Composition of Fruit and Vegetable Processing Wastes

B.A. PRIOR and H.J. POTGIETER
Department of Microbiology, University of the Orange Free State, P.O. Box 339, Bloemfontein 9300

Abstract

The chemical and microbiological composition of effluents from a pineapple cannery and a fruit and vegetable cannery were examined over a period of a year. The following analyses were done on all samples: chemical oxygen demand, Kjeldahl nitrogen, phosphorus, carbohydrate, reducing sugars, pH and microbial count. The effluent from the fruit and vegetable cannery was produced in two streams viz. from whole fruits and vegetables and from comminuted fruits. The pineapple effluent consisted principally of carbohydrate (19,8 g/ℓ). The other effluents had a lower percentage carbohydrate. The principal cations of the effluents were potassium, calcium and sodium. The strength of the effluent poses problems in its disposal by conventional means. However, the high carbohydrate content makes it attractive as a substrate for yeast and/or ethanol production.

Introduction

Food processing plants produce significant quantities of waste materials which are normally disposed of in the easiest possible manner. However, plants in close proximity to urban areas are often required to treat the effluent before disposal in order to reduce the organic load. The expense of disposal can be a significant factor in production costs and these are likely to increase with the demands for a cleaner environment.

The conversion of food processing wastes into valuable by-products has in recent years received increasing attention. While many processes were investigated only on laboratory scale (Birch, Parker and Worgan, 1976), some have been commercially applied such as the production of yeast protein from potato (Skogman, 1976) and confectionary effluents (Forage, 1978). Alcohol is being produced from pineapple effluent in Hawaii (Yang, 1979). The recovery of such by-products can significantly reduce the costs of waste disposal for the food processor.

The purpose of this study was to examine the composition and variability of the effluent produced by pineapple and fruit and vegetable canneries. The pineapple effluent is produced from the various processes involved in the canning of pineapples and the manufacture of pineapple juice. It is available for 10 months of the year. The effluent from the fruit and vegetable cannery was released in two streams and is available throughout the year. Stream A originated from the canning of various whole fruits and vegetables whereas effluent from the canning of comminuted fruits to produce jam, purees, juices and pastes formed stream B (Table 1).

Methods and Materials

Collection of samples

Samples of effluent were collected in cans from the final effluent stream of a pineapple cannery and from two effluent streams of a fruit and vegetable cannery, sealed and immediately frozen. Accumulated frozen samples were sent by air to Bloemfontein and immediately placed in a freezer upon arrival in the laboratory.

Any completely thawed samples were not analysed. Samples were taken from April 1978 until April 1979. Pineapple effluent samples were collected weekly except during November 1978 when daily and hourly samples were also taken. Samples from the fruit and vegetable cannery were collected twice weekly except during November 1978 and January 1979.

Microbiological analysis

Micro-organisms in each sample were enumerated by standard pour plate methods using Plate Count Agar (Oxoid) after incubating the plates at 30°C for 3 days.

Chemical analysis

The chemical oxygen demand (COD) and ammonical and organic nitrogen (Kjeldahl nitrogen) were determined by the methods of the American Public Health Association (1976). Total carbohydrate and reducing sugars were analysed by the anthrone and the Somogyi methods respectively (Umbreit, Burris and Stauffer, 1972).

The pH was measured with a Metrohm pH meter. Before phosphate, calcium, copper, ferro-iron, potassium, magnesium, manganese, sodium and zinc were determined, samples (approximately 30 g) were dried and then ashed at 550°C for 15 min. Any remaining carbon was removed by adding a few drops of HNO_3, drying and ashing again. This was repeated until no traces of carbon remained. The total phosphate of the ashed samples was determined by the method of Fogg and Wilkinson (1958). The micro-elements were determined on an atomic absorption spectrophotometer (Perkin Elmer Model 605).

Results

Pineapple effluent

Results of the detailed examination of the various effluents are summarized in Table 2. The mean COD of the pineapple ef-

TABLE 1
ORIGINS OF THE EFFLUENTS FROM THE FRUIT AND VEGETABLE CANNERY

Month	Stream	
	A	B
April 78	Pears, peaches, beets, tomatoes, spaghetti, baked beans	Tomato sauce, tomato-paste, tomatoes, peach jam
May 78	Pears, tomatoes, baked beans, spaghetti, guava, beets	Tomatoes
June 78	Guava, beets, beans in sauce, mixed vegetables, butterbeans	Baked beans, guava nectar, guava
July 78	Guava, beet, butterbeans, potatoes, beans in sauce, mixed vegetables	Guava, baked beans, jam, marmalade, strawberries
August 78	Guava, mixed vegetables, beets, carrots, baked beans	Marmalade, guava
September 78	Beets, baked beans, mixed vegetables, pears, butterbeans	Mixed fruit jam, guava, marmalade
October 78	Beets, baked beans, guava, spaghetti, strawberries	Tomato sauce, marmalade, guava, strawberries
February 79	Pears, fruit cocktail	Fig jam, pear and plum sauce and puree, tomato juice, plum jam, peach pieces
March 79	Pears, fruit cocktail	Pear, peach and tomato puree, peach pieces, chutney, tomato cocktail and juice
April 79	Pears, fruit cocktail	Pear puree, peach puree, tomato sauce, puree, and paste

TABLE 2
ANALYSES OF FOOD CANNERY EFFLUENTS DURING 1978 — 1979[a]

	Pineapple cannery effluent			Vegetable and fruit cannery effluent	
	Weekly	Daily	Hourly	Stream A	Stream B
No. samples	29	6	7	76	76
Period	Apr 78—Apr 79	Nov 78	Nov 78	Apr 78—Apr 79	Apr 78—Apr 79
Volume (kℓ)	2902[b] (25,5)			1278[c] (72,1)	
Log. microbial count/mℓ	4,1 (24,4)	3,2 (15,6)	3,7 (18,9)	4,1 (39,0)	4,5 (33,3)
pH	3,8 (10,5)	3,9 (2,6)	4,2 (4,8)	6,7 (37,3)	4,0 (87,5)
COD (g/ℓ)	19,2 (34,4)	18,1 (12,2)	14,6 (23,3)	4,4 (70,5)	3,0 (126,7)
Total carbohydrate (g/ℓ)	19,8 (45,5)	20,3 (22,7)	14,2 (23,9)	2,1 (85,7)	1,9 (215,8)
Reducing sugars (g/ℓ)	12,0 (66,7)	15,3 (34,0)	1,9 (63,2)	1,1 (181,8)	0,5 (80,0)
Kjeldahl nitrogen (mg/ℓ)	60,8 (36,5)	70,5 (16,6)	37,2 (78,2)	40,4 (97,5)	24,7 (115,4)
Phosphorus (mg/ℓ)	1,4 (57,1)	1,0 (20,0)	1,1 (45,5)	6,0 (73,3)	3,6 (111,1)
$\% \frac{\text{reducing sugar}}{\text{total carbohydrate}}$	60,6	75,4	13,4	50,9	27,2
COD:N:P	13714:43:1	18100:70:1	13273:34:1	733:7:1	856:7:1

[a] Results expressed as mean (% coefficient of variation)
[b] Volume per week of water used. Effluent was estimated to be 75% of this amount
[c] Combined volume for stream A and B per day

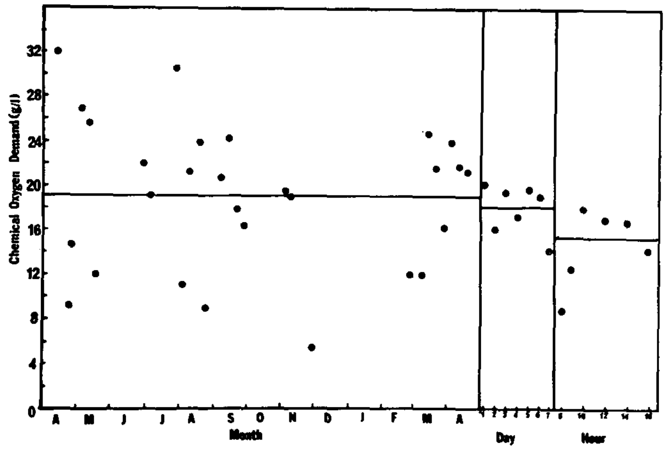

Figure 1
Weekly, daily and hourly variations in the chemical oxygen demand of pineapple effluent

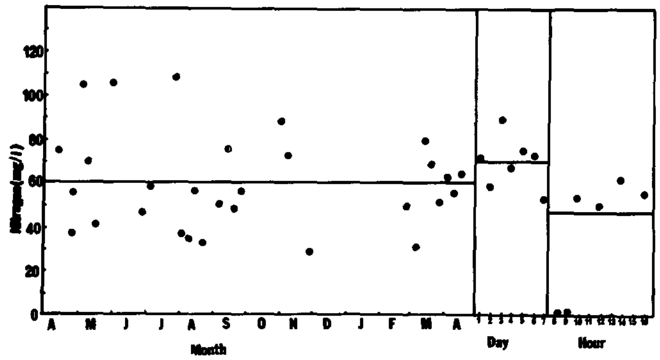

Figure 2
Weekly, daily and hourly variations in the Kjeldahl nitrogen of pineapple effluent

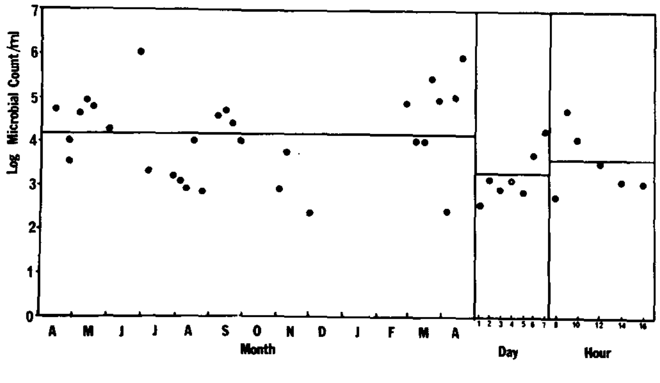

Figure 3
Weekly, daily and hourly variations in the microbial count of pineapple effluent

fluent was 19,2 g/ℓ and varied from 32 g/ℓ in April 1978 to 6 g/ℓ in November 1978 (34,4% CV) (Fig. 1).

The effluent was generally strongest from April until July. When samples collected daily at the same time for two weeks were analysed, a lower variability in the COD was observed (12,2% CV) (Fig. 1). Samples collected hourly on one day showed that the COD concentrations were lowest at 08h00 when production started and reached a maximum at 10h00 after which it dropped slowly.

The mean weekly, daily and hourly carbohydrate concentrations were 19,8, 20,3 and 14,2 g/ℓ respectively (Table 2). The carbohydrate concentration was similar to the COD suggesting that most of the carbon in the pineapple effluent was in the form of carbohydrate. The carbohydrate and COD concentrations showed similar variability (Table 2). The reducing sugar concentration was 61% of the mean weekly carbohydrate concentration (Table 2). However, this percentage varied considerably and is possibly due to seasonal factors.

The mean weekly Kjeldahl nitrogen concentration was 60,8 mg/ℓ and gave a COD:N ratio of 13 714:43 (Table 2). Nitrate and nitrite concentrations were not measured but were expected to be low since most of the nitrogen was likely to be of organic origin. There was a considerable variation in nitrogen concentration in the weekly samples whereas daily samples showed a lower variability (Fig. 2 and Table 2). Concentrations of Kjeldahl nitrogen were lowest at the start of the canning day but increased rapidly and were fairly constant thereafter.

The mean weekly phosphorus concentration was 1,4 mg/ℓ(Table 2) and ranged from 3,2 mg/ℓ to 0,2 mg/ℓ. Daily and hourly phosphorus concentrations were similar to the weekly values but the variability was lower.

The mean pH of the weekly, daily and hourly samples were 3,8 3,9 and 4,2 respectively and there was very little variation (Table 2). The weekly counts of micro-organisms averaged 13 000/mℓ and were slightly lower in the daily and hourly samples. There appeared to be slightly higher counts during the late summer and autumn months (Fig. 3).

Potassium, calcium, sodium, magnesium and ferro-iron were the micro elements with the highest concentrations in the pineapple effluent (Table 3) but there was considerable variation during the year. Coefficients of variation ranged from 15,2% for zinc to 53,4% for potassium.

Fruit and vegetable effluent

The effluent stream A of the fruit and vegetable cannery had a mean COD of 4,4 g/ℓ whereas the COD of the effluent stream B was 3,0 g/ℓ (Table 2). The COD of stream A ranged between 17 g/ℓ in March 1979 and 1 g/ℓ in September 1978 (Fig. 4). In the case of stream B, the COD ranged from 0,4 g/ℓ in May 1978 to 29,9 g/ℓ in September 1978 (Fig. 5). The COD from the effluent was highest during February and March in stream A but no definite seasonal trend was obvious in stream B effluent concentration. There was also considerable variability in the COD strength in a single week in both streams.

The mean carbohydrate content of both streams was considerably lower than the COD which suggests that other non-carbohydrate material contributed significantly to the COD (Table 2). However, in many samples COD and carbohydrate values were similar. Fifty-two percent of the carbohydrate consisted of reducing sugars in stream A. In stream B, only 27% of the carbohydrate occurred as reducing sugar (Table 2). The mean Kjeldahl nitrogen concentrations were 40,4 mg/ℓ (stream A) and 24,7 mg/ℓ (stream B) (Table 2) whereas the mean phos-

TABLE 3
ANALYSES OF MICRO-ELEMENTS IN FOOD CANNERY EFFLUENT, 1978 – 1979[a,b]

Element	Pineapple cannery effluent	Vegetable and fruit cannery effluent	
		Stream A	Stream B
Zinc	2,23 (15,2)	0,89 (53,9)	0,72 (36,1)
Calcium	57,24 (49,4)	29,03 (70,0)	41,32 (99,1)
Copper	0,45 (20,0)	0,21 (57,1)	0,45 (131,1)
Ferro-iron	29,94 (40,9)	16,75 (54,6)	22,50 (100,9)
Potassium	191,57 (53,4)	85,04 (53,2)	34,12 (71,3)
Magnesium	35,78 (47,0)	7,56 (56,6)	5,21 (64,5)
Manganese	1,54 (30,5)	6,24 (62,5)	0,23 (56,5)
Sodium	54,98 (21,9)	144,89 (77,6)	49,79 (79,4)

[a]Results expressed as mean (mg/ℓ) (percent coefficient of variation)

[b]Samples collected weekly but all samples for one month were pooled before analysis

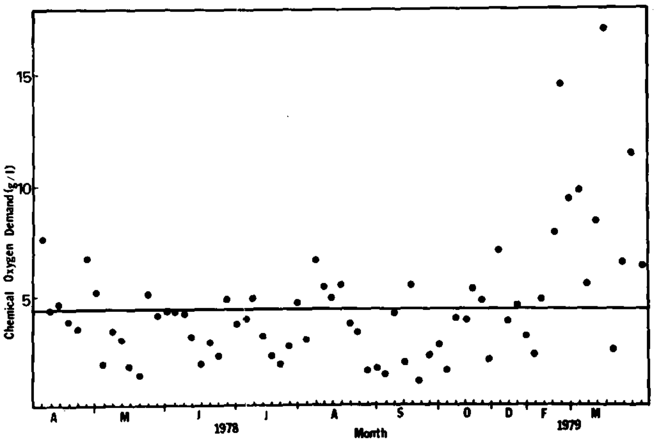

Figure 4
Twice-weekly variations in the chemical oxygen demand of effluent from the fruit and vegetable cannery (stream A)

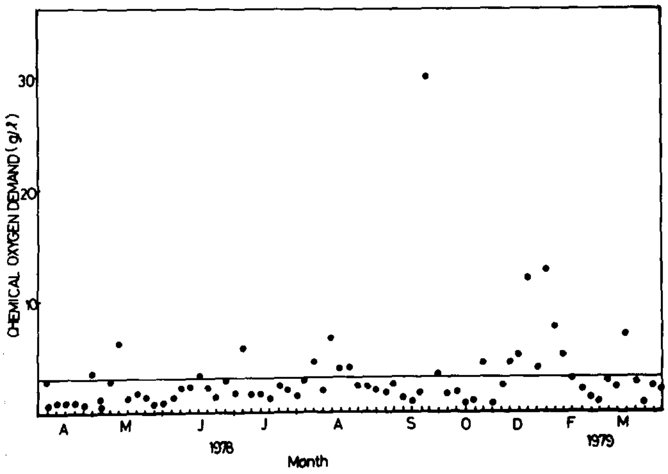

Figure 5
Twice-weekly variations in the chemical oxygen demand of effluent from the fruit and vegetable cannery (stream B)

phorus concentrations were 6,0 mg/ℓ (stream A) and 3,6 mg/ℓ (stream B).

The mean concentrations of cations in the two streams were fairly similar (Table 3). Sodium was the most concentrated cation but potassium, calcium, ferro-iron and magnesium were present in significant amounts. However, the cation concentrations varied considerably, especially in stream B (for example, the coefficients of variation were 131%, 101% and 99% for zinc, ferro-iron and calcium respectively).

The mean pH of stream A was almost neutral (6,7) whereas stream B was more acid (4,0) (Table 2). The use of NaOH to peel the fruit could cause the higher pH in stream A. This is also reflected in the significantly higher concentrations of sodium ions in stream A than in stream B (Table 3). The microbial count in streams A and B were usually between 10 000 and 100 000/mℓ (Table 2). There did not appear to be a significant difference in the count between summer and winter.

Discussion

This study shows that a considerable amount of effluent rich in carbohydrate material is disposed of by the pineapple and fruit and vegetable canneries. This could potentially be recovered as valuable by-products such as yeast protein or ethanol. The pineapple cannery disposes 1724 t of carbohydrate during a year of 40 working weeks whereas the fruit and vegetable cannery disposes 511 t of carbohydrate over a similar period. The conversion of the effluent into yeast protein is technically feasible.

A process was previously described where pineapple effluent supplemented with nitrogen, phosphorus and magnesium is used for the cultivation of the yeast, *Candida utilis* in a laboratory batch fermenter with a reduction of the COD of the effluent (Prior, Lategan, Botes and Potgieter, 1980). Such a fermentation process could be carried out on a commercial scale but the economics are dependent upon a number of favourable factors, such as the availability of the effluent throughout the year so that the process can be run continuously, and the effluent having a biochemical oxygen demand (BOD) greater than 20 g/ℓ (Tannenbaum and Pace, 1976). The latter is important for efficient utilization of the fermentation equipment. Although BOD was not measured in this study, it is likely that only the pineapple effluent would qualify as a substrate for economic conversion into yeast protein. Based on these analyses, approximately 6 t/d of carbohydrate would be available as a yeast substrate. Assuming a conversion rate of 50%, 3 t of dried yeast per day could continuously be produced which compares favourably with present yeast production facilities in South Africa. The production of yeast from pineapple wastes should receive high priority. Furthermore, the economics would be more favourable if the strength of the effluent could be increased. Large amounts of pineapple peel rich in soluble sugars (unpublished results) are available in the East London area and this could be used to increase the concentration of the effluent.

A second alternative would be to convert the effluents into ethanol. Such a process would involve the fermentation of the substrate with a suitable ethanol-producing yeast such as *Saccharomyces cerevisiae*. In light of the rapidly increasing costs of fuel, this could be an attractive economic possibility. For reasons similar to those for yeast protein production, the pineapple effluent would be a more feasible substrate. However, the effluent would probably have to be supplemented with additional carbohydrate to attain the ethanol concentrations in the fermenter necessary for economic distillation (Chye and Meng, 1975). Factors affecting this alternative are the high capital costs to install such a plant and the low revenue from the sale of ethanol. Treatment of the pineapple and fruit and vegetable cannery effluents by the traditional sewage disposal processes would also present problems because of the low nitrogen and phosphorus concentrations present in the effluent relative to the high COD (Table 2). Hattingh (1963 a,b) showed that the BOD:N:P ratio should not be greater than 81:19:1 for efficient biological growth in an activated sludge system. Direct comparison of data is not possible since BOD was not measured. However, BOD values are usually lower than COD and it appears likely that the BOD:N:P ratio of the effluents especially from pineapple canning would be too high for treatment without adding additional nitrogen and phosphorus. However, this could be supplied from town domestic sewage if mixed with the effluent. High ratios result in bulking and poor sedimentation of the solid wastes in the effluent and thus inefficient organic load reduction (Hattingh, 1963 a). However, nitrogen and phosphorus supplementation would also be necessary for conversion to yeast protein and probably ethanol.

The low pH of the pineapple effluent and stream B from the fruit and vegetable cannery would also need to be neutralized before treatment. Most biological treatment systems operate best in a neutral environment between pH 6,5 and 8,5 (Clark, Viessman and Hammer, 1971).

Conclusions

The effluents from two food canneries are shown to be especially rich in carbohydrates. However, the strength of these effluents varied considerably throughout the year. The strength of the pineapple effluent suggests that it could be converted into valuable by-products such as yeast protein or ethanol. However, the effluent produced by a fruit and vegetable cannery is not suitable for by-product recovery and more traditional disposal systems should be considered such as land-treatment. Screening before piping the effluent, and addition of gypsum to counteract the ill-effects of sodium, could be essential.

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