and consumers. In the manufacturing process, ascorbic acid may be oxidized to dehydroascorbic acid which can be further oxidized to degradation products with no vitamin C activity. The rate of oxidation is dependent on availability of oxygen and the break temperature. The longer the paste is held at higher temperature, the lower will be the retention of ascorbic acid in the product.

The organic acid in tomatoes is largely citric acid (Ukai and Luh, 1972). Acetic, formic, pyrrollidone carboxylic, malic, phosphoric, and galacturonic acids were also found in canned tomato juice. Miladi et al. (1969) have separated eight organic acids from tomato juice. Malic acid was found to be the second major organic acid in fresh juice, whereas pyrrollidone carboxylic acid was found to be the second major organic acid in the processed juice. The present work found a higher acidity in the pastes made at break temperatures of 148 and 171 °F. The phenomenon may be explained by the formation of galacturonic and oligouronic acids in the product when the pectic enzyme PG was activated to hydrolyze the pectic materials during maceration (Garces and Luh, 1972). Higher break temperatures result in rapid inactivation of the pectic enzymes, resulting in a lower acidity in the product (Luh and Daoud, 1971). Loss of volatile acids and carbon dioxide at higher break temperatures may also contribute to the difference in acidity between the samples.

Low acids and the resultant high pH in certain varieties of tomatoes are considered a weak point for processing. This occurred because thick-walled, firm-fruited lines had been used in breeding for new varieties for mechanical harvest. The average acidity of processing tomatoes is about 0.35% as citric acid. However, if the solids content is increased considerably, it may be desirable to increase the acidity level through breeding. The M-32 tomatoes appear to be comparatively low in acidity for processing. Research has shown that decreased phosphorus in the fruits helps to alleviate high pH problems in low acid lines (Stevens and Dickinson, 1974).

Consistency is one of the criteria for quality of pastes used in reprocessing into ketchup and sauce. It is demonstrated that pectic retention and consistency of the tomato pastes are influenced by the break temperature. The M-32 tomatoes appear to be excellent in their character except for their lower acidity.

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Processing of Fresh Artichoke Trimmings for Use in Animal Feeds

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Fresh artichoke waste trimmings were dehydrated in a pilot scale Arnold dehydrator with and without prior mechanical dewatering. Dewatering increased the quantity of meal produced per cubic meter of gas consumed by up to 80%. The protein content of the dehydrated meal ranged from 14.2 to 23.1%; dewatering and dehydration resulted in a slight reduction of protein and an increase in crude and acid-detergent fiber, acid-detergent lignin, and cellulose in the meal. The carotene and xanthophyll contents of the dried meals were less than that required for a poultry pigmentation source. Although the lysine, methionine, and arginine content of freeze dried artichoke meal was comparable to that of dehydrated alfalfa or bermuda grass meal, the quantities of lysine and methionine were decreased during dehydration, as was in vitro crude protein digestibility.

Fresh artichoke trimmings produced at the packing shed are an example of a waste product which may be converted to a useful animal feed. Previous experience in the processing and dehydration of fresh alfalfa (Spencer et al., 1971; Livingston et al., 1968), turf grass clippings (Livingston et al., 1971c), cauliflower (Livingston et al., 1972), and pimento (Livingston et al., 1974) trimmings suggested possible grinding, dewatering, and drying procedures that

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Table I. Dehydration of Artichoke Trimmings

Treatment	Dehydrator outlet temp, °C	Fresh material		Dehy. meal		kg of water evap. per m^3 of gas	kg of meal prod.[c] per m^3 of gas
		Wet wt, kg	Total solids, %	Dry wt, kg	Total solids, %		
Trial 1							
Chopped[a] + dehy	163	357	10.8	38.7	85.2	10.01	1.24
Chopped[a] + pressed + dehy	152	384	17.4	66.7	97.1	9.46	2.00
Chopped[a] + pressed + juice + dehy	152	312	12.3	38.4	91.9	10.23	1.45
Trial 2							
Ground[b] + dehy	152	330	13.1	43.2	93.2	9.01	1.37
Ground[b] + pressed + dehy	152	359	19.8	71.1	97.8	9.71	2.41
Trial 3							
Sliced[c] + dehy	152	419	16.4	68.8	97.0	11.24	2.20
Sliced[c] + pressed + dehy	138	336	23.1	77.6	97.6	9.80	2.96
Chopped[a] + dehy	152	302	16.1	48.6	86.9	9.09	1.79
Chopped[a] + pressed + dehy	143	364	21.5	78.2	95.6	11.90	3.29

[a] Chopped in silage chopper prior to pressing or dehydration. [b] Ground in hammer mill prior to pressing or dehydration. [c] Sliced in food slicing mill prior to pressing or dehydration. [d] Moisture-free basis.

might be suitable for processing artichoke trimmings. An evaluation of such treatments with regard to the compositional quality of the product is described in the following study.

EXPERIMENTAL SECTION

Fresh artichoke trimmings, leaves, and cores were collected at the packing shed and brought to the laboratory, approximately 2 h driving time away. The artichoke trimmings were either dehydrated directly in a pilot Arnold dehydrator (Model 5D45-12), or first ground or chopped and then dehydrated with or without dewatering by pressing in a Bauer twin screw press (No. 585 Helipress). Since the nutrient-containing pressed juice from the trimmings might constitute a disposal problem, the efficiency of dehydrating the trimmings with and without the juice added back to the bagasse was also investigated.

Four machines were evaluated for processing the plant material. These included: a forage silage chopper (International Harvester Model No. 350), a hammer mill (Jacobson, Model 15DFD), a grinding mill (Rietz Disintegrator, Model RD9), and a food slicing mill (Fitzpatrick, Model D). Fresh samples from each dehydration study were also freeze-dried in a Stokes vacuum drier; these samples served as controls in determining nutrient losses during dehydration.

All samples were ground through a 40 mesh screen prior to analyses. Carotenoid analyses were carried out by the procedure of Livingston et al. (1971b), amino acid analyses according to Kohler and Palter (1967), protein digestibility by the in vitro pepsin–trypsin method of Saunders et al. (1973a), and roughage digestibility according to Guggolz et al. (1971). Acid-detergent fiber and lignin were determined according to van Soest (1963) and cellulose according to Crampton and Maynard (1938). Proximate analyses were by standard methods. Meal moisture was determined by drying in a forced draft oven for 24 h at 105 °C.

RESULTS AND DISCUSSION

Pressing the chopped artichoke trimmings prior to dehydration increased the solids content and enabled the dehydrator to be operated at a lower outlet temperature (trial 1, Table I). Although addition of the pressed juice to the bagasse prior to dehydration decreased the quantity of meal produced per unit of gas burned, the efficiency of this procedure was greater than that of dehydrating unpressed artichoke, using natural gas as a fuel source.

Trial 1 was conducted in the winter months during a time of low production, trial 2 near the harvest peak, and trial 3 at the harvest peak. The solids content of fresh unpressed artichoke trimmings during the harvest peak would be approximately 16%.

Due to the fibrous nature of the artichoke leaves little juice was lost during grinding; therefore, differences found in the efficiency of moisture evaporation may be attributed to the fineness of chopping or grinding. Thus, preparation of artichoke waste in the food slicing mill (trial 3) led to greater water evaporation rates than preparation in the silage chopper. In all cases, less gas was required to produce dehydrated meal after pressing the fresh trimmings.

The artichoke meals (Table II) produced in trial 1 were of high quality as evidenced by the high protein (21.0 to 23.1%) content. However, the protein level dropped slightly, as the season progressed, to a value of 14.2% (after pressing) in trial 3.

Pressing the chopped or ground artichoke trimmings and the loss of soluble solids in the whole pressed juice resulted in lowering the protein content of the dehydrated pressed cake. However, this was restored in trial 1 by adding the pressed juice back to the bagasse. No attempt was made in this study to recover the protein in the juice phase.

The crude fiber in the dehydrated unpressed meal ranged from a low of 19.7% in trial 2 to a high of 31.4% in trial 3. Pressing increased the crude fiber in the meal by as much as 49% (trial 2). The acid-detergent fiber and lignin and the cellulose were also substantially increased by pressing. The cellulose increased by 41 to 50%, the acid-detergent fiber by 20 to 46%, while the acid-detergent lignin increased by as much as 121% in trial 1. This increase was reduced to only 52% when the juice was added back to the press cake prior to dehydration. The acid-detergent fiber and cellulose were also substantially reduced by adding the juice back to the press cake. The xanthophyll content of the meals produced (24.4 to 130.1 mg/kg) would seem insufficient for a pigmentation source of most poultry feeds and is, therefore, not reported in Table II. However, the carotene would be adequate for most animal feeds.

In all treatments, the crude protein of the freeze-dried meals was more digestible than that of the comparable

Table II. Compositional Analyses[a] and in Vitro Digestibility of Dehydrated Artichoke Meals

	Meal sample and preparation						
	Trial 1			Trial 2		Trial 3	
Composition (%)	Chopped[b]	Chopped[b] + pressed	Chopped[b] + pressed + juice	Ground[c]	Ground[c] + pressed	Chopped[b]	Chopped[b] + pressed
Meal moisture	14.8	2.9	8.1	6.8	2.2	13.1	4.4
Protein	23.1	21.0	22.7	20.4	16.8	17.4	14.2
Fat	3.00	1.78	1.63	1.71	1.48	3.04	2.43
Calcium	0.23	0.25	0.26	0.32	0.33	0.40	0.32
Phosphorus	0.65	0.51	0.59	0.53	0.37	0.24	0.25
Carotene (mg/kg)	43.7	33.3	43.4	26.6	26.4	51.3	42.3
Crude fiber	21.1	24.2	25.6	19.7	29.3	28.9	31.4
Acid-detergent fiber	24.0	35.1	28.6	26.7	32.0	24.7	35.8
Acid-detergent lignin	2.9	6.4	4.4	4.9	5.6	3.3	5.2
Cellulose	24.3	34.4	27.8	22.8	34.2	24.2	36.3
Protein digestibility[d]							
Freeze-dried meal	81.3	83.3	83.0	87.4	78.6	80.8	74.0
Dehydrated meal	75.9	74.4	78.4	82.2	72.7	77.5	73.0
Roughage digestibility[e]							
TSAE[f]	65.9	43.8	50.9	60.8	49.0	55.2	43.3

[a] Moisture-free basis. [b] Chopped in silage chopper prior to dehydration. [c] Ground in hammer mill prior to dehydration. [d] Determined by pepsin-trypsin digestion. [e] Determined by cellulose-protease digestion. [f] Total solubles after enzymes.

Table III. Amino Acid Analysis of Artichoke and Other Forages (Grams of Amino Acid/16 g of Nitrogen)

Amino acid	Freeze-dried artichoke[a]	Sample 1 dehydrated artichoke[b]	Dehydrated alfalfa (blend)[c]	Dehydrated bermuda grass[d]
Lysine	4.3	3.8	4.0	4.3
Histidine	1.6	1.3	1.9	1.7
Ammonia	3.8	4.2		
Arginine	4.7	5.1	4.1	3.6
Aspartic acid like	26.8	27.7	10.2	12.7
Threonine	3.2	3.1	4.2	3.3
Serine	3.4	3.6	4.2	3.7
Glutamic acid	8.3	8.1	9.4	9.8
Proline	2.8	2.8	4.4	3.1
Glycine	3.2	3.5	4.9	4.3
Alanine	3.7	3.8	5.3	6.1
Valine	4.0	4.1	5.8	5.9
Isoleucine	3.2	3.4	4.6	4.3
Leucine	5.1	5.7	7.3	8.4
Tyrosine	1.5	2.7	3.0	2.7
Phenylalanine	3.2	3.4	5.1	4.0
Methionine	1.5	1.3	1.6	1.2
Cystine	0.8	0.7	1.0	0.9
% N recovered	85.7	88.7	78.7	

[a] Freeze dried after chopping, 17.4% crude protein. [b] From trial 3, outlet temperature of dehydrator 152 °C, meal moisture 13.1%, 17.4% crude protein. [c] Blend of commercially dehydrated alfalfa meals, average 17% crude protein; Livingston et al., 1971a. [d] Wilkinson et al., 1968.

dehydrated meal, even though over-drying of the meals had been carefully avoided. In vitro crude protein digestibility has previously been found by Saunders et al. (1973b) to be affected by dehydration conditions and temperatures. The crude protein of the unpressed dehydrated meals was equally or more digestible that that of the pressed and dehydrated meals.

The total solubles after enzymes (TSAE) value was lower for the dehydrated meals following pressing due in part to the loss of soluble solids, including protein, in the pressed juice. The higher fiber contents of the pressed meals would seem to be related to decreasing TSAE digestibility.

The amino acid analyses of both a freeze-dried and a dehydrated artichoke meal are presented in Table III. For comparison, amino acid analyses of a blend of commercially dehydrated alfalfa meals and of a dehydrated Bermuda grass meal are also presented. The freeze-dried and the dehydrated artichoke meals were prepared from the same fresh trimmings containing 17.4% crude protein. Although the freeze-dried artichoke meal compared favorably with the dehydrated alfalfa and Bermuda grass meals in lysine, arginine, and methionine, during dehydration there was a slight loss of lysine and methionine. It has previously been shown that substantial losses of lysine and methionine may occur during dehydration of alfalfa to low meal moisture levels (Livingston et al., 1971a). In this study the artichoke trimmings were carefully dehydrated to high meal moisture levels; therefore, the apparent loss of lysine and methionine was unexpected.

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Uptake of Manganese in *Hydrilla verticillata* Royle

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The effect of five transition metals (Fe, Zn, Cu, Mn, and Co) on the growth of the submersed aquatic plant *Hydrilla verticillata* Royle was investigated by adding the trace metals (as EDTA salts) to Hydrilla in well water, and comparing the production of oxygen for a given period with those samples for which a given trace metal had not been added. The effect of concentration of added manganese on the rate of oxygen production by the plant was subsequently investigated, and the results follow an Eadie relationship indicating the presence of a manganese-requiring enzyme. The concentration of manganese in the plants at equilibrium was measured and the apparent concentration factor was calculated. The implications of the use of the recovered plant as mulch and fodder are considered.

Hydrilla verticillata Royle (Long and Lakela, 1971) is a perennial, submerged aquatic plant that is generally rooted by means of long, white adventitious roots which effectively anchor the plant firmly to the water bottom of lakes, rivers, and canals of the southeastern United States, but particularly in Florida. This plant is capable of forming dense mats and that portion of the plant toward the stem tips can completely occupy the top foot of the water; some plants have been observed to grow in water 20 ft deep.

The plant seems to be remarkably well adapted for survival and spreading. It reproduces primarily by vegetative processes and occasionally by seeding. It can survive as a pleustophyte or free-floating plant when up-rooted or broken from the bottom. Existence as a pleustophyte increases the survival advantage of the plant, and is one of the reasons for rapid spread and reinfestation. Hydrilla can also deposit vegetative propogules on the water bottom that can regenerate the plant, even after the rest of the parent plant has been destroyed. Finally, Hydrilla appears to spread at the expense of other plants as a result of the so-called "umbrella effect": the majority of the biomass of the plant is near the surface of the water column, in contrast to other plants, and Hydrilla can evidently gain a photosynthetic advantage over other aquatic plants (Haller and Sutton, 1975).

Aquatic weeds such as Hydrilla obstruct water flow and affect the water cycle (increasing water loss through transpiration and preventing satisfactory land drainage). The consequences of these two effects are economically significant and include: navigational loss, which can be profound when Hydrilla invades; flood control problems, which can result from up to 90% retardation of water flow in a flood control canal (Holm et al., 1969); economic costs, which include a lowering of the economic tempo of a tourist-recreation-oriented area or which include maintenance costs.

Presently, Hydrilla is controlled by chemical means, using such herbicides as 2,4-D (2,4-dichlorophenoxyacetic acid), cutrine (triethanolamine complex of copper sulfate), and other similar agents (cf. Baker et al., 1975). Unfortunately, chemical treatment also releases into the ecosystem those micronutrients that were responsible for the spread of Hydrilla originally. Biocontrol has been limited, but the use of the white amur (*Ctenopharyngodon ilella* Val.) is promising (Sutton, 1974) as a control means and as a potential food source. Mechanical control, e.g., by mowing has not been recommended because of the possibility of further proliferation.

Few studies have been concerned with understanding the micronutrient requirements of Hydrilla, but with this information available, the possibility of limitation of plant growth through management of trace-metal input would be worth considering. Past studies have indicated that two adjacent lakes in Hillsborough County are notable for the presence of Hydrilla in one and the absence in another (Martin et al., 1971). More recent studies have indicated the importance of inorganic carbon levels on the spread of Hydrilla (Martin et al., 1976) and the interesting possibility that certain levels of chelated iron may limit the growth of Hydrilla in the laboratory (Reid et al., 1974) and in the field (Martin et al., 1976).

The possibility that Hydrilla could be deprived of critical trace metal nutrients has been raised (Martin et al., 1970, 1971), but the present study is also concerned with another possibility. Could Hydrilla be regarded as a potential crop and harvested for trace metal content to be used as mulch and/or fodder? In part, utilization would depend upon trace-metal composition and/or ability of plants to accumulate trace metals. The present paper summarizes the results of a deprivation study (wherein plants were grown in trace-metal-free media with the addition or omission

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