.176	.010	0.01	9	44
2	.332	.072	0.2	35	60	.184	.014	0.01	12	48
3	.688	.116	0.3	56	112	.240	.032	0.01	16	108
4	.972	.118	0.4	70	132	.276	.041	0.01	22	108
5	1.016	.098	0.4	96	140	.300	.020	0.01	27	140
6	1.104	.100	0.5	125	276	.368	.044	0.01	31	104
7	1.276	.096	0.8	130	356	.456	.042	0.08	36	224
8	1.424	.104	0.8	154	552	.468	.078	0.01	37	208
9	1.620	.082	0.4	175	596	.560	.080	0.08	42	312
10	1.684	.106	0.4	200	356	.556	.086	0.04	48	318
11	2.196	.106	0.4	26	520	.540	.100	0.04	5	84
12	1.752	.126	0.4	42	400	.604	.110	0.04	5	80
13	1.844	.116	0.4	64	456	.656	.120	0.06	6	120
14	2.268	.122	1.6	79	516	.672	.124	0.06	6	144
15	2.280	.128	1.2	94	880	.728	.102	0.06	6	204
16	2.528	.110	2.8	125	688	.764	.130	0.08	9	208
17	2.772	.128	1.2	138	608	.788	.142	0.10	7	200
18	2.840	.226	0.8	163	640	.832	.138	0.10	10	216
19	3.072	.178	0.8	178	980	.820	.194	0.10	10	248
20	3.280	.144	0.8	200	776	.956	.184	0.10	11	260
21	3.348	.216	0.8	218	788	.944	.152	0.40	12	260
22	3.448	.190	1.2	238	888	1.116	.150	0.40	8	240

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[1] TS-Total Solids, TSS-Total Suspended Solids, SS-Settleable Solids, NO_s-Nitrates, COD-Chemical Oxygen Demand

Table II-4. Effect of washing on water quality in spinach processing.[1]

Wash Cycle[2]	TS[3] (g/l)	TSS (g/l)	SS (ml/l)	NO3 (mg/l)	COD (mg/l)
1-a	.252	.042	.12	9.6	216
b	.140	.020	.04	6.3	216
c	.176	.008	T	3.5	224
2-a	.312	.126	.20	16.9	224
b	.184	.028	.40	9.4	240
c	.160	.036	T	3.6	224
3-a	.668	.094	.22	22.2	224
b	.312	.020	.20	12.8	256
c	.180	.012	T	4.1	216
4-a	.692	.284	2.0	28.0	264
b	.360	.106	2.0	15.8	216
c	.168	.052	T	5.1	224
5-a	.724	.540	2.0	31.9	248
b	.384	.084	2.0	19.2	232
c	.188	.036	.4	6.4	224
6-a	.748	.496	2.4	37.9	240
b	.404	.180	1.6	22.2	232
c	.184	.020	.1	6.8	240
7-a	.788	.380	1.6	40.2	312
b	.504	.044	2.8	24.7	312
c	.196	.034	.1	7.6	264
8-a	.960	.420	4.0	46.0	240
b	.540	.386	2.0	28.1	272
c	.292	.060	1.2	9.0	152
9-a	.980	.626	2.4	50.9	240
b	.584	.672	2.0	30.1	280
c	.228	.062	.8	10.2	184
10-a	1.060	.720	2.4	54.1	288
b	.624	.248	1.2	34.0	312
c	.248	.074	.6	11.3	280

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[1] Successive 8 lb. lots were washed in 200 lb. water tanks per wash cycle.

[2] a-1st wash
b-2nd wash
c-recycle water

[3] TS-Total Solids, TSS-Total Suspended Solids, SS-Settleable Solids, NO_3-Nitrates, COD-Chemical Oxygen Demand.

Table II-5. Effect of sequence of water blanching and cooling on water quality in spinach processing.[1]

Blanch Cycle	TS[2] (g/l)	TSS (g/l)	SS (ml/l)	NO3 (mg/l)	COD (mg/l)	Cool Cycle	TS (g/l)	TSS (g/l)	SS (ml/l)	NO3 (mg/l)	COD (mg/l)
1	.256	.010	T	27	164	1	.128	.002	T	8.2	28
2	.344	.034	0.4	54	188	2	.168	.004	T	14.6	40
3	.480	.058	0.8	79	180	3	.184	.010	0.1	19.0	92
4	.624	.072	1.6	102	204	4	.220	.012	0.2	25.4	96
5	.808	.074	2.0	12	292	5	.344	.034	0.4	32.3	124
6	.888	.090	0.1	147	324	6	.296	.046	0.6	37.7	128
7	1.108	.098	0.1	172	264	7	.288	.052	0.8	43.5	144
8	1.200	.104	0.1	200	400	8	.332	.062	0.6	49.7	152
9	1.428	.110	0.1	229	436	9	.416	.068	0.8	59.1	178
10	1.520	.114	2.0	258	456	10	.456	.086	0.8	64.6	193

[1] Successive 8 lb. lots were blanched in 320 lb. of water and cooled in 200 lb. of water in kettles.

[2] TS-Total Solids, TSS-Total Suspended Solids, SS-Settleable Solids, NO_3-Nitrates COD-Chemical Oxygen Demand.

Table II-6. Effect of steam blanching and cooling on water quality in spinach processing.

	Steam Blanched[1]				Cooling			
Blanch Time (min)	TS (g/l)	TSS (g/l)	COD (mg/l)	NO_3 (mg/l)	TS (g/l)	TSS (g/l)	COD (mg/l)	NO_3 (mg/l)
½	2.674	.686	1189	1246	.125	.146	64	84
1	3.116	1.019	529	910	.172	.125	27	51
1½	2.906	.762	463	709	.221	.138	19	59
2	3.081	.800	346	637	.188	.112	16	47
2½	2.200	.320	390	800	.197	.134	66	53
3	2.195	.390	341	878	.262	.139	40	60
3½	1.867	.507	204	573	.240	.402	10	59
4	2.740	1.400	384	838	.216	.128	46	61

[1] TS-Total Solids, TSS-Total Suspended Solids, COD-Chemical Oxygen Demand, NO_3-Nitrates.

Table II-7. Effect of blanching and cooling on some quality attributes of canned spinach.

Blanch Cycle	Drained wt (g)	Shear-press (kg/100g)	Panel Rating[1] Color	Texture	Flavor	Color Attributes L	-a	b	NO_3 (mg/l)	OD Liquor 475nm
1-a[2]	268	55	7.0	7.5	7.0	21.4	0.6	10.8	138	.323
b	264	69	7.0	7.0	7.0	21.3	0.6	10.7	124	.348
2-a	261	53	8.0	7.5	7.5	21.5	0.6	10.8	145	.324
b	251	61	7.0	8.0	7.5	21.0	0.6	10.6	129	.326
3-a	276	50	8.0	6.5	6.5	21.6	0.9	10.9	138	.361
b	232	56	8.0	6.5	6.5	21.1	0.4	10.6	108	.337
4-a	251	54	7.5	7.0	7.0	20.9	0.4	10.6	123	.320
b	273	67	7.5	7.5	6.5	21.2	0.6	10.7	158	.340
5-a	276	55	9.0	7.5	7.0	21.4	0.7	10.8	132	.358
b	235	62	8.0	7.0	7.0	20.7	0.7	10.7	110	.290
6-a	273	67	8.5	8.0	8.0	21.2	0.7	10.8	130	.310
b	238	68	8.0	7.5	6.5	21.4	0.4	10.8	103	.319
7-a	274	51	8.0	6.5	7.0	22.2	0.5	11.4	124	.410
b	250	66	7.3	7.0	7.0	22.5	0.5	11.8	104	.375
8-a	271	56	7.0	7.0	6.0	22.5	0.5	11.3	133	.395
b	231	58	6.0	6.0	5.0	22.4	0.5	11.3	111	.360
9-a	278	65	6.0	5.0	6.0	22.5	0.5	11.3	137	.377
b	246	66	6.0	7.0	6.0	22.3	0.5	11.3	113	.385
10-a	285	61	6.0	6.0	6.0	22.4	0.5	11.3	161	.370
b	266	71	6.0	6.3	6.0	22.6	0.5	11.3	118	.350
11-a	247	71	6.0	7.0	6.5	22.3	0.1	11.3	118	.310
b	292	72	7.0	6.5	6.5	2217	0.1	11.7	125	.347
12-a	293	63	6.5	7.0	7.0	22.7	0.1	11.7	139	.330
b	256	62	6.5	7.0	7.5	22.5	0.1	11.7	115	.315
13-a	276	70	7.0	6.0	5.0	21.2	0.4	11.7	130	.332
b	254	69	7.0	7.0	6.0	21.5	0.4	11.7	121	.250
14-a	268	64	7.0	6.0	6.0	21.8	0.4	11.1	144	.301
b	250	58	8.0	7.0	7.0	21.8	0.1	11.1	117	.261
15-a	277	76	7.0	6.0	6.0	21.4	0.1	11.1	141	.302
b	255	60	6.0	7.0	6.0	21.7	0.1	11.1	115	.296
16-a	291	103	7.0	6.0	7.0	21.8	0.1	11.1	131	.293
b	267	72	7.0	6.0	7.0	22.0	0.1	11.1	113	.287
17-a	285	63	8.0	7.0	6.0	21.0	0.1	11.1	160	.302
b	258	54	7.0	6.0	7.0	21.0	0.1	11.1	97	.339
18-a	286	54	7.0	6.0	6.0	21.6	0.1	11.1	132	.301
b	251	57	6.0	6.0	6.0	21.5	0.1	10.8	93	.290

Table II-7. Continued.

Blanch Cycle	Drained wt (g)	Shear-press (kg/100g)	Panel Rating[1] Color	Texture	Flavor	Color Attributes L	-a	b	NO_3 (mg/l)	OD Liquor 475nm
19-a	275	69	7.0	7.0	7.0	21.8	0.1	11.1	150	.271
b	276	66	7.0	7.0	7.0	21.8	0.1	11.1	133	.287
20-a	288	57	8.0	7.0	7.0	21.8	0.1	11.1	152	.346
b	274	66	7.0	6.0	7.0	21.7	0.1	11.1	135	.310
21-a	275	58	6.0	7.0	6.0	21.8	0.1	11.1	169	.328
b	267	68	7.0	6.0	6.0	22.1	0.1	11.1	152	.292
22-a	275	65	7.0	7.0	7.0	21.8	0.1	11.1	131	.321
b	256	71	6.0	7.0	6.0	21.7	0.1	11.1	129	.270

[1] Rated on scale of 10-best to 1-poor.

[2] a-blanched--not cooled
b-blanched--cooled

Table II-8. Effect of blanching and cooling on some quality attributes of canned spinach.

Blanch Cycle	Drained wt (g)	Shear-press (kg/100g)	Panel Rating[1]			Color Attributes			NO_3 (mg/l)	OD Liquor 475nm
			Color	Texture	Flavor	L	-a	b		
1-a[2]	251	105	7.5	8.0	7.0	21.3	0.0	11.2	158	.310
b	218	126	7.0	6.5	6.0	21.0	0.0	11.0	123	.275
2-a	249	99	8.8	8.5	9.0	21.1	0.0	11.1	159	.335
b	228	105	7.0	7.5	7.5	21.8	0.0	11.5	114	.285
3-a	252	102	8.3	8.0	8.0	20.6	0.0	10.9	137	.315
b	241	105	9.0	8.0	8.0	20.6	0.0	10.9	129	.305
4-a	249	108	7.8	8.0	7.5	21.2	0.0	11.4	160	.305
b	235	113	6.5	8.0	7.5	21.8	0.0	11.6	112	.290
5-a	249	112	8.0	7.8	8.0	20.7	0.0	11.0	155	.290
b	243	84	7.5	7.5	7.5	22.2	0.0	11.9	127	.300
6-a	252	78	7.0	8.0	7.5	21.4	0.0	11.3	144	.325
b	233	80	8.0	8.0	8.0	20.7	0.0	10.9	112	.300
7-a	234	83	7.0	7.5	7.5	22.2	0.7	11.2	142	.260
b	241	92	7.3	8.0	7.0	22.1	0.7	11.2	141	.300
8-a	256	91	7.5	8.0	7.8	22.5	0.7	11.2	151	.269
b	231	103	8.3	8.0	7.5	22.4	0.7	11.2	136	.298
9-a	262	73	8.0	8.0	8.0	22.0	0.7	11.2	161	.213
b	240	79	7.5	7.0	7.0	22.4	0.7	11.2	128	.250
10-a	252	103	6.5	8.0	7.0	21.7	0.7	11.8	149	.289
b	244	107	8.5	8.5	8.5	22.1	0.7	11.3	127	.253

[1] Rated on scale of 10-best to 1-poor.

[2] a-blanched--not cooled
b-blanched--cooled

Table II-9. Effect of steam blanching and cooling at various times on some quality attributes of canned spinach.

Blanch Cycle	Drained wt (g)	Shear-press (kg/100g)	Panel Rating[1]			Color Attributes			NO_3 (mg/l)	OD Liquor 475 nm
			Color	Texture	Flavor	L	a	b		
½-a	257	116	8.0	7.7	8.0	22.8	0.0	10.7	216	.405
b	279	95	8.7	8.3	8.0	20.1	0.0	9.7	.86	.385
1 -a	263	100	9.0	9.0	8.3	22.1	0.0	9.3	208	.385
b	257	84	6.7	6.7	6.7	22.6	-0.8	9.8	148	.350
1½-a	288	104	7.8	8.0	7.7	20.6	-0.4	9.3	223	.383
b	239	98	7.7	7.7	7.7	23.0	-0.3	9.8	150	.374
2 -a	281	79	7.5	7.0	7.5	21.7	0.7	11.1	180	.370
b	229	88	8.5	8.0	8.5	21.8	0.4	11.2	148	.325
2½-a	274	104	8.0	8.0	8.5	23.0	0.4	11.9	210	.370
b	214	83	8.0	7.5	8.0	22.1	0.4	11.3	130	.310
3 -a	278	95	8.0	7.5	7.5	22.9	0.4	11.8	182	.380
b	217	80	5.0	5.5	5.0	21.3	0.4	k0.9	104	.275
3½-a	274	90	7.0	7.0	5.5	22.2	0.3	11.5	199	.345
b	247	104	6.5	7.0	7.0	22.2	0.3	11.5	148	.330
4 -a	267	91	7.0	7.0	7.0	23.5	0.3	12.2	202	.355
b	245	72	7.0	6.5	6.5	22.6	0.3	11.7	158	.345

[1] Rated on scale of 10-best to 1-poor.

[2] a-steam blanched--not cooled
b-steam blanched--cooled

III. Bean type, soak time, soak temperature and storage of canned dry beans.

This study was instigated as a result of the high wastestrength of the effluent from processing dry beans found in the preliminary survey of water quality (Section I). Alternate methods of processing appear to offer great reductions in wastewater strength when evaluating data from this research (Appendix B-1). More detailed information has been recorded in a Master's thesis (Appendix D-5).

The materials and methods of this research have been described in the journal article (Appendix B-1) and in the thesis. Bean types significantly influenced the COD, total phosphorus (TP) and TSS of the effluent from soaking dry beans. Navy beans generated much higher wastestrength than pinto and Red Kidney. Longer soak times and higher temperatures leached out more soluble constituents, thus greater wastestrength. Among the soak treatments, which included different concentrations of EDTA and malic and citric aicds in comparison to tap and deionized water controls, acid treatments increased COD due to the chemical structure and probably more leaching.

In the canned product which was set up as a factorial experiment with 3 bean types, 11 treatments, 3 soak temperatures, and 3 soak times, the canned beans were stored for 3,6, and 18 months prior to sensory evaluation and other objective determinations. There were significant differences among bean types (Table III-1). Navy beans had more splits but were rated lower in sensory color. Drained weight was higher on pinto beans while Red Kidney rated higher in general appearance possibly due to low % splits and color brightness.

Soaking treatments did not greatly affect quality except that most of the EDTA and acid treatments produced better color. However, only EDTA did not influence COD (Appendix B-1). Soaking times did not greatly influence quality as shown by 'a' values, sensory color and appearance (Table III-1), yet drained weights and % splits were higher and shearpress values lower on beans soaked 14 hours. A higher soak temperature ($35^{o}C$) increased % splits and decreased shearpress values but did not affect other quality parameters appreciably. The effects of 18 month storage on quality parameters varied although the canned beans became slightly lighter as shown by the 'L' values and redder by the 'a' values. This effect was probably produced by the slow change during storage due to the EDTA and acid treatments.

Table III-1. Quality attributes of canned dry beans as affected by bean type, soaking conditions and duration of storage.

Main effects	Drained wt(g)	% Splits	Shear values lb/150g	CDM			Color	
				L	a	b	Color	General appearance
Bean Type								
Navy	172b[z]	68.1a	226a	53.8a	2.9c	15.4a	6.8c	7.0b
Red Kidney	173b	21.6c	230a	20.4c	10.6a	2.8c	7.5a	7.6a
Pinto	177a	45.6b	178b	40.4b	8.6b	13.6b	7.2b	7.1b
Soaking Solution								
200 ppm EDTA	174bcde	45.0b	206def	37.7de	7.4bc	10.4de	7.0cd	7.1cd
400 ppm EDTA	178a	46.5b	197f	37.9cde	7.7a	10.6bcd	7.1bc	7.1cd
600 ppm EDTA	177ab	42.8b	202ef	38.4abc	7.8a	10.7bc	7.3b	7.3bc
0.1% Malic acid	173cde	44.6b	211cde	37.8cde	7.2bc	10.5cd	6.8de	7.0de
0.2% Malic acid	171ef	44.7b	221abc	38.3bcd	7.2bc	10.6bcd	6.9cde	7.1cd
0.3% Malic acid	170f	44.1b	232a	39.0a	7.5ab	11.0a	7.6a	7.5ab
0.1% Citric acid	175bcd	43.3b	209de	38.1bcd	7.1c	10.5cd	7.1bc	7.1cd
0.2% Citric acid	172def	44.8b	213bcd	38.7ab	7.3bc	10.8ab	7.7a	7.6a
0.3% Citric acid	171ef	44.6b	223ab	38.9a	7.5ab	11.0a	7.8a	7.7a
Tap water	175bcd	48.0a	207def	37.4e	7.1c	10.2e	6.7e	6.8e
Deionized Water	175abc	47.7a	203def	37.7de	7.0c	10.2e	6.9cde	7.9de
Soak Time								
3 hr	171b	41.9c	241a	37.4c	7.3a	10.5b	7.1b	7.1b
6 hr	169c	45.1b	204b	38.2b	7.3a	10.7a	7.2ab	7.3a
14 hr	181a	48.2a	189c	39.0a	7.4a	10.7a	7.3a	7.3a
Soak Temperature								
15°C	172b	44.4b	240a	37.5b	7.2b	10.4c	7.0c	7.0b
25°C	175a	45.1b	208b	38.5a	7.6a	10.8a	7.4a	7.4a
35°C	174a	48.2a	187c	38.5a	7.3b	10.6b	7.2b	7.2b
Storage								
3 mo	175a	42.7b	215a	37.6b	6.4b	10.1c	7.4a	7.3a
6 mo	174a	47.8a	206b	37.2c	6.6b	10.6b	7.1b	7.2a
18-24 mo	172b	44.8b	213a	39.8a	9.1a	11.7a	7.1b	7.2a

[z] Mean comparisons within each variable of a quality attribute established using Duncan's Multiple Range Test, 5%.

IV. Method of peeling and bleaching corn for hominy.

The present method of peeling hominy used by the regional industry involves cooking of the dry corn in 1.5 to 2% caustic soda (NaOH) for 20 to 30 minutes followed by peeling in a reel with water sprays. All pericarp, germ and other residue is washed into the effluent. The experimental peeling method that was compared with the conventional method in this study involved dipping the dry corn in 10% boiling caustic soda for 1 to 5 minutes followed by 5 to 20 minutes of holding in steam. A 3 minute dip and 10 minute holding time was the better procedure since the corn held for longer times was more difficult to bleach.

The yield of drained canned hominy from the two methods of peeling was the same (Table IV-1). Corn gained approximately 50% in weight during peeling, bleaching and pre-cooking and the remainder during retorting for 29 minutes at 116^{o}C. The experimental dip method resulted in a smoother peel of corn although the tips were more difficult to remove. The corn peeled by the conventional method was more difficult to bleach because of the deeper penetration of caustic and longer time exposure. Apparently in the dip method there is more uniform exposure to lye which resulted in a smoother peel. There appeared to be very little difference in color and firmness of canned hominy although tips remaining on the grains in the dip-peeled corn affected the rating for tips (Table IV-2). In general, the corn peeled by the dip method was more attractive although data did not definitely reflect this observation.

It was noted that bleaching in HCl instead of $NaHSO_3$ resulted in a better color in canned hominy (Table IV-3). However, shearpress values were slightly higher, indicating firmer grains. Corn peeled by the dip method was lighter in color as shown by the higher 'L' values. Also, the HCl-bleached corn was higher in 'L' values and more attractive.

The main advantage of the dip method would be the smoother peel and the ease of bleaching the corn after peeling, However, the pericarp, caustic and other residue could be removed as heavy solid residue with a minimum of water in the first stage of scrubbing; whereas, a second stage could be used for the final rinsing of corn. Apparently there is very little difference in total COD removed in the peeling operation regardless of the method (Table IV-4). However, there is a greater proportion of COD removed in the bleaching step following the dip method but most of the COD is removed in the initial peel in the conventional method. Samples that were dip-peeled and bleached with HCl were lower in average COD of the residue. Soluble sugars, starch and other carbohydrates are removed at each step in the preparation process as shown by the distribution of COD values.

The dip method of peeling hominy offers several advantages over the conventional method that should be considered by the canning industry. Also, changing the method of residue removal following caustic treatment by isolating the heavy residue would significantly reduce COD of the effluent. This would involve adding an additional peeling reel or modifying the present peeling equipment.

Table IV-1. Comparison of the yield of hominy from conventional and experimental methods of peeling corn.[z]

Method	Rep..	After bleach (g)	After pre-cook (g)	After canning (g)	Yield[y]
Conventional	1	264	317	461	230.5
	2	265	321	480	240.0
	3	240	299	464	232.0
Experimental	1	267	294	467	233.5
	2	257	316	468	234.0
	3	280	352	536	268.0

[z] 200g samples of dry corn peeled.

[y] Yield (lb) of drained hominy per 100 lb dry corn.

Table IV-2. Effect of peel method on color, firmness and sensory quality of canned hominy.[z]

Method	Rep.	CDM			Shearpress lb/150g	Sensory[z]	
		L	-a	b		General appearance	tips
Conventional	1	75.5	3.0	7.1	290	9	9
	2	74.3	2.2	8.2	268	8	9
	3	76.2	2.9	7.6	355	8	9
Experimental	1	75.8	3.2	7.7	326	9	8
	2	74.7	2.9	7.4	308	9	8
	3	77.6	3.4	8.3	354	8	7

[z] Rated by panel of 4 judges on scale of 10-best to 1-poor.

Table IV-3. Effect of method of peeling and bleaching on quality of canned hominy.

Peel method	Bleach method	Rep.	CDM L	CDM -a	CDM b	Shearpress lb/150g	Sensory[z] color
Conventional	$NaHSO_3$	1	72.0	2.1	8.3	216	8
	$NaHSO_3$	2	73.7	2.6	7.7	255	8
	HCl	1	74.4	2.7	8.4	298	9
	HCl	2	74.3	2.8	7.3	284	9
Experimental	$NaHSO_3$	1	75.5	3.0	6.1	268	8
	$NaHSO_3$	2	74.9	2.8	6.3	257	8
	HCl	1	77.6	3.2	7.6	291	9
	HCl	2	76.9	3.0	7.2	284	10

[z] Rated by a panel of 4 judges on a scale of 10-best to 1-poor.

Table IV-4. Comparison of Chemical Oxygen Demand (COD) of effluent from conventional and experimental peeling of corn for hominy.

		Preparation Step[z]					
Method	Rep.	Peel	Rinse	Bleach	Soak	Cook	Average
				mg/l effluent			
Conventional	1	35,360	6,400	14,560	4,800	7,700	13,776
	2	39,480	3,480	10,200	3,960	6,900	12,816
Conventional	1	24,400	13,360	4,560	13,360	7,360	12,608
Neutralized[y]	2	26,040	7,080	8,640	13,320	8,040	12,624
Experimental	1	7,040	10,048	25,728	9,280	11,328	12,685
	2	5,640	4,320	32,520	8,880	14,880	13,248
Experimental	1	4,800	5,040	20,360	11,328	10,688	10,443
Neutralized	2	4,080	3,840	19,320	8,040	16,800	10,416

[z] For 100g of corn the following water volumes were used: rinse-2500 ml; bleach- 500; soak-200; and boil-500.

[y] Sample neutralized with HCl after peeling.

V. Spinach and Leafy Greens Washing System

A. Spinach

1. Water quality

The industrial washer produced a greater amount of total suspended solids (TSS), total solids (TS), settleable solids (SS) as well as chemical oxygen demand (COD) and nitrates (NO_3) (Tables V-1, V-2, V-3). This was evidenced by the large differences in values between the two systems. The sampling sites could possibly contribute to part of the differences between TS and SS as shown by earlier workers (36). In the experimental washing system the sample was taken from the top of the settling tank, in which all heavy particles had settled to the bottom. Whereas, in the industrial washer, the samples were taken from beneath the reels and from the top of the two paddle washers. Heavy sand and other particles would have settled out from the water in the paddle washers. The NO_3, TS, and COD were expected to be lower in the experimental washer rather than the industrial washer since there is much more physical damage to the produce in the industrial washer, which causes more sugars, NO_3 and organic acids to be leached out. Similar results on TSS, BOD, and COD were reported by Wright et al. (36) when comparing the prototype washer and conventional washers. The runs or days show the combined data of the two systems in which there was some variability among days in both 1978 and 1979 (V-1,2,3). There was a significant difference for TSS, SS, COD, and NO_3. The time of day that the sample was taken was significant only for TSS in 1978 indicating that the product was uniform in soil residue. In 1979, a great difference in the amount of soil on the raw product which increased TS and SS (Tables V-2,3) affected the results.

When looking at the interaction of system and runs, the industrial system produced water with more waste in the 2nd and 3rd runs as evidenced by the large difference in values between the two systems in TSS, TS, COD and nitrates (Table V-4,5). The regulation of the overflow in the experimental washer and heavier product flow through this system in the 1st run probably accounted for this smaller difference in water quality. The greater physical damage imposed on spinach washed in the industrial washer also contributed to the interaction.

There was greater variability among the times of day for TSS and TS between the two systems that contributed to the interaction of systems and times (Table V-6). In all cases the industrial washer produced more waste but the differences were much greater at certain sampling times (1st, 3rd, 5th, 7th).

2. Canned Spinach

Washing systems had no significant effect on the CDM color when color measurements were made on the whole spinach (Tables V-7,8,9). However, when the color of the pureed spinach was measured, the 'a' values of the samples washed in the experimental washer were higher (Tables V-8,9). Time of day had a significant influence on color of pureed samples. Some of the variation in color between runs and time of day could be accounted for by changes in the type of spinach, savoy and semi-savoy, being processed.

The interaction between runs and times on 'L' value (pureed) of canned spinach was due primarily to the lighter colored spinach in the first 3 samples of the 2nd run (Table V-10).

Spinach from the experimental washer generally showed greater amounts of ascorbic acid and nitrates than the industrial washer (Tables V-11,12,13). This was probably caused by more physical damage to the product in the industrial washer and the leaching of solutes. In 2 of the 3 studies, drained weight of spinach canned from the experimental washer was significantly lower than that canned after being washed in the industrial washer. The drained weight, ascorbic acid, nitrates and shearpress values varied between days of operation. This variation on different days was probably due to the leaf type as the product varied from smooth-leaf to savoyed-leaf between days. Time of day had some influence on quality of the spinach. The quality factors affected here varied between studies (Tables V-11,12,13). Type of spinach processed at a particular time had a definite effect on most quality attributes. The smooth-leaf type was damaged more by the industrial washer; whereas, very little damage was evident when washed by the experimental washer. Neither washing system, runs nor times of day affected the amount of sand or grit in canned spinach.

The interaction between system and runs on ascorbic acid of canned spinach was caused by greater differences in ascorbic acid during runs (Table V-14). Phosphates were slightly higher in samples from the first run of the experimental washer; whereas, the opposite was true for the industrial washer (Table V-15). The decrease in ascorbic acid between the first and second runs of the experimental washer was greater than that occurring with the industrial washer; ascorbic acid levels in samples from the second run from both systems were similar. Although both washers produced samples of equivalent toughness during the first run, the second run samples washed in the industrial washer were more firm than those from the experimental washer.

The interaction of systems and times on nitrates of canned spinach indicated that there was more variability in the 1st and 7th sampling time between the two systems (Table V-16). The highest amount of nitrates were found at the 4th sampling time which was the only time the water from the experimental systems was higher in nitrates.

The interaction of runs and times was contributed largely by the wide variation in nitrates during the 2nd run. The only explanation offered for this difference might be changes in spinach type (V-17).

The interaction of runs and times on shearpress values of canned spinach was caused by the tougher spinach during part of the 1st run and the first sample of 2nd run (Table V-18). More resistance to shear was attributed to the fact that more smooth-leaf spinach was processed during the 1st run and the beginning of the 2nd run.

The interaction of runs and times was significant for canned spinach when looking at the drained weight (Table V-19). The high drained weights at the 2nd, 3rd and 5th time of the 2nd run contributed to part of the interaction. Drained weights were low in most samples from the 3rd run.

3. Frozen Spinach

When comparing the two systems on the frozen spinach, there was no significant difference in either ascorbic acid, 'L' value or 'a/b' ratio (Table V-20). Again, as the canned spinach, there was a significance in ascorbic acid and CDM 'L' value when comparing runs or days (Table V-20). The time of day was significant for ascorbic acid, being the highest earlier in the morning and the values were lowest at the later time of sampling. This cannot really be explained since the washed samples from the earlier times were held longer after washing before processing, yet the later samples came from spinach that remained on the truck longer.

B. Turnip and Mustard Greens

1. Water Quality.

The data from a 4 hour run on each of turnip and mustard greens were analyzed as one experiment. The effluent from the industrial washer was higher in TSS, TS, SS, COD and nitrates than the effluent from the experimental washer (Table V-21). Again, the industrial washer produced more physical damage to the product, although it was not as distintive as in spinach. Effluent from the mustard greens were significantly higher in TSS, TS, SS, and COD. Time of sampling during the day did not affect water quality except in TSS. The value for TSS was much higher at the 1st sampling time, indicating more soil on the greens from the first load.

The interaction of systems and type of greens on TSS indicated that there was a greater difference in the lb/ton of TSS between the systems when washing mustard greens (Table V-22).

When looking at the interaction of systems and time, the TSS of the effluent from the industrial washer was much higher than that of the experimental washer (Table V-23). Most of the interaction was caused by the large difference between systems in the 1st sample and small differencein the 4th effluent sample from the experimental washer.

2. Canned turnip and mustard greens.

There was no significant differences between the two washing systems, whether the sample was whole or pureed, for color of the samples according to the 'L' value and 'a/b' ratio (Table V-24). Whereas, the mustard greens were lighter in color than the turnip greens as noted in the 'L' value (pureed and whole), and 'a/b' ratio (pureed). Also, there was a difference in color of the greens at different sampling times, as shown by the 'L' value (whole) and 'a/b' ratio (whole and pureed). Neither washing system, type of greens nor time of sampling had a significant effect on liquor color.

The interaction of type of greens and time of sampling on liquor color of canned turnip and mustard greens demonstrated that there was more variation in liquor color of canned mustard (Table V-25). The interaction was caused by the larger differences of the mustard at the 3rd, 5th and 6th sampling times and the small differences of the turnips at the 5th and 7th sampling times.

When comparing the two washing systems, there was no significant difference for drained weight, grit, ascorbic acid, NO_3 and shearpress values (Table V-26). The mustard was lower in drained weight, NO_3, and grit but higher in ascorbic acid. The time of sampling during the runs had a significant effect on all quality attributes measured except NO_3 values and grit. The chloride was not removed from the samples before the NO_3 analyses. This effect was expected since the greens varied between loads and between turnip and mustard greens.

The interaction of type of greens and time of sampling on drained weight of canned turnip and mustard was significant (Table V-27). Generally, the drained weight was significantly higher on turnip than on mustard greens but the fact that the difference in drained weight was much greater at the 2nd and 5th sampling time produced an interaction between type of greens and time.

C. Bacterial Count of Wash Water

Total plate counts on the effluent from washing spinach and leafy greens were inconsistent during the operation on different days, depending on the amount of soil and grit on the raw product. There were significant differences between sampling sites in water from both the industrial and experimental washers (Table V-28), also, there was a difference in bacterial count between runs or days of operation. In most instances, the highest counts were found in water from the first washer. However, there were no differences in counts between washing systems. Recycling water did not increase counts. In fact, there was a tendency for counts to be lower on recycled water. Wright et al (36) reported that total plate counts were lower on water that was recycled. There were no significant interactions on total plate counts due to washing systems, runs and time of sampling. The most important differences occurred in samples from different days of operation.

In turnip and mustard greens, similar results were obtained except that mustard greens were lower in counts than turnip greens (Table V-29). Again, water from different sampling sites showed significant differences but there were no differences between washing systems. In recycling of water, if sufficient make-up water was added, the bacterial counts were not higher than the first wash water.

Table V-1.Main effects of washing systems, runs and time of day on water quality of the effluent from washing spinach, 1978.

Variable	Suspended Solids lb/ton	Total Solids lb/ton	Settleable Solids lb/ton	COD lb/ ton	Nitrates lb/ ton
System					
Industrial	12.15	19.63	49.10	4.76	1.30
Experimental	5.49	7.23	18.61	1.02	0.34
$LSD_{.05}$	0.43	1.75	5.98	0.50	0.17
RUNS (days)					
1st	9.65	13.60	47.17	1.54	0.88
2nd	8.01	13.88	33.17	2.84	0.95
3rd	8.80	12.81	20.69	4.31	0.61
$LSD_{.05}$	0.17	NS	7.33	0.605	0.21
Time					
8:30	8.10	10.69	29.73	2.44	0.75
9:00	8.75	12.87	34.62	2.66	0.74
9:30	9.84	13.51	38.57	2.75	0.79
10:00	7.37	12.61	35.04	3.12	0.74
10:30	9.97	15.51	27.60	3.01	1.08
11:00	8.62	14.35	34.18	3.30	0.78
11:30	9.10	14.47	37.26	3.01	0.80
$LSD_{.05}$	0.26	NS	NS	NS	NS

$LSD_{.05}$ - least significant difference at 5% level.
NS - Non-significant

Table V-2. Main effects of washing systems, runs and time of day on water quality of the effluent from washing spinach, 1979.

Variable	Suspended solids kg/mt	Total solids kg/mt	Settleable solids l/mt	COD kg/mt
System				
Industrial	11.27	18.77	29.94	20.66
Experimental	2.25	3.97	5.05	4.57
LSD .05	2.73	2.19	7.12	3.47
Runs				
1st	4.67	8.32	13.55	11.34
2nd	8.85	14.42	21.44	13.90
LSD .05	2.73	2.19	7.12	NS
Time				
8:15	9.91	13.31	21.80	15.88
9:00	9.81	17.14	35.27	16.11
9:45	5.81	10.41	21.89	15.34
10:30	5.44	10.15	7.25	9.59
11:15	5.51	11.48	14.99	7.75
12:00	4.09	5.70	3.76	11.03
LSD .05	NS	3.80	12.33	6.01

Table V-3. Main effects of washing systems, runs, and time of day on water quality of the effluent from washing spinach, 1979.

Variable	Suspended solids kg/mt	Total solids kg/mt	COD kg/mt	Nitrates lb/ton
System				
Industrial	4.46	9.50	9.72	17.50
Experimental	2.84	3.94	3.63	6.52
LSD .05	.76	1.09	1.58	1.73
Runs				
1st	3.49	5.54	8.15	8.12
2nd	3.82	7.90	5.20	15.89
LSD .05	NS	1.09	1.58	1.73
Time				
9:30	2.05	5.04	4.83	9.95
10:00	2.36	4.69	6.82	8.76
10:30	3.29	5.09	7.21	11.23
11:00	3.31	5.56	6.41	13.06
11:30	2.72	6.36	6.78	10.73
12:00	3.03	6.34	5.75	12.01
1:15	3.29	6.50	7.81	12.54
1:45	2.57	7.50	7.51	15.06
2:15	4.86	8.31	5.32	15.00
2:45	6.32	10.55	7.39	12.68
3:15	5.61	7.38	6.58	11.67
3:45	4.43	7.31	7.69	11.41
LSD .05	1.87	2.68	NS	NS

Table V-5. Interaction of systems x runs on water quality of the effluent from washing spinach, 1979.

	Total solids (Feb.-March)	COD (April-May)	Nitrates (April-May)
Industrial			
Run I	14.27	12.29	11.96
Run II	23.26	7.15	4.29
Experimental			
Run I	2.36	4.00	23.04
Run II	5.57	3.25	8.75
LSD .05	3.05	2.23	2.43

TableV-4. Interaction of Systems X Runs on water quality of effluent from washing spinach, 1978.

Variable	Suspended Solids lb/ton	Total Solids lb/ton	COD lb/ ton	Nitrate lb/ ton
Run 1				
Industrial	11.26	16.99	2.13	1.26
Experimental	8.04	10.21	0.94	0.50
Run 2				
Industrial	11.91	21.53	4.53	1.57
Experimental	3.90	6.23	1.14	0.32
Run 3				
Industrial	13.06	20.36	7.63	1.03
Experimental	4.50	5.26	0.98	0.20
$LSD_{.05}$	0.24	3.10	0.86	0.30

$LSD_{.05}$ - Least significant difference at 5% level.

Table V-6.Interaction of Systems X Times on suspended and total solids of effluent from washing spinach, 1978.

Variable	8:30	9:00	9:30	10:00	10:30	11:00	11:30
Suspended Solids (lb/ton)							
Industrial	12.85	11.90	13.23	8.72	13.24	11.26	13.82
Experimental	3.36	5.60	6.45	6.01	6.71	5.97	4.32
$LSD_{.05}$	0.0002						
Total Solids (lb/ton)							
Industrial	18.19	18.99	19.08	16.59	22.26	20.12	22.15
Experimental	3.20	6.75	7.93	8.63	8.76	8.59	6.79
$LSD_{.05}$	4.62						

$LSD_{.05}$ - Least significant difference at 5% level.

Table V-7. Main effects of washing systems, runs and time of day on quality of canned spinach, 1978.

	Color Difference Meter				
Variable	"L" Whole	"L" Pureed	a/b Whole	a/b Pureed	Liquor Color (OD-475 nm)
System					
Industrial	24.2	23.6	0.136	0.061	0.357
Experimental	23.7	23.5	0.136	0.064	0.326
$LSD_{.05}$	NS	NS	NS	NS	NS
Runs (days)					
1st	24.44	23.7	0.150	0.084	0.430
2nd	23.91	23.8	0.148	0.057	0.771
3rd	23.54	23.3	0.112	0.048	0.253
$LSD_{.05}$	NS	0.31	0.010	NS	NS
Time (hr)					
8:30	25.1	24.0	0.154	0.066	0.327
9:00	23.9	23.5	0.138	0.064	0.333
9:30	23.5	23.5	0.140	0.066	0.436
10:00	22.9	23.0	0.142	0.067	0.411
10:30	24.0	23.7	0.133	0.056	0.294
11:00	25.6	23.6	0.127	0.063	0.293
11:30	23.8	23.9	0.125	0.056	0.297
$LSD_{.05}$	NS	0.5	NS	NS	NS

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Non-significant

Table V-8. Main effects of washing systems, runs and time of day on quality of canned spinach, 1979.

Variable	Drained weight (g)	Whole Spinach CDM 'L'	'-a'	'b'	Pureed Spinach CDM 'L'	'-a'	'b'	Liquor color (OD-475nm)
System								
Industrial	241	26.3	.19	11.3	26.3	.27	12.1	.277
Experimental	230	26.4	.09	11.4	26.2	.38	12.1	.304
LSD .05	7	NS	NS	NS	NS	.06	NS	NS
Runs								
1st	240	25.6	.01	11.0	26.3	.38	12.0	.289
2nd	231	27.1	.28	11.7	26.2	.27	12.2	.293
LSD .05	7	1.1	.14	.6	NS	.06	.1	NS
Time								
8:15	242	26.5	.06	11.5	26.4	.38	12.2	.297
9:00	243	25.8	.28	11.2	26.1	.18	11.9	.317
9:45	236	26.9	.11	11.6	26.6	.36	12.2	.287
10:30	233	26.9	.20	11.5	26.1	.25	12.1	.287
11:15	234	25.3	.08	10.8	26.3	.28	12.2	.291
12:00	226	26.5	.08	11.7	26.0	.51	12.1	.266
LSD .05	NS	NS	NS	NS	.3	.11	NS	.018

Table V-9. Main effects of washing systems, runs and time of day on quality of canned spinach, 1979.

Variable	Whole Color CDM 'L'	Whole Color CDM '-a'	Whole Color CDM 'b'	Puree Color CDM 'L'	Puree Color CDM '-a'	Puree Color CDM 'b'	Liquor color (OD-475nm)
System							
Industrial	27.4	.60	12.2	26.2	.05	12.7	.304
Expimental	27.3	.42	12.2	26.1	.12	12.8	.341
LSD .05	NS	0.14	NS	NS	.05	NS	.008
Runs							
1st	27.1	.36	12.2	26.3	.11	12.9	.307
2nd	27.5	.66	12.2	27.1	.06	12.6	.338
LSD .05	NS	0.14	NS	0.2	.05	0.1	.008
Time							
9:30	27.2	.49	12.0	26.3	.10	12.8	.328
10:00	28.7	.68	13.0	27.1	.03	13.3	.332
10:30	26.9	.58	12.1	25.5	.04	12.4	.309
11:00	27.6	.42	12.2	25.7	.17	12.5	.301
11:30	26.3	.34	11.7	26.3	.09	12.8	.333
12:00	27.4	.29	12.3	26.2	.12	12.8	.335
1:15	27.3	.63	12.0	25.9	.19	12.6	.325
1:45	27.3	.64	12.1	26.2	.04	12.8	.320
LSD .05	NS	NS	NS	0.4	.10	0.2	.017

Table V-10. Interaction of Runs X Times on "L" (Pureed) value of canned spinach, 1978.

Variables	8:30	9:00	9:30	10:00	10:30	11:00	11:30
				CDM "L" Values			
<u>Runs</u>							
1st	23.8	23.0	23.2	22.9	24.3	24	24.2
2nd	25.0	24.4	24.2	22.9	23.1	22.9	24.1
3rd	23.1	23.1	23.0	23.1	23.8	23.8	23.3
$LSD_{.05}$	.826						

$LSD_{.05}$ - Least Significant Difference at 5% level.

TableV-11.Main effects of washing systems, runs and time of day on quality of canned spinach, 1978.

Variable	Drained Weight(g)	Grit g/150g	Ascorbic Acid mg/100g	Nitrate PPM	Shearpress lb/150g
System					
Industrial	258.9	0.005	12.7	696	92
Experimental	269.4	0.004	14.3	766	92
LSD$_{.05}$	4.5	NS	0.8	4.8	NS
Runs(days)					
1st	263.6	0.003	8.4	644	122
2nd	275.9	0.004	14.9	1,053	89
3rd	252.9	0.007	17.3	495	65
LSD$_{.05}$	5.5	NS	1.0	6.8	13.8
Time					
8:30	261.8	0.003	13.4	633	107
9:00	268.2	0.005	14.2	657	88
9:30	271.0	0.004	13.8	640	91
10:00	264.8	0.006	13.0	936	77
10:30	262.4	0.004	14.4	831	90
11:00	263.7	0.005	13.5	822	92
11:30	257.1	0.004	12.2	594	101
LSD$_{.05}$	8.4	NS	NS	8.9	NS

LSD$_{.05}$ - Least Significant Difference at 5% level.

NS - Not Significant

Table V-12. Main effects of washing systems, runs and time of day on quality of canned spinach, 1979.

Variable	Drained weight (g)	Grit g/300g	Ascorbic acid mg/100g	Nitrate ppm	Phosphates mg/ml	Shearpress lb/150g
System						
Industrial	241	.0125	23.3	433	69	99
Experimental	230	.0120	24.4	487	78	96
LSD .05	7	NS	NS	10	5	NS
Runs						
1st	240	.0170	26.3	390	76	95
2nd	231	.0075	21.4	530	71	101
LSD .05	7	.006	1.3	12	NS	NS
Time						
8:15	242	.0130	20.8	427	47	112
9:00	243	.0187	21.9	449	75	104
9:45	236	.0083	25.2	495	75	99
10:30	233	.0121	22.4	493	76	93
11:15	234	.0084	21.8	463	56	95
12:00	226	.0133	31.0	459	114	84
LSD .05	NS	NS	2.3	18	9	11

Table V-13. Main effects of washing systems, runs, and time of day on quality of canned spinach, 1979.

Variable	Drained weight (g)	Grit g/300g	Ascorbic acid mg/100g	Nitrate ppm	Phosphates mg/ml	Shearpress lb/150g
System						
Industrial	246	.0089	24.6	501	99	90
Experimental	230	.0114	29.5	678	116	81
LSD .05	5	.0024	1.7	37	NS	4
Runs						
1st	239	.0094	39.9	423	166	85
2nd	245	.0109	14.2	755	49	87
LSD .05	5	NS	1.7	37	18	NS
Time						
9:30	245	.0101	24.9	598	69	79
10:00	236	.0101	28.2	566	63	83
10:30	244	.0117	25.4	599	126	71
11:00	237	.0127	23.8	664	119	74
11:30	238	.0111	23.3	578	108	95
12:00	235	.0095	26.5	581	119	92
1:15	254	.0075	31.9	550	129	98
1:45	243	.0086	32.6	579	128	94
LSD .05	10	NS	3.4	NS	35	8

Table V-14. Interaction of Systems X Runs on ascorbic acid of canned spinach, 1978.

Variables	Ascorbic Acid Run 1	Run 2	Run 3
System			
Industrial	8.46	15.94	18.51
Experimental	8.40	13.77	16.00
LSD $_{.05}$	0.47		

LSD $_{.05}$ - Least Significant Difference at 5% level.

Table V-16. Interaction of Systems X Times on nitrates of canned spinach, 1978.

Variables	8:30	9:00	9:30	10:00 Nitrates (PPM)	10:30	11:00	11:30
System							
Industrial	709	709	665	884	870	868	654
Experimental	556	605	616	988	793	777	534
LSD $_{.05}$	12.57						

LSD $_{.05}$ - Least Significant Difference at 5% level.

Table V-17. Interaction of Runs X Times on nitrates of canned spinach, 1978.

Variables	8:30	9:00	9:30	10:00 Nitrates (PPM)	10:30	11:00	11:30
1st Run	778	720	605	794	521	505	588
2nd Run	528	818	858	1688	1533	1308	638
3rd Run	593	434	459	328	441	654	558
LSD $_{.05}$	1540						

LSD $_{.05}$ - Least Significant Difference at 5% level.

Table V-15. Interaction of systems x runs on quality of canned spinach, 1979.

	Phosphates mg/ml (Feb.-March)	Ascorbic acid(mg/100g) (April-May)	Nitrates ppm (April-May)	Shear lb/150g (April-May)
Industrial				
Run I	66.5	36.1	373.0	83.8
Run II	71.5	13.1	628.5	96.8
Experimental				
Run I	85.8	43.8	473.4	85.2
Run II	71.1	15.3	882.4	77.5
LSD .05	7.4	2.4	52.3	5.8

Table V-18. Interaction of Runs X Time on Shearpress values of canned spinach, 1978 .

Variables	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	Shearpress (lbs/15og)						
1st Run	83	104	106	99	141	152	169
2nd Run	145	91	84	73	74	72	86
3rd Run	92	69	82	60	54	53	47
$LSD_{.05}$	36						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-19. Interaction of Runs X Times on drained weight of canned spinach, 1978.

Variables	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	Shearpress (lb/15og)						
1st Run	263	270	273	276	254	257	252
2nd Run	267	292	284	274	280	272	262
3rd Run	255	243	256	245	253	262	257
$LSD_{.05}$	15						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table VI-20. Main effects of washing Systems, runs, and time of day on quality of frozen spinach, 1978.

Variables	Ascorbic Acid mg/100g	CDM Values "L"	a/b
System			
Industrial	17.9	20.2	0.746
Experimental	16.2	20.2	0.767
$LSD_{.05}$	NS	NS	NS
Runs (days)			
1st	9.8	21.2	0.751
2nd	14.6	19.8	0.756
3rd	26.7	19.5	0.761
$LSD_{.05}$	3.0	1.2	NS
Time (hr)			
8:30	18.1	19.9	0.746
9:00	21.6	20.5	0.726
9:30	17.2	20.4	0.746
10:00	16.4	20.9	0.786
10:30	16.6	19.5	0.784
11:00	14.4	19.3	0.766
11:30	15.0	20.6	0.741
$LSD_{.05}$	4.6	NS	NS

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Not Significant

Table V-21. Main effects of washing systems, runs and time of day on water quality of the effluent from washing turnip and mustard greens, 1978.

Variable	Suspended Solids lb/ton	Total Solids lb/ton	Settleable Solids lb/ton	COD lb/ton	Nitrate lb/ton
Systems					
Industrial	3.44	12.1	16.53	4.66	1.20
Experimental	1.10	3.6	4.83	1.28	0.37
$LSD_{.05}$	0.13	1.4	3.73	0.76	0.16
Runs					
1st	1.63	7.36	9.67	2.71	0.93
2nd	2.86	8.36	11.67	3.23	0.63
$LSD_{.05}$	0.13	1.4	3.73	NS	NS
Time					
8:30	3.95	6.14	12.81	2.95	0.77
9:00	1.53	6.35	9.51	2.25	0.66
9:30	1.81	8.28	8.84	2.52	0.80
10:00	1.36	7.80	8.79	3.43	0.80
10:30	2.37	8.11	11.16	3.05	0.70
11:00	2.47	9.50	14.17	3.38	0.92
11:30	2.34	8.66	9.49	3.34	0.79
$LSD_{.05}$	0.26	NS	NS	NS	NS

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Not Significant.

Table V-22. Interaction of Systems X Times X Runs on suspended solids of effluent from washing turnip and mustard greens, 1978.

Variable	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	Suspended Solids (lb/ton)						
Run 4							
Industrial	0.336	0.247	0.239	0.202	0.491	0.372	0.455
Experimental	0.063	0.085	0.092	0.103	0.185	0.189	0.203
Run 5							
Industrial	1.718	0.400	0.514	0.293	0.514	0.625	0.483
Experimental	0.081	0.142	0.178	0.182	0.167	0.227	0.193
$LSD_{.05}$	0.183						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-23. Interaction of Systems X Time on suspended solids of effluent from washing turnip and mustard greens, 1978.

Variable	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	Suspended Solids (lb/ton)						
System							
Industrial	7.190	2.263	2.634	1.732	3.516	3.488	3.283
Experimental	0.504	0.800	0.950	0.997	1.233	1.457	1.389
$LSD_{.05}$	0.343						

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Not Significant

Table V-24. Main effects of washing systems, runs and time of day on quality of canned turnip and mustard greens, 1978.

Variable	Color Difference Meter Values "L" Value(whole)	"L"Value (Pureed)	a/b (Whole)	a/b (Pureed)	Liquor Color (OD-475nm)
<u>System</u>					
Industrial	25.8	24.9	0.166	0.077	
Experimental	26.0	24.7	0.168	0.077	
$LSD_{.05}$	NS	NS	NS	NS	
<u>Runs</u>					
1st	25.6	23.6	0.186	0.071	
2nd	26.2	25.8	0.149	0.083	
$LSD_{.05}$	NS	0.31	0.10	0.02	
<u>Time</u> (hr)					
8:30	27.1	24.7	0.193	0.113	
9:00	25.9	24.7	0.182	0.082	
9:30	24.0	24.8	0.164	0.081	
10:00	27.4	25.2	0.167	0.062	
10:30	26.0	24.4	0.162	0.071	
11:00	24.8	24.8	0.143	0.062	
11:30	26.2	24.9	0.160	0.065	
$LSD_{.05}$	1.7	NS	0.04	0.02	

$LSD_{.05}$ - Lease Significant Difference at 5% level.

NS - Not Significant

Table V-25. Interaction of Runs X Times on drained weight of canned turnip and mustard greens, 1978.

	Times						
Variable	8:30	9:00	9:30	10:00	10:30	11:00	11:30
<u>Runs</u>							
4th	298.25	298.25	307.75	298.0	318.75	300.0	304.75
5th	292.75	252.50	299.25	303.5	300.25	297.25	291.5
LSD$_{.05}$	15.10						

LSD$_{.05}$ - Least Significant Difference at 5% level.

Table V-26.Main effects of washing systems, runs and time of day on quality of canned turnip and mustard greens, 1978.

Variable	Drained Weight (g)	Grit g/150g	Ascorbic Acid mg/100g	Nitrate (PPM)	Shearpress lb/150g
System					
Industrial	297.1	0.064	8.2	1393	454
Experimental	297.6	0.049	7.9	1379	471
LSD $_{.05}$	NS	NS	NS	NS	NS
Runs(days)					
1st	303.7	0.017	7.1	1900	472
2nd	291.0	0.048	9.0	871	453
LSD $_{.05}$	5.5	0.001	3.4	324	NS
Time(hr)					
8:30	295.5	0.003	8.4	1364	490
9:00	275.4	0.001	9.2	1357	463
9:30	303.5	0.209	5.9	1355	507
10:00	300.8	0.004	7.7	1424	414
10:30	309.5	0.003	8.0	1414	483
11:00	238.9	0.003	8.8	1356	436
11:30	298.1	0.003	8.3	1431	445
LSD $_{.05}$	8.4	0.002	2.4	229	65

LSD $_{.05}$ - Least Significant Difference at 5% level.

NS - Not significant

Table V-27. Interaction of Runs X Times on liquor color of canned turnip and mustard greens, 1978.

	Times						
Variable	8:30	9:00	9:30	10:00	10:30	11:00	11:30
Run 4	0.140	0.147	0.141	0.137	0.134	0.155	0.133
Run 5	0.168	0.159	0.228	0.190	0.221	0.212	0.185
$LSD_{.05}$	.0195						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-28. Comparison of bacterial counts of effluent from industrial and experimental washers in washing spinach for canning, 1978.

Systems x sites	Runs (4 hours each day)		
	1	2	3
Industrial washer			
1st reel	8.4×10^5 a[z]	6.6×10^5 b	2.0×10^6 a
1st paddle	5.3×10^5 b	2.5×10^5 c	2.0×10^6 a
2nd reel	2.1×10^5 c	1.6×10^4 e	3.1×10^5 b
2nd paddle	4.8×10^5 b	2.7×10^4 e	2.2×10^5 b
Average	5.1×10^5	2.4×10^5	1.1×10^6
Experimental washer			
1st washer	3.4×10^5 bc	3.5×10^5 c	1.6×10^6 a
2nd washer	4.5×10^5 b	8.4×10^4 d	7.1×10^4 c
1st recycle	2.0×10^5 c	6.3×10^4 d	5.5×10^5 b
2nd recycle	4.4×10^5 b	8.0×10^5 a	1.4×10^6 a
Average	3.6×10^5	2.0×10^5	9.0×10^5
Grand total	4.4×10^5 c[y]	2.2×10^5 b	1.0×10^6a

[z] Mean separation within columns for systems x sites by Duncan's Multiple Range Test.

[y] Mean separation in row for runs by Duncan's Multiple Range Test.

Table V-29. Comparison of bacterial counts of effluent from industrial and experimental washers in washing turnip greens and mustard for canning, 1978.

Systems x sites	Type of Greens	
	turnip	mustard
Industrial washer		
1st reel	4.6×10^6 a[z]	1.2×10^6 a
2nd reel	1.9×10^6 c	2.5×10^5 bc
1st paddle	3.4×10^6 b	4.9×10^5 b
2nd paddle	2.9×10^6 b	1.2×10^5 c
Average	3.2×10^6	5.3×10^5
Experimental washer		
1st washer	1.7×10^6 c	1.3×10^6 a
2nd washer	1.3×10^6 c	$.9 \times 10^5$ c
1st recycle	2.9×10^6 b	6.4×10^5 b
2nd recycle	3.5×10^6 b	1.4×10^6 a
Average	2.4×10^6	8.6×10^5
Grand total	1.8×10^6 a[y]	6.9×10^5 b

[z] Mean separation within columns for systems x sites by Duncan's Multiple Range Test.

[y] Mean separation in row for type of greens by Duncan's Multiple Range Test.

VI. Solid waste fermentation, handling and storage.

The changes in regulations regarding landfills and other means of disposal promoted this study. One processing plant in the region utilized covered storage pits for Irish and sweet potato wastes before this research was begun. Because of the pausity of information on fermentation and handling, the nature of the problem and the interest of local processors a number of studies were conducted successively. Two articles have been published in journals (Appendix C-1, C-2) and one Master's thesis (appendix D-3). More detailed information can be found in the thesis on Irish potato wastes. The disposal of high alkalinity wastes constitutes one of the major problems in the region. Combining this fermented waste with poultry wastes or ground dry hay appears to be a practical and economical means of utilizing this material (Appendix C-1) but no progress has been made at this date to establish a commercial operation.

The materials and methods for this research are described in detail in the appendices C-1 and D-3. Similar studies were conducted on sweet potato high alkalinity wastes (Appendix C-2). Sweet potato wastes fermented more readily and there appeared to be less problems with obnoxious odors during fermentation. High temperatures have been shown to be the primary cause of off-odors in Irish potato wastes (Appendix C-1).

Separate storage experiments were set up to determine the storage life and changes in carbohydrates of Irish and sweet potato wastes.

A. Irish Potato Wastes

The fresh high alkalinity waste was analyzed and stored in 21 liter polypropylene containers with tightly fitting lids. One half of the containers were inoculated with fermented Irish potato waste and the other half was not inoculated. The experiment was begun in October and terminated in July, a period of 9-months. The containers remained outside under a covered porch. The non-inoculated lots did not ferment and the carbohydrate composition and pH remained essentially the same as the original sample except for a decrease in starch content (Table VI-1). The hemicellulose increased during the storage period.

There was a decrease in starch and an increase in sugar content during fermentation. The pH reached 4.60 approximately in 7 days and remained constant during 9 months storage. The waste became much thinner after fermentation but did not change appreciably in viscosity during storage. There appears to be a gradual loss in starch content during storage after the initial 7 days of fermentation and a slight decrease in hemicellulose and cellulose, resulting in a decrease in dry matter of approximately 2%.

B. Sweet Potato Wastes

The fresh high alkalinity sweet potato waste was stored in 55 gal steel drums, 6 barrels approximately 2/3 full. The fresh waste was analyzed immediately and stored outside in the open except the barrels contained steel covers and a tarpaulin was used to prevent rain water from entering the barrels. Preliminary experiments showed that mold was a problem on the surface of the containers. Also, the industrial storage pits had been plagued with the same problem. It was found that either dehydroacetic acid (2%) or potassium sorbate (3%) solution sprayed on the top of the barrels the first week and at monthly intervals controlled the mold growth.

After 6 days of fermentation the pH of the waste had dropped to approximately 7.0, then there was a gradual decrease in storage (Table VI-2). There was very little decrease in dry matter during the first 3 months and a slight increase by 9 months as compared to the original. In contrast to Irish potato wastes (Table VI-1), there was a gradual decrease in sugars as well as starch during storage although not much change took place in starch after the initial fermentation.

There were variations in pectins, hemicellulose, cellulose, nitrates and total nitrogen during fermentation and storage but these values do not appear to change significantly. As stated previously, sweet potato wastes store well and there appears to be less problems of stability after fermentation, and no off-odor problems occurred in the various experiments conducted.

Table VI-1. Effect of storage on composition of Irish potato high alkalinity peeling wastes (fresh wt. basis).

		pH	% Dry matter	% Total sugar	% starch	% Water soluble pectin	% Calgon soluble pectin	% Hemi-cellulose	% Cellulose
Sample	Rep.								
Fresh	1	11.30	17.6	.64	10.02	.37	.10	.25	.54
	2	11.30	17.4	.58	10.13	.38	.09	.28	.67
Fermented	1	4.65	17.7	2.55	6.63	.44	.10	1.32	.94
(7 days)	2	4.60	17.4	1.93	6.09	.45	.11	.78	.99
Stored 4 mos									
Not inoculated	1	11.30	17.7	.69	10.02	.39	.10	.78	.71
	2	11.30	17.3	.53	8.38	.41	.11	.90	.73
	3	11.20	17.4	.74	7.81	.39	.08	.76	.69
Inoculated	1	4.60	15.6	2.33	2.75	.34	.07	.50	.71
	2	4.65	16.0	3.08	3.72	.30	.05	.48	.64
	3	4.65	16.2	2.33	3.31	.49	.10	.62	.66
Stored 9 mos									
Not inoculated	1	11.30	17.6	.51	7.38	.47	.09	.92	.76
	2	11.30	17.2	.54	6.88	.44	.09	1.24	.81
	3	11.10	17.4	.59	6.69	.43	.08	1.27	.77
Inoculated	1	4.55	15.5	2.25	1.94	.43	.08	.67	.61
	2	4.50	15.6	2.90	1.75	.35	.05	.49	.54
	3	4.40	16.0	2.45	2.22	.43	.08	.86	.63

Table VI-2. Effect of storage on composition of sweet potato high alkalinity peeling wastes (fresh wt.basis).

Storage	Rep.	pH	% Dry matter	% Total sugars	% Starch	% Pectins	% Hemicellulose	% Cellulose	NO_3 ppm	% Total nitrogen
Fresh	1	11.7	27.05	5.02	7.80	1.09	.78	1.24	478	.197
	2	11.6	25.03	5.50	7.30	.88	1.28	1.51	448	.230
	3	11.5	26.48	5.50	7.90	1.13	1.00	1.24	432	.233
6 Days	1	7.6	26.46	5.30	7.70	1.21	1.15	1.33	418	.157
	2	6.6	27.53	4.60	5.60	1.08	1.13	1.24	380	.207
	3	7.6	24.99	4.70	6.30	1.05	.90	1.11	390	.193
1 Month	1	6.9	24.84	4.20	6.20	.98	.84	.91	538	.197
	2	5.7	23.96	4.30	6.00	1.10	1.06	1.33	478	.230
	3	6.4	25.04	4.00	6.50	1.23	1.16	1.06	492	.230
3 Months	1	6.4	25.57	4.10	5.95	.69	.94	1.25	460	.187
	2	5.8	24.91	3.20	6.90	1.56	1.11	.98	506	.207
	3	5.1	23.25	3.80	5.80	1.25	.73	.85	432	.243
9 Months	1	5.9	26.39	3.75	4.83	.90	.96	2.40	430	.195
	2	5.7	30.20	2.88	5.71	.85	.91	1.68	515	.230
	3	5.0	28.70	3.36	4.67	.80	.89	2.11	438	.249

CONCLUSIONS

1. There are a number of vegetables canned in the Ozark region that produce high wastestrength effluent by the methodology presently used.
2. Alternate methods of preparation were demonstrated that could reduce the wastestrength of effluent from vegetable processing by over 50%.
3. Water can be recycled for washing, blanching, and cooling of vegetables without affecting quality of the canned product if properly done.
4. Processing of hominy produces the highest wastestrength of effluent of all canned products in the Ozark region. Suitable alternate methods were developed that could drastically reduce wasteloads.
5. Washing spinach and leafy greens utilizes more water in preparation than other vegetables. The use of a new prototype washing system reduced water use by 70% without affecting quality of the canned product.
6. One of the major causes of high pollutional strength in effluent from processing vegetables is the type of washing and transporting equipment used in the plant.
7. Wastestrength of effluent from canned dry beans can be significantly reduced by using the alternate methodology developed.
8. The quality of canned dry beans soaked for shorter times at 25°C was equal to or better than that canned by commercially accepted procedures.
9. Low volume water sprays were as efficient for washing leafy greens as high volume sprays used by industry and physical breakage of the leaves was practically eliminated.
10. High alkalinity lye peeling wastes from Irish and sweet potato canning can be fermented and stored for 9 months without a great loss in total solids and carbohydrates.
11. Covered pits with screened gables are necessary for fermentation and storage of solid wastes in the Ozark region because of high rainfall.

12. Maintaining quality of the finished product is the primary concern of processors in the region although pollution abatement is rapidly becoming the first priority.

13. By cooperatively working with the vegetable processing industry in the region throughout the duration of this project better liquid and solid waste disposal systems have been installed in most of the plants. These include better separation and/or screening of suspended solids, better peeling methods, better solid waste utilization and/or disposal, more recycling of water and better control over blanching times and temperatures.

14. More research needs to be conducted to demonstrate systems of pollution abatement. Although wastestrength of effluent from processing vegetables in the region has been significantly reduced during the last 5 years much greater reductions could be accomplished during the next 5 years by appropriate technology without affecting quality of the finished product, even with normal expansion of production.

15. **More research needs to be conducted on flocculation and separation of suspended solids under varying pH conditions. This particular problem is important not only from the standpoint of reducing surcharges but for recycling water as well.**

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APPENDIX A-1

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EFFECT OF PROCESSING METHODOLOGY ON QUALITY ATTRIBUTES AND NUTRITIONAL VALUE OF CANNED SPINACH

Marcia Mahon, W. A. Sistrunk, and D. W. Freeman

Spinach is the most important leafy vegetable crop produced and processed in Arkansas. The standard commercial method of blanching spinach for canning is in water at temperatures ranging from 155° to 190°F with the time of blanch varying from 3 to 7 minutes. We have shown in previous studies that blanching spinach in water at 165°F for 8 to 12 minutes resulted in much better color and texture than other combinations of time and temperature. For a shorter time, 4 minutes at 175°F was also found to give highly desirable color and texture.

Since the advent of new regulations on water quality, we have begun a series of studies on comparing steam blanching with water blanching. Blanching can account for as much as 50% of the total BOD (biological oxygen demand) of the processing effluent and steam blanching can reduce BOD of the blanching effluent by as much as 90%. Preliminary studies have shown that the nutritional value of spinach was significantly higher in canned spinach that was blanched in steam as compared to water. In light of new regulations on nutritional labeling, this difference could prove to be important.

The purpose of this research was to determine the effect of blanch method, blanch temperature, cooling and exhaust time on quality and nutritional value of canned spinach.

Steam blanching resulted in lower shearpress values, but higher nitrates and ascorbic acid (Table 1). The spinach that was blanched by rotary steam blanch was slightly higher in nitrates but was greener than lots blanched in water. The lower nitrates and ascorbic acid in spinach blanched in water was attributed to leaching out of the two components during blanching. The steam blanched spinach reflected more light as shown by the higher CDM 'L' values. Rotary steam blanching probably makes more efficient use of steam since rotation allows steam to reach all leaf surfaces equally. The taste panel could not detect any significant differences in quality between the two methods.

In a separate experiment on another field of spinach, steam was compared to water for blanching, followed by either cooling or no cooling before filling into cans (Table 2). Again, the ascorbic acid and nitrates were higher in lots blanched in steam. The taste panel could not detect a difference between steam- and water-blanched lots, but the CDM 'a' values were higher on steam-blanched lots, indicating more green color. Water blanching leaches out chlorophyll and other soluble constituents which apparently decrease the green color. Cooling of blanched spinach resulted in lower drained weights because of the absorption of water during water cooling. Thus, when a constant weight is filled into cans, more leafy material is added to cans in lots with no cooling.

In two other experiments, two temperatures of blanch, 180° and 212°F, were compared as well as exhaust time after filling (data not shown). Higher temperatures of blanch leached out slightly more nitrates, but the other differences were not significant. Also, exhaust time after filling the cans did not affect the quality factors studied.

In conclusion, steam blanching of spinach for canning appears to be superior to water blanching for retention of ascorbic acid and green color. Concurrently, there is a large decrease in BOD of effluent from blanching, especially if the product is not cooled after blanching or is air-cooled.

Table 1. The effect of blanch method on quality of canned spinach.

Blanch Method	Dr. Wt.	Shear (150g)	Ascorbic Acid (mg/100g)	NO_3 mcg/g	Taste Panel[1] Color	Taste Panel[1] Texture	CDM[2] L	CDM[2] a
Still steam (180°)	287	63.0	16.4	1632	7.0	6.8	25.7	2.2
Rotary Steam (180°)	288	66.3	17.1	1944	7.0	7.0	25.4	3.3
Water (175°)	300	75.8	11.4	1032	6.9	6.1	24.5	2.6
F value	.12NS	6.6*	55.2**	57.2**	0.1NS	.34NS	28.0**	38.9**

[1] Average taste panel ratings of 6 panel members.

[2] CDM - Color Difference Meter

Table 2. The effect of blanch method and cooling on quality of canned spinach.

Main Effect	Dr. Wt.	Ascorbic Acid (mg/100g)	NO_3 mcg/g	Taste Panel[1]		CDM[2]	
				Color	Texture	L	a
Blanch							
Water (175°F)	301	15.2	1032	7.3	6.9	22.9	1.1
Rotary Steam (180°F)	299	26.5	1609	7.3	6.8	22.9	2.2
F value	.08NS	78.6**	10.5*	.01NS	.07NS	.07NS	201.7**
Cooling							
Cool	289	21.3	1088	7.3	7.0	23.0	1.2
No cool	311	20.4	1149	7.3	6.7	22.9	2.1
F value	15.9*	.45NS	1.43NS	.35NS	1.42NS	1.1NS	142.6**

[1] Average taste panel ratings of 6 panel members.

[2] CDM - Color Difference Meter.

APPENDIX A-2

HortScience 12(1):59–60. 1977.

Relationship of Processing Methodology to Quality Attributes and Nutritional Value of Canned Spinach[1]

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Additional index words. blanching, water quality, *Spinacia oleracea*

Abstract. **The volume of water utilized for washing did not affect either quality attributes or nutritional value of canned spinach (*Spinacia oleracea* L.). Dipping in a detergent solution prior to the washing decreased greenness, optical density of liquor, nitrates and ascorbic acid. The amount of grit and sand was not influenced by either detergent or volume of water used for washing. Shearpress values of canned spinach blanched in either steam or water did not differ. Color was rated slightly higher on spinach that was blanched in steam. Water blanching leached out more nitrates, riboflavin and ascorbic acid than steam blanching, but carotene was not affected.**

Blanching contributes significantly to Biochemical Oxygen Demand (BOD_5) of the effluent from vegetable processing operations, averaging 40% of the total BOD_5 at the discharge stream for all vegetables (10). Steam blanching leaches less soluble substances from the product than water blanching (4, 7). New concepts of hot-gas and steam blanching have been developed that could have a profound impact on vegetable processing, especially in reducing BOD_5 loads in the effluent (2, 6, 10). Nutritive value has been shown to be influenced by blanching (3, 5). Water-soluble vitamins and sugars were among the most important constituents affected. Nitrate nitrogen (NO_3-N) levels in spinach were reduced 15% by blanching at 89°C as compared to 71°, and 25% by blanching 16 min as compared to 4 min (11). Prior to commercial canning, spinach is blanched 3 to 7 min in water ranging from 70° to 85°. Steam blanching can reduce BOD_5 for the blanching operation by 90%, and other new concepts result in greater reduction in some vegetables (2, 6, 10). The impact of detergent use, washing, and cooling on quality attributes of canned spinach has not previously been documented.

Semi-savoy type spinach was harvested in the afternoon near Springdale, Ark., and hauled on an open truck to the plant. After overnight holding at ambient temp on the truck, the samples were taken from the truck during unloading; at that time the spinach was 24°C. Thirty-six 2 kg lots were randomly divided for processing, 18 of these were dipped in tap water and 18 dipped in a solution of 0.5% Metzo, a detergent, to test its effectiveness in removing foreign matter. All lots were washed in a rotary vegetable washer that was about 0.5 m in diam × 1.5 m long and contained 5 outlets for spray nozzles in a 2.5 cm diam water line in the upper half of the drum. Three sets of nozzles were employed to deliver 1.5, 3.0 or 30 liters of H_2O/min during a 2 min wash with the full pressure from the water line. After being washed, the lots were blanched either 4 min in H_2O at 80°C, 2 min in steam box (100°) or 2 min in a rotary steam blancher at 90°. Eighteen of the lots were filled directly into standard 303 enamel lined cans and 18 lots were cooled in tap water before being canned. A fill weight of 325 g was used and the cans were then filled up with 1.5% NaCl solution. The cans were exhausted 4 min in a steam box, closed and processed 50 min at 122°C. Cans were cooled in tap water and stored at 24°C until the analyses were made.

Drained wt, Hunter Color Difference Meter (CDM), optical density of liquor (OD), and taste panel evaluations were performed as described (11). Resistance to shear was measured on 150 g of drained spinach by placing the sample in a standard cell of a shearpress (Food Tech. Corp., Model Tp-1A). The sample was recovered and combined with the remaining contents of the can. Two parts of water, including the liquor, were added to the sample and blended 2 min. Ascorbic acid was determined colorimetrically (8) except that 1% oxalic acid was used as the extracting solvent. Riboflavin was determined fluorometrically (1). Carotene was determined by extracting 10 g of the above blend with a mixture of 60 ml acetone and 40 ml hexane and then removing the acetone by washing with cold 2% NaCl. The hexane fraction was chromatographed on a column containing a 50:50 mixture of MgO and Celite, diluted and read on a Spectronic 20 spectrophotometer at 440 nm. A standard curve was made by diluting β-carotene in hexane. Sand and grit were separated by gently floating the pulp from a 200 g sample of the spinach (600 g of blend) with a stream of water. The grit and sand were transferred into tared crucibles and weighed after being dried in an oven for 1 hr at 100°C. NO_3-N was determined with a nitrate selective electrode (9) on an aliquot of the samples extracted for riboflavin analysis.

The data were treated as a factorial experiment with 3 replications.

Drained wt of canned spinach was lowest when the product was blanched in H_2O (Table 1). Lots blanched in still steam were rated slightly higher in color, with lower "L" and "–a" values, than lots blanched in H_2O. Both steam blanches resulted in significantly higher NO_3-N, ascorbic acid, and riboflavin, and higher OD of liquor than spinach blanched in H_2O. The rotary steam blancher removed H_2O from the product during blanching, which resulted in a higher drained wt. The Chemical Oxygen Demand (COD) was 5.72 kg/ton for the water blanch and 0.71 kg/ton for the steam blanches.

Hydrocooling caused water to adhere to the blanched spinach, and thus lowered the drained wt since a constant fill wt was used for all cans. Lots that were not hydrocooled lost more H_2O after blanching than those that were hydrocooled which may account for the slightly higher shearpress values of the former. Cooling of spinach after blanching leached out more NO_3-N and reduced optical density of the liquor. Also, hydrocooling leached out significant quantities of ascorbic acid and riboflavin.

Adding detergent to the wash water did not have any detectable effect on drained wt, texture, taste panel color and "L" and "b" values. However, use of detergent decreased greenness ("–a" values), NO_3-N, ascorbic acid, and optical density of liquor. The detergent leached out more chlorophyll and other soluble substances into the blanching and cooling water. This fact showed up not only in a lower OD of liquor from canned spinach, but also in a higher COD. The COD value for the detergent dip plus wash was 0.94 kg/ton as compared to 0.31 kg/ton in lots not dipped in detergent.

The use of lower volumes of water than normal to wash spinach, either with or without detergent, did not have a significant effect on any quality attributes except on riboflavin, which was lower with detergent use (data not shown). Sand and grit in canned spinach were not significantly affected by either washing method, detergent dip, blanch method, or hydrocooling, but there was a tendency toward less com-

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Table 1. Effect of blanch method, hydrocooling, and detergent dip on some quality attributes of canned spinach.

Variable	Drained wt (g)	Shear-press (kg/150g)	Panel rating^z		Color attributes			NO_3-N (µg/g)	Ascorbic acid (mg/100g)	Riboflavin (µg/g)	Carotene (µg/g)	OD liquor 475 nm	Grit & sand (mg/200g)
			Color	Texture	L	−a	b						
Blanch method^x													
Rotary steam	275a	54a	7.4ba	7.3a	20.9a	.23a	10.9b	1707a	17a	24.0a	183a	.266a	7a
Still steam	260b	55a	7.5a	7.0b	20.7b	.05b	11.0a	1225b	15b	23.5a	183a	.259b	8a
Water	256c	55a	7.3b	7.2ab	20.9a	.20a	10.9b	1013c	9c	21.0b	179a	.213c	5a
Hydrocooling^x													
Yes	251b	54b	7.4a	7.1a	20.7b	.16a	10.9b	1223b	13b	21.5b	182a	.227b	6a
No	277a	56a	7.4a	7.2a	20.9a	.16a	11.0a	1407a	14a	24.1a	181a	.266a	8a
Detergent dip^x													
Yes	265a	55a	7.4a	7.2a	20.8a	.10b	11.0a	1258b	13b	22.6a	182a	.236b	8a
No	263a	55a	7.4a	7.1a	20.8a	.21a	10.9b	1372a	14a	22.6a	183a	.257a	6a

[z] Rated on scale of 10-best to 1-poor by a 5-member trained panel.

[x] Mean separation in columns within variable by Duncan's multiple range test, 5% level.

plete removal of sand in lots blanched in still steam, in those not cooled, and in those washed in 1.5 liters/min H_2O.

Exhausting the filled cans 2 to 8 min in steam had no significant effect on any quality attributes. Large volumes of H_2O for washing spinach appeared to crush and break the leaves more than low volume sprays since the COD value was 2.19 kg/ton in the 30 liters/min wash water as compared to 0.61 kg/ton in the 3 liters/min wash.

Apparently, steam blanching and omitting hydrocooling after blanching helped retain higher nutritional value without affecting other quality attributes. Washing with low volume water sprays effectively removed sand and grit without deleterious effects on any quality attributes. Detergent dipping before washing resulted in the leaching out of more ascorbic acid and NO_3-N and a reduction in "−a" values.

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APPENDIX A-3

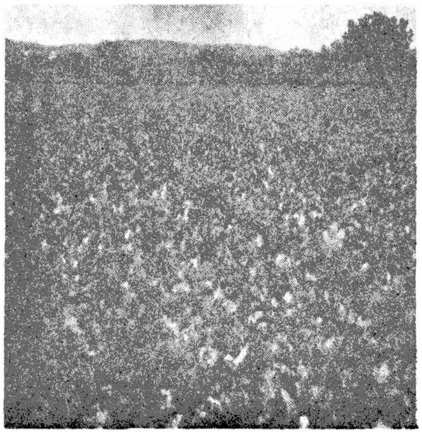
Quality and Nutritional Value of Canned Turnip Greens as Influenced by Processing Technique

By W.A. SISTRUNK, and G.A. BRADLEY

TURNIP GREENS are a popular leafy green crop in Southern United States. The conventional method of blanching turnip greens for canning is to blanch in hot water and then cool in cold tap water before filling into cans. Because of the emphasis on blanching with small volumes of water and on reducing soluble constituents in the effluent, it is important to find alternate methods of processing. Conserving energy during processing is also important.

In this research the Crawford cultivar of turnip greens was grown at two nitrogen (N) levels and three in-row spacings at the Main Station, Fayetteville. The greens were cut at optimum maturity 1 inch above the ground level, washed in a reel-type vegetable washer, and separated into lots for processing.

Half of the lots were blanched in water at 190° F for 2½ minutes and the other half in steam for 3 minutes. After blanching, half of each lot was cooled in tap water while the other half was not cooled before being filled into cans. Cans were filled with 2% salt brine, sealed, and processed 50 minutes at 252° F. The canned greens were analyzed for carotene, riboflavin, ascorbic acid, color, and resistance to shear.



Turnip greens are an important processing crop in Arkansas.

Carotene and ascorbic acid contents were higher in turnip greens that were blanched in steam (see table). There was no effect of cooling on carotene but ascorbic acid, a water-soluble vitamin, was leached out significantly during cooling after blanching.

Both vitamins were higher in greens grown under wider in-row spacings because of greater exposure of the total plant to sunlight. High N on the plots increased carotene but decreased ascorbic acid. This could have resulted either from greater leaching during blanching where more N had been applied, or that the more rapid growth of these plants reduced ascorbic acid content.

Effect of Processing Technique, In-Row Spacing, and Nitrogen Level on Nutritional Value and Quality Attributes of Turnip Greens

Main effects	Carotene mg/100g	Ascorbic acid, mg/100g	Ribo-flavin u/g	Hunter CDM 'L'	Hunter CDM -'a'	Shear-press, lb/150g
Method of blanch						
Water	44.1	14.2	6.71	21.6	3.33	670
Steam	48.7	23.4	6.03	21.4	3.00	689
F value	15.84**	303.25**	3.03NS	3.17NS	13.21**	2.26NS
Cooling after blanch						
Cool	46.1	17.2	6.16	21.5	3.19	678
No cool	46.8	20.4	6.58	21.5	3.14	680
F value	0.47NS	35.23**	1.18NS	0.0NS	0.26NS	0.03NS
In-row spacing						
1 inch	44.9	17.6	6.68	21.7	3.26	693
3 inches	46.2	18.9	6.34	21.4	3.11	704
5 inches	48.2	19.9	6.09	21.4	3.20	640
F value	12.60**	6.52**	0.78NS	2.72NS	2.34NS	11.01**
Nitrogen level						
High	48.1	16.7	6.72	21.2	3.03	696
Low	44.7	20.9	6.02	21.8	3.30	633
F value	8.53**	62.70**	3.20NS	16.25**	8.40**	7.39**

* indicates significance at 5% level.
** indicates significance at 1% level.

Riboflavin was higher in lots of greens that were blanched in water, and in those from high N plots. Cooling after blanching and in-row spacing did not influence riboflavin content.

The canned turnip greens were greener in color (Hunter 'a') when blanched in water. Neither cooling nor in-row spacing had any marked effect on color, although there was a tendency for the 1-inch spacing to produce greens that were lighter in color. Greens from plots with high N were darker in color (Hunter 'L') although the color was less green, possibly due to higher carotene content.

Furthermore, greens grown under closer in-row spacing were tougher, which was probably caused by the longer stems produced by closer spacing. The higher shearpress values in greens from plots with high N were due to the production of larger stems under rapid plant growth.

In conclusion, steam blanching appears to have an advantage over water blanching, resulting in higher carotene and ascorbic acid contents. Steam blanching reduced the soluble constituents leached out during blanching by about 80 percent, especially when the blanched product was not cooled. A definite advantage in not cooling blanched greens was the improved ascorbic acid content, with no harmful effect on the color.

Closer in-row spacing reduced carotene and ascorbic acid contents, and resulted in tougher greens. High N on the plots increased carotene but reduced ascorbic acid and produced tougher greens.

Dr. Sistrunk is horticultural food scientist and Dr. Bradley is horticulturist. Cecelia Dumeny, a student in horticultural food science, conducted the research as a special problem.

Yield Performance, and Baking and Canning Quality, of Sweet Potato Varieties and Breeding Lines, 1972 to 1974

Variety or line	Fayetteville			Van Buren			Score[1]		Plant production[2]	Storage[3]
	U.S. #1's	Canners	Marketables	U.S. #1's	Canners	Marketables	Baked	Canned		
				Bushels per acre yield						
Centennial, range	91.0	141.0	317.0	120.0	45.0	255.0	56.3	65.5	—	—
	274.0	244.0	554.0	253.0	124.0	594.0	69.4	71.7	—	—
" average	**210.0**	**192.3**	**466.0**	**176.3**	**93.3**	**440.7**	**61.1**	**69.1**	2.5	3.5
L7-177[4] range	190.0	174.0	387.0	86.0	118.0	228.0	66.1	82.6	—	—
	369.0	225.0	690.0	332.0	139.0	712.0	80.0	88.9	—	—
" average	**278.3**	**192.7**	**534.7**	**212.7**	**130.3**	**467.0**	**73.1**	**85.8**	2.5	3.0
L9-190, range (Jasper)	217.0	204.0	467.0	74.0	89.0	228.0	60.9	75.5	—	—
	288.0	236.0	578.0	219.0	158.0	522.0	78.5	80.1	—	—
" average	**248.3**	**217.0**	**498.0**	**151.3**	**133.0**	**394.0**	**66.8**	**77.8**	2.0	2.0
Jewel, range	127.0	127.0	325.0	61.0	63.0	140.0	66.3	61.3	—	—
	314.0	194.0	493.0	186.0	84.0	358.0	71.1	73.9	—	—
" average	**222.0**	**168.3**	**416.3**	**138.7**	**75.3**	**283.7**	**67.0**	**67.7**	4.0	4.0
Gem, range	265.0	177.0	479.0	181.0	89.0	343.0	68.8	70.5	—	—
	344.0	206.0	657.0	287.0	156.0	519.0	72.8	81.0	—	—
" average	**292.3**	**195.3**	**543.7**	**237.7**	**115.0**	**431.0**	**71.5**	**77.4**	2.0	4.0
Redmar, range	146.0	170.0	339.0	71.0	164.0	257.0	65.5	78.2	—	—
	309.0	289.0	502.0	326.0	208.0	523.0	72.3	84.3	—	—
" average	**202.7**	**212.0**	**425.3**	**201.3**	**192.7**	**426.3**	**69.9**	**80.4**	5.0	4.0
Georgia Jet,[4] range	283.0	107.0	496.0	347.0	51.0	565.0	57.1	72.8	—	—
	407.0	188.0	769.0	446.0	131.0	759.0	64.0	78.7	—	—
" average	**359.3**	**139.3**	**666.0**	**396.5**	**91.0**	**662.0**	**60.6**	**75.8**	3.0	4.5
LSD at .05, average	64.0	71.0	106.0	88.5	37.0	149.0	—	—	—	—

[1] Scores for baked and canned samples based on a total of 100 points by a test panel.

[2] Scores: 1 represents very poor plant production; 5 represents very good plant production.

[3] Scores: 1 represents very poor storage quality; 5 represents excellent storage quality.

[4] Only two years are represented in average for Georgia Jet at Van Buren, and only two values for baked and canned samples of L7-177 and Georgia Jet are represented in the averages.

Testing Sweet Potatoes in Arkansas

By J.L. BOWERS, W.A. SISTRUNK, C.F. BOETTINGER, and D.R. MOTES

THIS STATION has participated in the testing of cultivars and breeding lines sponsored by the National Sweet Potato Collaboration Group since 1955. We have evaluated breeders' material (potential new cultivars) for yields and for baking and canning quality at Fayetteville and Van Buren. Members of the Horticulture and Forestry and Horticultural Food Science Departments cooperate in the program.

During the 1972-74 period, 27 entries were evaluated from the standpoint of yield, baking, canning, storage, and plant production characters. Most were dropped from the program because one or more characterictics did not "measure up."

Data on 7 entries are presented in the table because they merit further testing and evaluation. The cultivars Centennial and Jewel were used in the national trials and the Arkansas trials as checks.

Georgia Jet was the most productive entry tested from 1972 to 1974, based on U.S. #1 and total marketable yields. Other entries such as L7-177, L9-190 (released as Jasper), and Redmar did not differ from either check on the basis of #1's and total marketables, except that the average yield of L7-177 was significantly higher than Centennial in #1 roots and higher than Jewel in total marketables.

Although Georgia Jet was more productive than other entries it possesses three faulty characteristics which should be taken into consideration: (1) it is susceptible to fusarium wilt, (2) it is extremely susceptible to scurf, and (3) it is only fair to poor in plant production.

L9-190, recently released as Jasper by the Louisiana Agricultural Experiment Station, possesses resistance to fusarium wilt, internal cork, and soil rot. The latter disease is generally found in sites where the soil pH is in the range of 6.5 to 7.0.

Redmar, developed by the Maryland Agricultural Experiment Station, produced a very good yield of canning-grade roots at both locations and rated high in canning quality. It also is an excellent plant producer and stores well.

Three cultivars observed during the three years of testing merit consideration by Arkansas growers with certain qualifications:

Georgia Jet gives very excellent yields provided it is grown in soil that is not infected with fusarium wilt.

Redmar warrants consideration for processing and fresh market since it produces high yields of excellent quality medium-sized roots. Also, it has been an excellent plant producer for us.

If the soil rot fungus has been a problem, growers should plan to use Jasper, which possesses considerable resistance to the disease. This cultivar does not store as well as others, so it should be marketed early, sold to a processor, or stored for a shorter period.

Dr. Bowers is horticulturist; Dr. Sistrunk is horticultural food scientist; Mr. Boettinger is research asst.; Mr. Motes is research asst. located at Van Buren.

APPENDIX B-1

INFLUENCE OF PROCESSING METHODOLOGY ON THE STRENGTH OF WASTEWATER FROM CANNING DRY BEANS

M. NEELY and W. A. SISTRUNK

ABSTRACT

A study was conducted to determine the effect of soaking procedures on wastewater strength during canning of dried beans. Several soaking times (3, 6, 14 hr), temperatures (15°, 25°, 35°C) and soaking solutions (EDTA, citric acid, malic acid, H_2O, deionized H_2O) were studied. Wastewater strength was measured as Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and Total Phosphorus (TP). Reducing soaking times and temperature and the addition of EDTA reduced wastewater strength, while the addition of citric and malic acid increased wastewater strength. Navy beans generated more COD and TP than Pinto or Red Kidney beans. The wastewater strength from soaking Navy beans increased dramatically at 25° and 35°C as compared to 15°C. Significant interactions indicated that the type of soaking solution was of greater importance on Navy and Pinto beans than on Red Kidney.

INTRODUCTION

THERE IS A GREAT NEED in the food processing industry to search for methods to reduce total pounds of polluting or effluent discharged. Studies conducted for the Environmental Protection Agency have found that at least 100 food processing plants will soon go out of business because of pollution controls and at least another 300 may be similarly affected (Dunlap and Assoc. Inc., 1971). The increasing cost for the processor to meet the effluent discharge requirements set by the 1972 Water Pollution Control Act Amendments, either when discharging to a receiving water or to a municipal treatment plant, has in effect made the industry search for methods to reduce effluent discharge.

Over 60% of the food processing wastewaters in the U.S. are treated in municipal systems (Eckenfelder, 1976). Pollutional strength on which to base sewer rates for municipal treatment of industrial waste is usually based on Biochemical Oxygen Demand (BOD) or Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and total flow and possibly in the future, Phosphorus (P). In addition, these criteria are used for design of the plant treatment system, measurement of treatment plant efficiency and measurement of stream pollution (Mercer and Rose, 1968).

Weckel (1967) reported that most canning plant wastes have a BOD more than 10 times greater than that of domestic waste. Money expended to find ways of reducing the total pounds of polluting matter in industrial waste will result in savings due to reduced requirements for waste treatment, and possibly provide income from by-product recovery and sale (Nemerow, 1971).

Wide variations in wastewater generated from processing dried beans have been reported. A recent report recorded 15–182 lb BOD and 2.6 lb TSS per ton of raw product with a water requirement of 2.5 to 33 × 10^3 gal per ton (CH2M Hill, 1976). The NCA (1971) indicated that dried beans produced 75 lb BOD and 59 lb TSS per ton of raw product with a water requirement of 9.8 × 10^3 gal per ton. Steebin and Reid (1971) reported that Red Kidney beans produced 0.3–0.7 lb BOD and 0.1 lb TSS per ton of finished product with a water requirement of 1.7 × 10^3 gal per ton.

Surveys of canneries have shown that an average of 40% of the total BOD is liquid waste from vegetable blanching (EPA, 1971). In green peas, hot water blanching produced 1000 gal wastewater per ton; steam, 48.4 gal; microwave, 42.5 gal; and hot air, 0.018 gal (Ralls, 1970). Woodruff and Luh (1975) stated that both blanching and cooling water dissolve less plant juices after they have been used once or twice. The same should be true for soaking water. He mentioned that the real solution to liquid waste treatment will come from finding alternated methods that require less water.

Beneficial effects of shorter soaking times for dried beans for canning have been demonstrated (Nordstrom and Sistrunk, 1977). Additives have been shown to have a beneficial effect on quality as well as diminishing the amount of solid matter (Daoud et al, 1977; Masters, 1918; Furia, 1972).

Due to the rising cost of pollution abatement there is a need for information on ways to reduce the strength of the effluent from processing dried beans without reducing the quality of the product. The objectives of this study were to determine the effect of soaking time, soaking temperature and soaking agents and/or chelating agents on the quality of wastewater generated during soaking prior to the processing of Pinto, Red Kidney and Navy beans.

MATERIALS & METHODS

Source

The dry beans for this study were obtained from a commercial processor in the northwest section of Arkansas in March, 1976. Types of dry beans included California Dark Red Kidney, Michigan Navy, and Colorado Pinto.

In order to determine moisture content, 200-g samples of each of the types were placed on open trays and allowed to dry in a 70°C drying oven for 48 hr. Samples were weighed and moisture content determined. Throughout the experiment the moisture content of the beans was maintained at 11% for the Red Kidney, 12.5% for the Pinto, and 4.3% for the Navy by storing in sealed plastic containers. To prevent mold growth and insect damage the beans were stored at 0°C.

Experimental design

This experiment was designed as a four-way factorial involving 3 bean types, 11 soaking solutions, 3 soaking times, and 3 soaking temperatures. The experiment was replicated 3 times.

Preparation

Three replications of eleven random, 100-g samples of each type of bean were placed in 1 liter sealable polypropylene containers. To each container was added 500 ml of soaking solution. Solutions were as follows: 200, 400 and 600 ppm EDTA (ethylenediaminetetra-acetate disodium salt); 0.1%, 0.2%, 0.3% malic acid; 0.1%, 0.2%, 0.3% citric acid; tap water and deioninzed water. All 99 samples were sealed, to retard evaporation and randomly placed in an incubator set at either 15°C, 25°C or 35°C. One sample of each soaking solution and bean type was removed after 3, 6 and 14 hr. The samples were canned for quality determinations, and analyzed after

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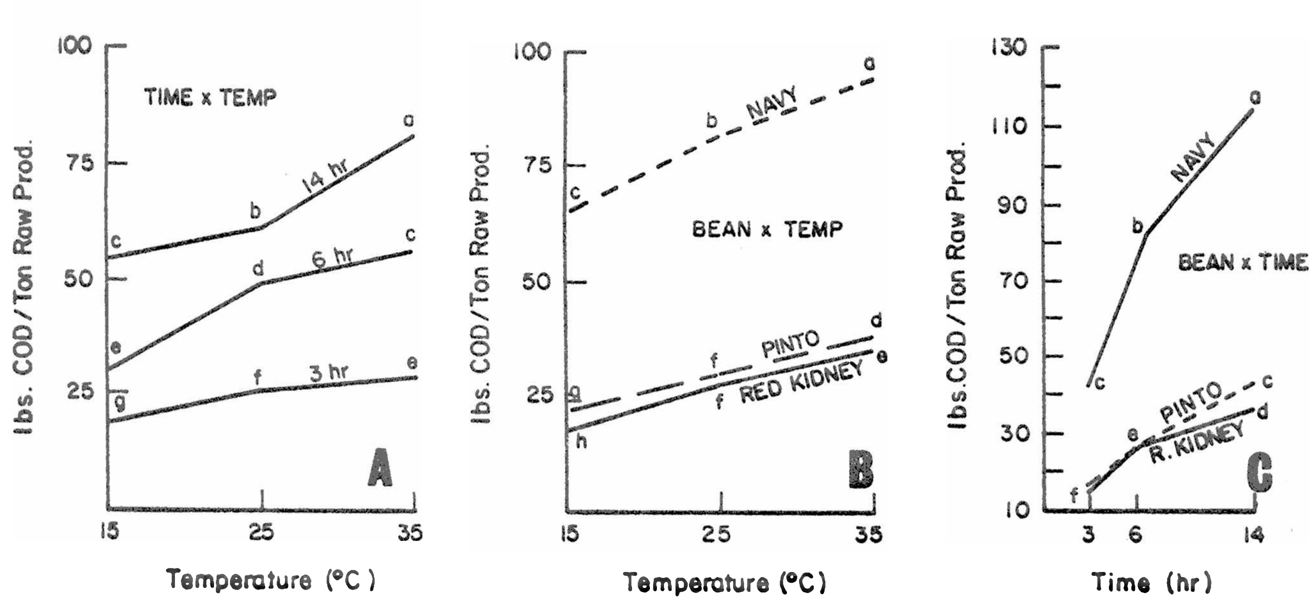

Fig. 1—Interactions of soaking time X soaking temp, bean type X soaking temp and bean type X soaking time on lb COD/ton raw product (dried beans).

3, 6 and 12 months storage but these data are not reported in this paper.

Analyses

The following determinations were made on the water samples: Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and Total Phosphorus (TP).

The COD was determined by the procedure described by Mercer and Rose (1968). Three replications with duplicate samples were analysed and the median value of the 3 replications times a factor of 0.01, to convert from ppm to lbs/ton raw product, was used for the statistical analyses.

The TSS were determined by the procedure described by Standard Methods (APHA, 1971) and National Canners Association (1971).

Table 1—Main effects of bean type, soak time and soak temperature on lb COD, lb TP and lb TP per ton raw product

Main Effects	lb COD/ton raw product	lb TP/ton raw product	lb TSS/ton raw product
a. Bean type			
Navy	79.44 a[a]	92.68 a	0.84 b
Red Kidney	25.79 c	11.17 b	0.33 c
Pinto	28.42 b	13.11 b	1.30 a
b. Soak time (hr)			
3	24.02 c	24.13 b	0.44 c
6	44.67 b	27.08 b	0.78 b
14	64.96 a	46.62 a	1.27 a
c. Soak temp (° C)			
15	34.10 c	25.74 b	0.66 c
25	44.71 b	32.73 b	0.80 b
35	54.84 a	58.45 a	1.02 a
d. Soak solution			
200 ppm EDTA	34.16 e	34.47 a	0.71 a
400 ppm EDTA	36.40 e	34.28 a	0.86 a
600 ppm EDTA	36.53 e	35.34 a	0.93 a
0.1% Malic acid	43.64 d	39.47 a	0.78 a
0.2% Malic acid	53.03 c	41.73 a	0.77 a
0.3% Malic acid	62.74 a	43.41 a	0.88 a
0.1% Citric acid	43.95 d	40.68 a	0.75 a
0.2% Citric acid	53.08 c	43.06 a	0.86 a
0.3% Citric acid	58.67 b	45.15 a	0.78 a
Tap water	34.00 e	35.56 a	0.91 a
Deionized water	34.36 e	35.59 a	0.89 a

[a] Means separated in columns by Duncan's multiple range test, 5% level

The TP was determined by the procedure described by Standard Methods (APHA, 1971) as the stannous chloride method. The samples were read in percent transmission and converted to parts per million phosphorus from a standard curve.

Statistical analyses included analysis of variance with Duncan's Multiple Range Test for means comparison. The analyses were conducted on an IBM 3600 computer by the University of Arkansas computer laboratory.

RESULTS

BEAN TYPE significantly affected lb COD, Tp and TSS per ton raw product in the effluent (Table 1a). Navy beans generated 2.8 and 3.1 times greater COD than Pinto or Red Kidney beans, while also generating 7.1 and 8.3 times greater TP than Pinto or Red Kidney beans, respectively, (Table 1a). The effluent from soaking Pinto beans was higher in TSS than Navy beans while the effluent from Red Kidney beans was lowest (Table 1a). The higher values for COD and TP for Navy beans may be due to the bean having a higher amount of soluble sugars and/or having a more porous skin which would allow for greater diffusion to the soaking solution. The higher values for TSS in Pinto beans was probably partly due to the beans having more soil adhering to the surface as a result of harvest location (Table 3).

Soaking time significantly affected lb COD, TP, and TSS per ton raw product in the effluent (Table 1b). Soaking for 14 hr resulted in a COD of 1.5, TP of 1.7, and TSS of 1.6 times that generated by a three hour soak (Table 1b). This was due to more soluble solids leaching from the beans as time increased. The significant interaction between bean type × soaking time demonstrated that Navy beans increased more in COD and TP at 6 and 14 hr soaks than Pinto and Red Kidney beans (Fig. 1c and 2c).

Soaking temperature significantly affected lb COD, TP, and TSS per ton raw product in the effluent (Table 1c). Soaking at 35°C generated 1.2 times COD, 1.9 times TP, and 1.3 times greater TS than beans soaked at 25°C, and resulted in 1.6 times COD, 2.3 times TP and 1.6 times greater TSS than beans soaked at 15°C. The significant bean type × soaking temperature interaction on COD and TP indicated that Navy beans increased more in COD and TP at 25° and 35°C than the other two types (Fig. 1b and 2a). The wastewater from Pinto and Red Kidney beans did not increase in COD and TP as drastically at 35°C, although the differences were significant. There was a significant

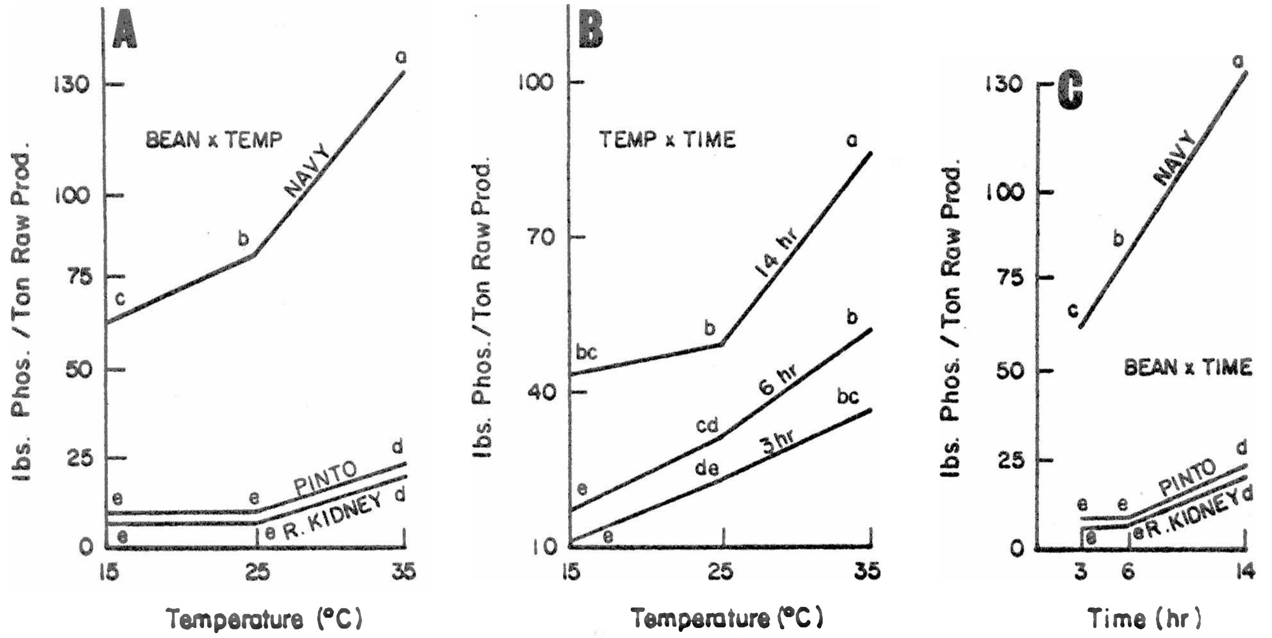

Fig. 2–Interaction of bean type X soaking temp, soaking temp X soaking time and bean type X soaking time on lb TP/ton raw product (dried Beans).

soaking time × soaking temperature interaction on COD and TP of the wastewater that was caused by greater differences at 35°C than at 15° and 25°C (Fig. 1a and 2b). Most of the interaction between soaking time × soaking temperature on TP resulted from higher TP in beans soaked at 35°C for 14 hr.

Soaking solutions significantly influenced lb COD per ton raw product in the effluent, but differences between solutions in TSS and TP were not significant (Table 1d). The soaking solutions EDTA, tap water and deionized water were lower in COD than the acid solutions. This was caused partly by the fact that acid solutions added COD to the water (citric acid 0.1%; 6.47 lb COD: malic acid 0.1%; 5.92 lb COD). Also, acid solutions leached out more soluble constituents and altered the carbohydrate structure of the beans. Addition of EDTA did not significantly alter the COD (Table 1d). The chelating action of EDTA actually decreased COD since EDTA contributes to the total COD of the effluent (200 ppm EDTA; 0.71 lb COD).

The interaction of soaking time × soaking solution on COD indicates that the differences between soaking solutions at 14 hr were much greater (Table 2a). This was especially true of the 0.2 and 0.3% acid solutions. Furthermore, similar differences occurred due to soaking at 35°C as compared to 15° and 25°C (Table 2b). These differences were mainly responsible for the significant soaking solution × soaking temperature interaction on COD.

Soaking solutions did not significantly affect TSS and TP (Table 1d), although acid solution leached more TP. However, because of the significant interactions, differences between soaking solutions on TSS and TP could not be

Table 3–Interaction of bean type × soaking solution on lb TSS/ton raw product

	lb TSS/ton raw product		
Solution	Navy	Red Kidney	Pinto
200 ppm EDTA	0.92 fghij[a]	0.27 k	0.94 fghij
400 ppm EDTA	0.83 hij	0.25 k	1.49 ab
600 ppm EDTA	0.81 hij	0.35 k	1.64 a
0.1% Malic acid	0.73 j	0.27 k	1.36 abcd
0.2% Malic acid	0.79 hij	0.34 k	1.17 cdef
0.3% Malic acid	0.83 hij	0.42 k	1.39 abcd
0.1% Citric acid	0.81 hij	0.29 k	1.15 defg
0.2% Citric acid	1.75 ij	0.39 k	1.44 abc
0.3% Citric acid	0.87 ghij	0.44 k	1.04 efghi
Tap water	1.08 efgh	0.33 k	1.32 bcde
Deionized water	0.92 fghij	0.37 k	1.40 abcd

[a] Means separated by Duncan's multiple range test, 5% level.

Table 2–Interaction of soaking time × soaking solution and soaking temperature × soaking solution on lb COD per ton raw product (dry beans)

	lb COD / ton raw product		
(a) Soaking soln	3 hr	6 hr	14 hr
200 ppm EDTA	16.01 o[a]	36.00 jkl	51.47 fg
400 ppm EDTA	16.36 o	38.39 j	54.27 fg
600 ppm EDTA	16.56 o	39.84 ij	53.38 fg
0.1% Malic acid	23.07 n	44.84 hi	63.00 d
0.2% Malic acid	28.13 lm	53.42 fg	77.53 c
0.3% Malic acid	37.24 jk	55.56 ef	91.10 a
0.1% Citric acid	23.27 n	44.13 i	64.44 d
0.2% Citric acid	31.29 m	52.62 fg	75.33 c
0.3% Citric acid	36.91 jk	59.87 de	83.53 b
Tap water	18.81 no	32.18 klm	49.47 gh
Deionized water	17.53 o	34.49 jkl	51.05 fg

	lb COD / ton raw product		
(b) Soaking soln	15°C	25°C	35°C
200 ppm EDTA	27.15 mn[a]	35.75 jkl	39.62 fghijk
400 ppm EDTA	28.68 m	37.87 ghijkl	42.67 fg
600 ppm EDTA	29.04 m	36.93 hijkl	43.60 f
0.1% Malic acid	34.71 kl	43.16 fg	53.04 de
0.2% Malic acid	41.96 fgh	51.41 e	65.72 b
0.3% Malic acid	50.40 e	59.78 c	78.03 a
0.1% Citric acid	33.91 l	44.06 f	53.86 de
0.2% Citric acid	41.30 fghi	52.47 e	65.47 b
0.3% Citric acid	41.74 fghi	57.78 cd	76.48 a
Tap water	22.91 n	36.44 hijkl	41.16 fghij
Deionized water	23.32 n	36.24 ijkl	43.51 f

[a] Means separated by Duncan's multiple range test, 5% level

Table 4—Interaction of soaking time × soaking solution and soaking temperature × soaking solution on lb TP/ton raw product on dried beans

	lb TP/ton raw product		
(a) Soaking soln	3 hr	6 hr	14 hr
200 ppm EDTA	21.38 k[a]	28.46 hij	53.56 c
400 ppm EDTA	21.81 k	28.63 ghij	52.39 c
600 ppm EDTA	23.37 k	30.62 efgh	52.03 c
0.1% Malic acid	24.05 ijk	34.80 defg	59.46 abc
0.2% Malic acid	24.37 ijk	37.94 d	62.87 abc
0.3% Malic acid	25.86 hijk	35.47 def	68.89 ab
0.1% Citric acid	24.21 ijk	37.12 de	60.72 abc
0.2% Citric acid	24.29 ijk	35.66 def	69.23 ab
0.3% Citric acid	25.76 hijk	39.24 d	70.44 a
Tap water	22.11 k	29.17 fghij	55.39 bc
Deionized water	24.49 k	30.01 fghi	55.27 bc

	lb TP/ton raw product		
(b) Soaking soln	15°C	25°C	35°C
200 ppm EDTA	23.78 i	29.88 defg	49.74 bc
400 ppm EDTA	24.37 hi	29.79 defgh	48.68 c
600 ppm EDTA	24.95 ghi	30.81 defg	50.25 bc
0.1% Malic acid	25.62 ghi	32.52 def	60.27 ab
0.2% Malic acid	27.34 efghi	33.84 d	63.99 a
0.3% Malic acid	27.44 efghi	35.72 d	67.06 a
0.1% Citric acid	25.93 ghi	33.42 de	62.69 a
0.2% Citric acid	26.99 fghi	36.06 d	66.13 a
0.3% Citric acid	27.48 efghi	36.49 d	71.47 a
Tap water	24.17 hi	30.64 defg	51.86 bc
Deionized water	24.99 ghi	30.94 defg	50.83 bc

[a] Means separated by Duncan's multiple range test, 5% level

separated. The interaction of bean type × soaking solution on TSS showed that part of the solutions had a much greater effect on the TSS of Navy and Pinto beans than on Red Kidney beans (Table 3). Part of the discrepancy could have been due to the difficulty of duplicating the TSS results. Also, the Pinto beans had more soil adhering to the surface as a result of harvest location.

The interaction of soaking time × soaking solution on TP of the effluent indicates that TP was much higher in the acid solutions when compared to other treatments at 14 hr than at 3 hr (Table 4a). The differences between acid solutions and other treatments at 6 hr were intermediate. Similarily, the interaction between soaking solution and soaking temperature on TP demonstrated that the acid solutions leached out more TP at 35°C than at 15° and 25° (Table 4b). The greater diffusion during 14 hr soaking and the higher diffusion rate at 35°C contributed much greater COD and TP to the effluent.

SUMMARY & CONCLUSIONS

IT WAS FOUND that bean type, soaking time, and soaking temperatures significantly affected lb COD, TP and TSS per ton raw product in the effluent, while soaking solutions significantly affected COD values only. Navy beans generated the highest COD and TP, while Pinto beans generated the highest TSS. As soaking time and temperature were increased COD, TP and TSS of the effluent increased. Beans soaked in acid solutions generated the highest COD values, while those soaked in EDTA, tap water and deionized water were lowest.

The results show that Navy beans acted differently than either Red Kidney or Pinto beans under the same processing conditions. From the results, the ideal soaking procedure to use to reduce pollutional output and not adversely affect bean quality for Navy, Red Kidney and Pinto beans is: Navy, 3-hr soak, 25°C; Red Kidney, 6-hr soak, 25°C; and Pinto, 6-hr soak, 25°C. The use of chelating agents would not be economically feasible, although some beneficial results were obtained.

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APPENDIX C-1

BACTERIAL FERMENTATION OF HIGH ALKALINE WASTES FROM IRISH POTATOES

W. A. SISTRUNK, M. ISMAIL K. and J. A. COLLINS

ABSTRACT

A study was conducted on high alkalinity lye-peeling wastes from Irish potatoes to determine the optimum time and temperature of fermentation, predominant types of bacteria, and handling conditions suitable for fermentation. The optimum temperature for fermentation was 30°C. Both aerobic and anaerobic conditions were suitable for fermentation, but aerobic fermentation at 30–35°C was efficient in reducing the pH below 7.0. Wastes fermented more rapidly when seeded with previously fermented wastes. Starch content decreased in the wastes during fermentation, but total sugars and pectin increased in both nonsterilized and sterilized lots. Dry matter content decreased approximately 1% during fermentation but remained stable in storage. The greatest increase in acidity was due to lactic acid although small changes occurred in other organic acids. The major bacteria found in the fermented wastes were tentatively identified as *L. delbrueckii*, *S. faecium* and *S. lactis*.

INTRODUCTION

THE ANNUAL POTATO production in the U.S. is more than 300 million cwts, and more than half is processed as flakes, frozen, chips, flour, canned, peeled and starch (Agri. Stat., 1976). In preparation for processing, 20–50% of the raw product is discharged as waste (Streebin et al., 1971). Most of the wastes from potato plants arise from peeling, trimming, slicing, cleaning and rinsing operations, and the discharge of these liquid and solid wastes creates a pollution problem. With more emphasis on reduction of pollution, most potato processing plants have converted to "dry" caustic peeling in which most of the heavy viscosity peel waste is segregated from the wastewater (Graham et al., 1969). The solid by-products from potato processing have been utilized for feed for livestock after fermentation (Dickey et al., 1965; Gee et al., 1974; Blackstock and Skiver, 1974). A method for neutralization of the high alkalinity wastes has been described by a number of investigators (Block et al., 1973; Gee et al., 1974; Sistrunk and Karim, 1977; Vennes and Olmstead, 1961). Gee et al. (1974) reported that the organisms isolated from fermented alkaline potato wastes were of the lactic acid type, mostly *Micrococcus* and *Bacterium* species that were gram positive rods and cocci. In feedlot waste from feed grain, *Lactobacilli* were found to be dominant (Hrubant, 1975; Rhodes and Orton, 1975).

When the alkalinity was as high as pH 12, much longer time was required for fermentation (Gee et al., 1974; Sistrunk and Karim, 1977). Incubation at temperatures above 30°C accelerated the rate of fermentation but putrefactive anaerobes created disagreeable odors. The reduction in alkalinity and increase in acidity in potato wastes were due to production of lactic acid without any change in other organic acids (Gee et al., 1974). Lactic acid was also predominant in fermentation of feed grain wastes (Hrubant, 1975; Rhodes and Orton, 1975).

It has been shown that high alkaline potato waste can be fermented and stored in silos or pits for livestock feed (Blackstock and Skiver, 1974). Storage of waste in open pits in arid regions for feeding livestock is not a problem but in regions of high rainfall, such as the Ozark region, it is necessary to construct covered silos or pits. Also, because of the low volume of potato wastes as compared to potato producing states, longer storage times are necessary to maintain a supply of wastes. The objectives of this research were to determine the optimum time and temperature, predominant types of bacteria, and optimum conditions for fermentation and handling Irish potato peel wastes for livestock feeding.

EXPERIMENTAL

THE FERMENTATION STUDIES were conducted on peel wastes from Irish potatoes that had an initial total solids content of 16–18% and pH of 11.0–11.8.

Experiment I–Optimum temperature for fermentation

Two experiments were set up to study the rate of fermentation: (a) six temperatures (20–50°C) and (b) four temperatures (20–35°C). Both experiments were conducted at four incubation times (2, 4, 6 and 8 days) with three replications. The samples were prepared by blending the waste 1:1 part $W/V/H_2O$ in a heavy duty blender at low speed. One kg samples were placed in 9 lb glass bottles. One-half of the samples were incubated aerobically and the other anaerobically. In preliminary experiments, aerobic conditions were maintained by a continuous flow of air through a gas bubbling tube. However, since fermentation to a pH of 7.0 was only accelerated by one day by this method, the samples for this experiment were shaken vigorously each day and left open to the air. Anaerobic waste samples were flushed for 1 min with N_2 and stored with an anaerobic trap. After each sampling time for pH and internal temperature, anaerobic samples were flushed with N_2 and recapped. The initial pH of the waste was 11.8.

Experiment II–Isolation and screening of predominant microorganisms

It was set up in three parts to: (a) determine bacterial counts on various media, (b) isolate the predominant types of microorganisms in fresh and fermented wastes and screen these microorganisms for production of acid, and (c) determine optimum seeding rates for rapid fermentation of fresh wastes by using fermented wastes.

(a) Initial pH of fresh waste was 10.9 and fermented waste was 5.2. Samples were plated on Standard plate count (SPC), Tomato Juice (TJ), and Violet Red Bile (VRB) agars by standard methods and procedures (BBL Manual, 1977; Difco Manual, 1974). The SPC plates were incubated 48 hr at 30°C both aerobically and anaerobically before counting. Anaerobic conditions were attained by evacuating the plates and tubes in an air tight container, flushing the chamber with N_2 for 1 min and sealing the container. The TJ and VRB plates were incubated aerobically and anerobically at 30° and 35°C, respectively, for 48 hr. These counts were not determined on nonfermented waste except the aerobic count on VRB agar.

(b) Representative colonies were isolated from the plates of SPC and TJ plates and grown on agar slants to study morphological characteristics and obtain pure strains. Mold cultures were similarly isolated and classified by standard procedures (Difco Manual, 1974; Frazier, 1967).

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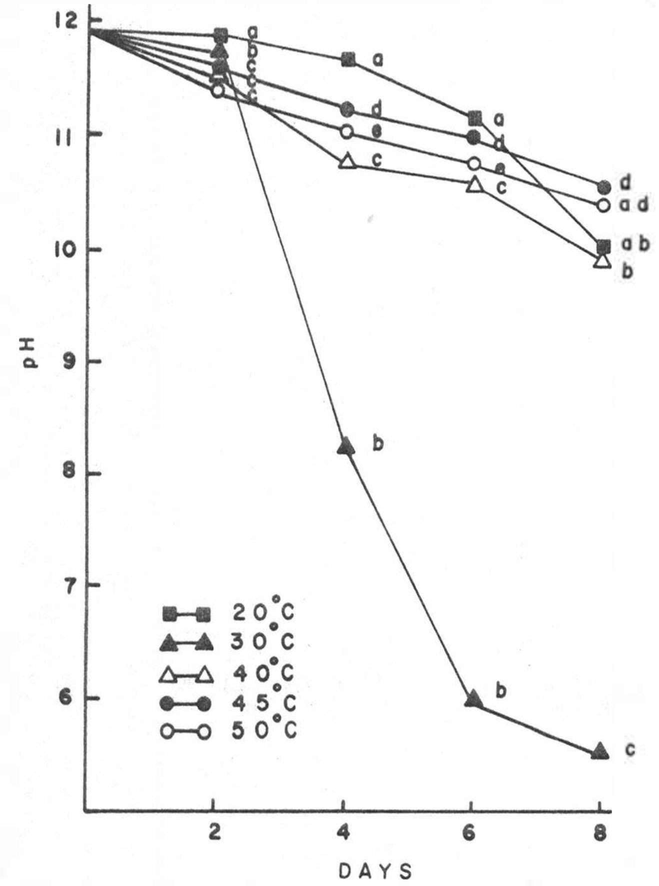

Fig. 1—Effect of temperature on the change in pH during incubation under aerobic conditions (mean separation within days by Duncan's Multiple Range Test).

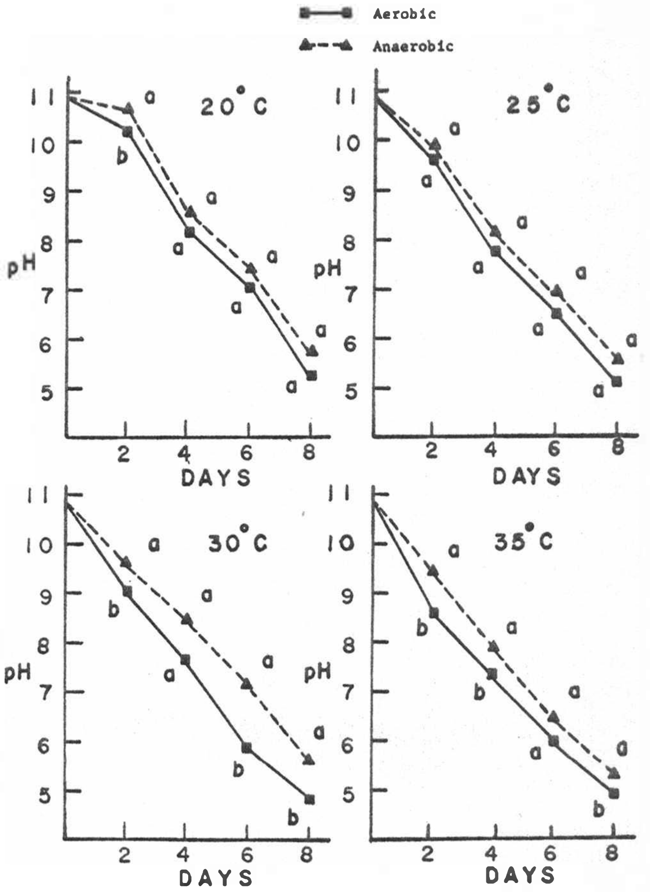

Fig. 2—Effect of temperature and fermentation conditions on change in pH during incubation (mean separation within days by Duncan's Multiple Range Test).

Isolates were screened for acid production by inoculation in Trypticase Soy Broth (TSB) adjusted to six pH levels (7–12). Again, tubes were incubated both aerobically and anaerobically. Further screening tests were conducted on those isolates that produced acid in TSB media by transferring an aliquot of the active cultures to 100g of both fresh and sterilized alkaline waste which had been adjusted to the six pH levels. For the lots of sterilized wastes, samples were cooked for 35 min at 121°C and cooled before inoculation.

(c) A 14-kg batch of lye-peeling waste at pH 11.4 was allowed to ferment to pH 5.4 to obtain fermented waste (inoculum) for seeding fresh waste at different rates from 0–40%. The experiment was set up in 10 kg stone crocks at a temperature of 24 ± 2°C for incubation times of 0–8 days.

Experiment III—Changes in composition during fermentation

Samples inoculated with isolates R_3, R_5, C_2 and C_3 of Expt. II(b) that were fermented under both aerobic and anaerobic conditions, sterilized and nonsterilized, were analyzed for carbohydrates, total N and minerals. Since the differences in carbohydrates among isolates were small, data shown in Table 3 are averages.

Total sugars, starch, pectins, hemicellulose and cellulose were analyzed by the methods reported previously (Sistrunk, 1965; Dubois et al., 1956; Dietz, and Rouse, 1953). Samples were wet-ashed and minerals Ca, K and Mg, and N determined by methods of AOAC (1965), and P by the Standard Methods for Examination of Water and Wastewater (1971). An atomic absorption spectrophotometer, Beckman Model 1301, was used for Ca, K and Mg analyses.

Organic acids were analyzed by methods described by Kushman and Ballinger (1968) and Buescher (1975). A varian aerograph 1000 gas-liquid chromatograph (GLC) with the following specifications was used: flame ionization detector; single 3.05m by 3.18 mm stainless steel columns with 3% SE52 on Chromosorb W, 10–100 h.p., DMCS treated; helium carrier gas at 35 ml/min; hydrogen carrier gas at 35 ml/min; air-flow at 250 ml/min; injector temperature 220°C, 80°C for 5 min, then program 6°C/min to 250°C and sample size 5 μl. The organic acids were identified by comparing retention times and detention temperatures with those of internal standard and the concentrations determined by their relationships to known concentrations of glutaric acid added before extraction.

Experiment IV—Identification of microorganisms

To identify acid producing isolates from Expt. II(b), the gram + rods (R_2, R_3, R_4, R_5) and gram + cocci (C, C_2, C_3), all acid producing, were subjected to a series of physiological and biochemical tests. Morphological and other preliminary tests indicated these isolates to be lactic acid producers, so the procedures described by Rogosa and Sharpe (1959) and Buchanan and Bibbons (1974) in Bergey's manual were closely followed.

Data were analyzed as factorials and recorded in tables. Wherever significant interactions occurred, they were graphed. Significant differences between means were separated by the Duncan Multiple Range Test (Duncan, 1955).

RESULTS & DISCUSSION

Experiment I—Optimum temperature for fermentation of wastes

The optimum temperature for fermentation was 30°C under aerobic conditions when comparing 20°, 30°, 40°, 45° and 50°C as indicated by the reduction in pH (Fig. 1). This confirmed the work of Gee et al., 1974. Growth under anaerobic conditions was poor at all temperatures, and at the end of 8 days the lowest pH was 11.3 (data not shown).

In a second experiment, a comparison was made of the changes in pH within a narrow range of temperatures from 20–35°C. There were no differences in growth of aerobic and anaerobic bacteria at 20° and 25°C as shown by the changes in pH (Fig. 2). However, at 30° and 35°C the aerobically incubated samples decreased more rapidly in pH.

The initial pH of the waste was 10.9. The small differences between aerobic and anaerobic growth at 20° and 25°C in this part of Expt. I could have been due to the lower initial pH.

Experiment II—Isolation and screening of predominant organisms

Bacterial count. Using SPC agar the aerobic plate count was 3.5×10^5 and anaerobic plate count 2×10^5 organisms/g on nonfermented (pH 10.9) wastes (Table 1). In fermented wastes (pH 5.2) counts were $> 3 \times 10^8$ aerobic and $> 2.5 \times 10^7$ anaerobic microorganisms/g. The fermented wastes contained mostly lactic acid types as determined by morphological characteristics. Using VRB agar, no bacterial growth was found on either the aerobic or anaerobic plates. The competition from the dominant acid tolerate bacteria found in fermented wastes could have inhibited coliform types. Hrubant (1975) has shown that the dominant *Lactobacilli* in fermented feedlot wastes from corn inhibited coliform and most other types of bacteria. In the TJ agar (medium for lactic acid bacteria) the counts were identical to those found on SPC agar in the fermented wastes, indicating that the perdominant bacteria were lactic acid bacteria (Table 1). In the nonfermented wastes, the counts on TJ agar were not determined.

Isolation and screening of predominant microorganisms in potato wastes. Four gram positive rods (R_2-R_5) and 3 gram + cocci (C_1, C_2, C_3) were chosen from the bacteria isolated and the morphological characteristics recorded for later reference. Most of the cultures of gram + rods were medium to long rods, appearing as singles, doubles and occasionally in chains. The gram + cocci were mostly singles, short chains and some in groups. Gram + cocci were predominant in fermented waste at pH 5.2.

Molds identifed as *Geotrichum*, *Aspergillus* and *Penicillium* were present in the fermented wastes but these appeared to be of secondary importance and were not studied in detail since they did not play a significant role in acid production.

A significant reduction in pH of sterilized potato wastes occurred in samples inoculated with gram + rod isolates R_2-R_5 at all pH levels (Table 2). Isolates R_3 and R_5 appeared to ferment the wastes more rapidly of the gram + rods, C_2 and C_3 were more active than C_1. Less change in pH occurred at pH 12.0 although all of the isolates appeared to survive and initiate a slight fermentation within 8 days.

Fermentation by seeding. It was found that the high alkalinity wastes fermented more rapidly when seeded with previously fermented wastes (Fig. 3). This waste was received from another plant where the pH was extremely high (pH 12.4). The fresh waste pH was reduced somewhat by the addition of fermented waste although in 6 days at 25°C there was little change in activity until the inoculum was increased to 25%. Even at 10 days there was no apparent change in un-inoculated samples and 5% seeded samples, indicating that at this pH and aerobic conditions the waste was essentially sterile. These results support the work done by Gee et al. (1974), who showed that potato waste at pH 12 required 2 wk or longer to ferment to pH 8.6. Sistrunk and Karim (1977) demonstrated that by increasing the fermented inoculum in sweet potato waste at pH 12.2 fermentation proceeded more rapidly. There appeared to be very little problem in fermenting wastes that were below pH 11.5

Table 1—Bacterial Plate Counts made on nonfermented and fermented lye-peeled Irish potato waste based on per gram fresh weight

	Nonfermented waste (pH 10.9)		Fermented waste (pH 5.2)	
Media used	Aerobic count	Anaerobic count	Aerobic count	Anaerobic count
Standard plate count (SPC) agar	3.5×10^5	2.0×10^5	$> 3.00 \times 10^8$	2.5×10^7
Tomato juice agar	ND[a]	ND	$> 3.00 \times 10^8$	2.5×10^7
Violet Red Bile (VRB) agar at 10^{-1} dilution	Nil[b]	ND	Nil	Nil

[a] No data available, and plate count was not determined here

[b] No growth found

Table 2—Acid production from isolated bacteria grown in sterilized potato waste incubated at 30°C at the end of 8 days of fermentation under aerobic condition

	pH value after 8 days					
	Initial pH of potato waste					
Inoculated bacteria	12	11	10	9	8	7
Control[a]	11.88a[b]	10.90a	9.90a	8.90a	7.90a	6.95a
R_2[c]	11.48b	10.25bc	9.20c	8.10bc	7.30b	6.40bc
R_3	11.13d	9.90bc	9.00d	7.95cde	6.70d	6.10d
R_4	11.28c	10.25bc	9.40b	8.05cd	7.10c	6.25cd
R_5	11.05d	9.90bc	8.95d	7.90de	6.85d	6.10d
C_1[d]	11.45bc	10.35ab	9.25bc	8.25b	7.15bc	6.53b
C_2	11.13d	9.73c	8.63e	7.78e	6.45e	6.05d
C_3	11.10d	9.68c	8.60e	7.75e	6.35e	6.13d

[a] Potato waste was not inoculated with any of the isolated bacteria.

[b] Mean separation in columns by Duncan's multiple range test, 5%

[c] Gram positive rods

[d] Gram positive cocci

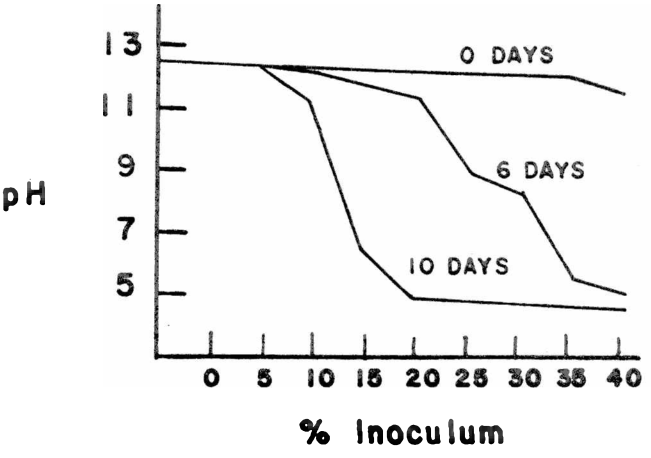

Fig. 3—Effect of amount of inoculum on changes in pH during incubation under aerobic conditions.

Experiment III—Changes in composition during fermentation of alkaline potato waste

Changes in composition during fermentation are important to the total energy value of waste for livestock feed. The regional industry is interested not only in the changes during fermentation, but during long-term storage. This study reports only the initial changes during fermentation for 8 days at 30°C (Table 4). There was approximately a 1% decrease in dry matter during fermentation but no difference between aerobic and anaerobic conditions, nor between sterilized and nonsterilized samples. This indicated that the isolates were capable of fermenting the waste. The % total sugars and pectin increased in both nonsterilized

Table 3—Changes in carbohydrate composition of lye-peeled Irish potato waste during fermentation at 30°C for 8 days (fresh weight basis)[a]

Treatment (Potato waste)	Percent.						
	pH	Tot. sugars	Starch	H_2O sol. pectin.	Hemicellulose	Cellulose	Dry Matter
Nonsterilized							
Nonfermented (control)	11.5	0.82b[b]	5.13a	0.56b	0.52b	0.36a	17.29a
Fermented (aerobic)	5.8	2.17a	2.27c	1.03a	0.61a	0.26b	16.23b
Fermented (anaerobic)	5.7	2.11a	2.75b	0.94a	0.61a	0.27b	16.38b
Sterilized[c]							
Nonfermented (control)	11.6	0.67b	4.83a	0.52b	0.49c	0.37a	17.18a
Fermented (aerobic)	5.7	1.80a	2.16b	0.89a	0.59a	0.25b	16.09b
Fermented (anaerobic)	5.6	1.75a	2.06b	0.90a	0.52b	0.27b	16.17b

[a] Average values from isolates R_3, R_5, C_2 and C_3.

[b] Mean separation in columns under nonsterilized and sterilized waste by Duncan's multiple range test, 5%

[c] Potato waste sterlized at 121°C (15 psi) for 35 min

Table 4—Average concentration of organic acids present in the nonfermented and fermented lye-peeled Irish potato waste

Treatment	pH of waste	Acid concentration (me/g dry weight)					
		Phosphoric	Succinic	Fumaric	Malic	Citric	Lactic
Nonsterilized							
Nonfermented	11.6	0.039b[a]	0.069a	0.044a	0.133a	0.093b	0.22b
Fermented	5.2	0.056a	0.039b	0.015b	0.085b	0.217a	1.80a
Sterilized[b]							
Nonfermented	11.4	0.044b	0.133a	0.031a	0.193a	0.141b	0.255b
Fermented	5.3	0.101a	0.072b	0.021a	0.145a	0.205a	2.033a

[a] Mean separation in columns under nonsterilized and sterilized waste by Duncan's multiple range test, 5%.

[b] Waste sterilized at 121°C (15psi) for 35 min

and sterilized samples during fermentation. Hemicellulose also increased except in the anaerobic samples of sterilized waste. There was a small, but consistent decrease in cellulose in fermented wastes. Since changes in composition were similar in both sterilized and nonsterilized wastes inoculated with the isolates it was assumed that these isolates were some of the important microorganisms that ferment potato wastes.

The composition of minerals (Ca, K, P and Mg) did not change during fermentation (data not shown). Nitrogen content decreased from 0.24 to 0.21% during fermentation. We have shown in other studies that changes in composition during 9 months storage are not great if the temperature is held below 25°C.

Organic acids present in nonfermented waste were phosphoric, succinic, fumaric, malic, citric and lactic (Table 5). There was a decrease in succinic, fumaric and malic acids during fermentation of nonsterilized wastes but an increase in phosphoric, citric and lactic acids. In sterilized waste, there was no change in fumaric and malic during fermentation. The greatest increase in acidity during fermentation was due to lactic acid, and this increase was greater in sterilized samples.

Experiment IV—Identification of bacteria

Two of the gram + rods (R_3 and R_5) showed a high correlation of 95% and 89% respectively when compared to *L. delbrueckii* in differentiating characteristics (Rogosa and Sharpe, 1959; Buchanan and Gibbons, 1974). All five gram + Rod isolates were compared to *L. delbrueckii* and *L. bulgaricus* which appeared to be the two lactobacilli more closely related. The correlations ranged from 65–80% with *L. bulgaricus* among the isolates, but these were not considered to be high enough for identification. The gram + cocci isolates were compared to *S. faecalis, S. faecallis var. liquifaciens, S. faecium, S. cremoris* and *S. lactis*, which appeared to have similar morphological characteristics. Isolates C_2 and C_3, the two best acid producing, showed high correlations of 92% with *S. faecium*. Isolate C_1 showed a correlation of 84% with *S. lactis*. Correlations with other streptococci above ranged from 38–77% which were not high enough for the purpose of identification.

Therefore, the major bacteria responsible for fermentation were tentatively identified as *L. delbrueckii* and *S. faecium* with one of the gram + cocci possibly being *S. lactis*.

In conclusion, after successive experiments with high alkaline wastes from two different processing plants that produced wastes of 10.9–12.4 pH, data showed that wastes with a pH above 11.0 could be fermented more rapidly by mixing previously fermented waste with the fresh waste. There was a change in carbohydrates, which was mostly starch to sugar, during 8 days fermentation and an increase in lactic acid. From these laboratory studies and other larger experiments with industry it appears feasible to store the wastes for several months in covered underground pits. Minor changes in total carbohydrates occurred but this seems to be a practical solution to usage of high alkaline wastes in the region.

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APPENDIX C-2

Disposal of Lye-Peeling Wastes from Sweet Potatoes by Fermentation for Livestock Feed

By W.A. SISTRUNK and M. ISMAIL KARIM

ONE OF the major solid wastes produced in vegetable canning plants in Arkansas is from sweet potato peels. When sweet potatoes are peeled for processing about 40 to 50 percent of the raw product becomes waste.

A boiling sodium hydroxide solution (lye) is the most efficient method of removing the peel. Although most plants use the "dry lye" peeling method in which most of the digested peel is removed with rubber scrubbers without addition of water, the volume of heavy viscosity solid waste is large and expensive to dispose of. Disposal of high alkalinity wastes by landfill continues to be opposed by the EPA because of the high sodium content and other problems.

Bacterial fermentation of the peel waste by *Lactobacilli* and *Streptococci* to reduce the pH from 11.8 or 12.4 to 6.0 or less, and then feeding it to livestock is one potential method of utilization.

A series of experiments was designed to study methods of handling, fermentation, and storage of the wastes. There was very little change in mineral and protein content of the waste during 7 days of fermentation (Table 1). The pH changed from 11.8 to 4.9 in 7 days, but the speed of fermentation depended on the temperature and aeration of the waste. Calcium and sodium appeared to decrease during fermentation.

The major changes in carbohydrates during fermentation were a decrease in starch and cellulose and an increase in pectin and hemicellulose (Table 2). In lots that were inoculated with enzymes there were additional changes, depending on the enzyme used. Adding hemicellulase to the waste after the initial 2 days of fermentation decreased hemicellulose, while pectinase decreased pectin as well as hemicellulose. Also, the percent total sugars and cellulose were slightly higher when pectinase was added. Diastase degraded most of the starch to sugars and appeared to affect solubility of pectins and hemicellulose. These enzymes are inactivated at pH of 10 or above and therefore were not added until the bacteria had reduced the pH to 7.0, which occurred after 2 days.

It would not be necessary to add enzymes when the wastes are fed to ruminant animals, but the enzymes could be beneficial in breaking down the larger carbohydrates and releasing other nutrients for feeding to other animals.

Systems for handling, fermentation, and storage appear to be the major problem in utilizing sweet potato waste. Because of the low volume of wastes and short processing season, the fermented waste would have to be stored for 6 to 9 months in order to establish an efficient feeding operation during the winter. It was found that the waste fermented more rapidly when seeded with previously fermented waste [Table 3]. There was apparently very little difference in speed of neutralizing the alkalinity beyond 20 percent inoculum.

This information should be helpful in establishing a stepwise system of fermentation and storage. By using a series of batch fermentation pits, the waste could be inoculated continuously and ready for feeding within 2 days if the temperature was between 25 and 30°C.

Table 3. Effect of Amount of Inoculum on Speed of Fermentation at 25°C

Percent inoculum	pH of waste after (days) 0	2	4	6
0	11.8	11.1	8.6	7.4
5	11.6	10.3	6.6	5.7
10	11.5	10.0	6.2	5.2
15	11.3	8.0	5.7	5.0
20	11.0	6.6	5.2	4.9
25	10.8	6.5	5.1	4.8
30	10.2	6.1	5.0	4.7

The waste must be aerated during fermentation to prevent development of objectionable odors. After the waste is fermented it can be stored for several months in covered storage pits or silos. Mold growth on the surface of the waste must be inhibited to prevent the danger of mycotoxins. Sodium sorbate and sodium dehydroacetate have been found effective inhibitors of mold.

In summary, high alkalinity wastes from peeling sweet potatoes for canning can be fermented and stored for livestock feed. It is necessary to store the waste in covered silos or pits and to prevent mold growth on the surface of the waste. Only minor changes occur in carbohydrate, mineral, and protein content during fermentation and storage.

Dr. Sistrunk is horticultural food scientist; Mr. Karim is a graduate student.

Table 1. Changes in Composition of Sweet Potato Waste during Fermentation [Dry Basis]

Days	pH	Nitrogen	Ca	K	Mn	Na
		Percent		Percent		ppm
0	11.8	1.29	.56	1.15	15	66
2	6.6	1.04	.53	1.10	10	65
3	6.2	1.70	.53	1.20	13	54
4	5.9	1.49	.46	1.45	11	46
5	5.5	1.47	.42	1.30	11	40
6	5.4	1.18	.37	1.30	10	38
7	4.9	1.43	.42	1.35	10	40

Table 2. Effect of Enzymes on Carbohydrate Changes During Fermentation of Waste for 7 Days[1]

Treatment	Total sugars	Starch	Pectin	Hemicellulose	Cellulose	Dry matter
			Percent			
Diastase	12.90	0.20	1.13	.74	1.48	24.98
Pectinase	8.40	2.20	1.24	.83	1.68	24.43
Hemicellulase	7.34	2.50	1.71	.61	1.54	25.27
Fermented control	7.30	2.30	1.66	1.08	1.40	25.66
Non-fermented control	8.01	3.86	1.37	.64	1.83	24.46

[1] Enzymes added 2 days after beginning fermentation at 20°C.

Color of Grain in Grain Sorghum

By ROY N. SHARP

THE relationship between color and feeding value of grain sorghum is very controversial. Researchers at this Station previously reported extreme variability in the feeding value of different grain sorghum cultivars (Arkansas Farm Research, Vol. 25, No. 2). In general, grain sorghums with brown pericarps are inferior to cultivars with commercial yellow pericarps in feeding value. Many times producers who use animal feeds containing grain sorghum are not sure whether they are feeding brown or commercial yellow cultivars.

To evaluate the degree to which color differences could be detected by individuals untrained in grain grading, samples were obtained from 14 different cultivars grown in varietal yield plots at the Main Station. A color classification was assigned to each sample, in accordance with U.S. Grain Standards. A five-member panel rated each sample on a scale of 0 to 100 (black to white). Color values also were obtained for each sample using a color difference meter (CDM).

Average panel scores were highly correlated with CDM color values [Table 1]. The panel ratings were highly associated with the degree of yellowness and redness as well as with lightness. Although individuals could assign color values that were highly correlated with instrumentation-derived values, the values assigned by the panel were quite different.

An examination of the CDM color values for each sample shows that some samples previously classified as brown have more yellow than some others classified as yellow (Table 2). Also, some browns were not as dark as some yellows. This indicates the complexity encountered in differentiating between yellow and brown cultivars. There are criteria other than pericarp color that must be considered. These other factors are sometimes difficult to assess even by trained personnel. For example, the presence of a brown-pigmented subcoat demands that a yellow-pericarped cultivar be classified as brown.

The method that appears to be the simplest and most reliable at this time is the bleach test. The grain industry utilizes this test at the elevator to detect the presence of brown subcoats. The method, described at the 1976 Arkansas Nutrition Conference, can be conducted on a farm as well.

All samples in this study that were previously classified as brown were dark after the bleaching process, while all those classed as yellow were white or very pale yellow.

These results indicate that external color of grain sorghum, whether observed visually or by instrumentation, does not reliably differentiate between yellow and brown grain sorghums. A relatively simple bleaching test is presently the most reliable method of detecting subcoats that place otherwise yellow grain sorghum into the brown classification. However, it should be remembered that the bleaching method tells nothing of the feeding value of brown grain sorghum, and that some brown cultivars have higher digestibility coefficients that some yellow types.

Table 1. Simple Correlation Coefficients between Color Observations of 14 Grain Sorghum Cultivars

Item	Correlation coefficients			Panel rating
	L	a	b	
L	1.000	.565*	.936**	.944**
a		1.000	.751**	.767**
b			1.000	.990**

*P less than .05 = .532.

** P less than .01 = .661.

Table 2. Classification, Color Difference Meter Values, and Panel Ratings of 14 Grain Sorghum Cultivars

Sample	Commercial classification[1]	L[2]	a[3]	b[4]	Panel[2] ratings
Ring Around 808	Y	33.8	8.1	12.4	48.8
Coop SG-40	Y	36.3	9.0	14.1	64.0
SFA E-110	Y	32.2	9.1	11.9	46.0
SFA ML-135	Y	36.0	7.9	13.7	59.2
Funks G-516 BR	B	28.9	7.0	8.7	20.4
Funks G-522	Y	35.1	7.9	13.1	57.6
AKS-614	B	30.5	8.9	11.6	43.6
AKS-663	B	28.7	7.3	10.3	30.2
ARK 71009	B	26.3	7.5	8.9	20.0
ARK 72005	B	28.1	7.6	9.8	31.0
ARK 72011	B	33.4	11.8	14.0	62.0
ARK 72020	B	35.0	11.2	15.0	69.2
ARK 72021	B	35.2	9.6	14.4	66.6
KS 692	Y	36.2	11.4	14.2	72.2
Mean		32.6	8.9	12.3	49.3

[1] Y, yellow; B, brown.

[2] O, black; 100 white.

[3] Samples with higher values contain more red color.

[4] Samples with higher values contain more yellow color.

Mr. Sharp is research assistant in Horticultural Food Science. The grain sorghum samples were furnished by the Agronomy Dept.

New Publications Available

The following publications have been released since the November-December issue of Arkansas Farm Research:

- Bul. 813—Economics Feasibility of Developing Additional Public Outdoor Recreation Areas at Beaver Lake, Arkansas
- Bul. 814—Deterrents to Training and Employment, as Perceived by Low-Income Household Heads in Western Arkansas
- Bul. 815—An Economic Evaluation of Three Haying Systems in Arkansas, 1975
- Bul. 816—Minimum Capital Requirements for Two Levels of Farm Income on Small Farms in Southeast Arkansas
- Rpt. Series 231—Adult Rice Water Weevil Feeding Preferences for Rice Plants and Leaves of Different Ages
- Spec. Rpt. 36—Attitudes Toward Planning and Management of Land Resources: Yell County, Arkansas
- Spec. Rpt. 37—Attitudes Toward Planning and Management of Land Resources: Cleburne County, Arkansas

You can obtain single copies of these publications, free of charge, from the Bulletin Office, Agricultural Experiment Station, University of Arkansas, Fayetteville, or from your County Extension Agent.

APPENDIX D

LIST OF PUBLICATIONS

1. Holley, E. M. 1979. Comparison of an experimental washer with a conventional washer for washing leafy greens: water and product quality. Master's thesis, University of Arkansas, Fayetteville, AR.

2. Junek, J. J., W. A. Sistrunk, and M. B. Neely. 1979. Influence of processing methodology on quality attributes of canned dry beans. Food Technol. 33: In press.

3. Karim, M. Ismail. 1977. Bacterial fermentation of high alkaline wastes from Irish potatoes. Master's thesis, University of Arkansas, Fayetteville, AR.

4. Mahon, M., W. A. Sistrunk, and D. W. Freeman. 1975. Effect of processing methodology on quality attributes and nutritional value of canned spinach. Proc. Ark. State Hort. Soc. pp. 28-30, 1975.

5. Neely, M. B. 1978. Effect of processing methodology on quality of wastewater and quality of canned dry beans. Master's thesis, University of Arkansas, Fayetteville, AR.

6. Neely, M. B. and W. A. Sistrunk. 1979. Influence of processing methodology on the strength of wastewater from canning dry beans. J. Food Sci. 44:407-410.

7. Sistrunk, W. A. 1979. Effects of preparation, processing and storage on quality and retention of certain vitamins in kale greens. J. Food Sci. 44: In press.

8. Sistrunk, W. A. and G. A. Bradley. 1975. Quality and nutritional value of canned turnip greens as influenced by processing technique. Ark. Farm Res. 24(2):5.

9. Sistrunk, W. A. and M. Ismail Karim. 1977. Disposal of lye-peeling wastes from sweet potatoes by fermentation for livestock feed. Ark. Farm Res. 26(1): 8.

10. Sistrunk, W. A., M. Ismail Karim and J. A. Collins. 1979. Bacterial fermentation of high alkaline wastes from Irish potatoes. J. Food Sci. 44:439-441.

11. Sistrunk, W. A., M. K. Mahon and D. W. Freeman. 1977. Relationship of processing methodology to quality attributes and nutritional value of canned spinach. HortScience. 12:59-60.