Tomato Processing Wastes as Essential Raw Materials Source

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Chemical composition of various fractions of tomato processing wastes was investigated. The seeds were found to contain about 27% hexane-extracted lipids. Oleic acid was the most predominant fatty acid, followed by palmitic acid. The seed flake obtained after hexane extraction had indicated a high protein content (~40%) high in threonine and lysine. Elemental analysis of the hexane-extracted tomato seed flour revealed that K, Mg, Na, and Ca were the major elements, followed by Fe, Mn, Zn, and Cu. Acetone extraction of the wet tomato skins yielded a highly colored concentrate consisting mainly of lycopene (total yield of about 12 mg per 100 g of wet tomato skins). The pigment freed skin residue was found to contain about 11% protein, with lysine, valine, and leucine as the most predominant essential amino acids. Elemental analysis showed that Ca, K, Na, and Mg were the major elements in tomato skins.

INTRODUCTION

About a third of tomatoes (*Lycopersicon esculentum* L.) delivered to processing plants ends as processing waste (Ries and Stout, 1962). The introduction of mechanical harvesting is estimated to have doubled the quantity of such waste material (Ben-Gera and Kramer, 1967). The waste during tomato processing is mainly obtained in the form of seeds and skin residues. The seeds were indicated as an edible oil source and tomato seed flake as a protein source (Boni and Sodini, 1981). Tomato is one of the most common vegetables in Iraq. It is mainly processed for the production of pastes, juice, and sauce. Al-Abadi (1981) estimated the annual quantity of wasted tomato seeds and skins (based on data for 1980) from tomato processing plants in Iraq at 10000 tons. The importance of utilization of these waste materials in Iraq may be judged from the fact that there is no revenue from the sale of these processing byproducts and dumping of these processing wastes at the nearest landfill site will add to the processing cost. On the other hand, if these wastes remain unutilized, they not only add to the disposal problem but also aggravate environmental pollution. The use of these wastes as animal feed during out season period is limited mainly to high mold susceptibility. Attempts to dry these residues to stable condition (10% moisture) will add to their cost. The present study was undertaken with the understanding that the results of this study will be of value in designing a unit to be installed on-site to produce some useful products from the tomato processing wastes.

EXPERIMENTAL SECTION

Tomatoes. Tomatoes (*Lycopersicon esculentum* L., cv. Pearson) are used by the cannery state plant in (Duhock) (northern part of Iraq) to produce tomato pastes.

Processing Procedure. On delivery to the cannery the fruits were washed with tap water and fed into a disintegrator. The seed portion was automatically separated from the fruit parts and collected. The remaining macerate (tomatoes cut into pieces) is exposed to a short-period steam treatment (75–80 °C for about 30 s) and then passed through a finisher equiped with a suitable screen to remove the skins. Tomato pastes are usually prepared by concentrating the resulting tomato juice to contain about 25–28% total solids. The ratio of tomatoes (as a raw material) to tomato pastes produced was about 7:1 (w/w).

Samples. As a standard procedure, samples were taken in triplicate (100 g each) and stored in a deep freezer until required for analyses. Prior to analysis, seed samples were cleaned to remove all visible foreign matter (these consisted of tomato pulp, sepals, etc., which pooled and weighted), washed twice with distilled water, spread as a thin layer, and left to stand for 24 h in an air-draft oven at 45 °C. The seeds were then ground to a fine powder. The skin samples were treated as above except when analyzed for coloring materials composition, where the samples were only washed twice with distilled water and left to stand on Whatman paper No. 3 for about 15 min at room temperature prior to analysis.

Table I. Composition[a] (% wet wt) of Various Fractions of Tomato Processing Wastes

fraction	% seeds	% skins	% other materials[b]
seeds	93.82	3.85	2.35
skins	7.61	78.20	14.20

[a] Data are an average of 2–3 determinations on separate samples. [b] Consists of pulp, crushed seeds, sepals, fibrous matter, etc.

Table II. Protein and Lipid Compositions of Various Fractions of Tomato Processing Wastes

fraction	crude protein ($N \times 6.25$)	lipids
tomato seeds, full-fat	31.6	27.1
tomato seeds, fat-free[b]	39.6	3.5
tomato skins, fat-free[c]	10.7	0

[a] Data are an average of 2–3 determinations on separate samples. [b] Free of hexane-soluble lipid. [c] Free of acetone-soluble lipid.

Chemical Analyses. Total Kjeldahl nitrogen, amino acids, lipids, fatty acids, and minerals were determined according to our previously reported methods (Al-Wandawi, 1983; Al-Wandawi et al., 1984).

Coloring Materials. For the determination of coloring materials triplicate samples (tomato and tomato seeds 25 g, tomato skins and tomato pastes 5 g) were taken for analyses. Each sample was exhaustively extracted with redistilled acetone and the nonsaponifiable fraction was partitioned with an equal volume (50 mL) of petroleum ether and 95% methanol. The carotenoids were then chromatographed on an alumina column and the individual carotenoids were identified as previously reported (Al-Wandawi et al., 1983).

RESULTS

A relative distribution of the seeds, skins, and other materials (e.g., pieces of fruit flesh, sepals, fibrous matter, etc.) in various fractions of tomato processing wastes is presented in Table I. It can be seen that the amount of skins and other materials in the seed fraction is about 6% (wet weight basis). The seeds and other materials represented about 22% (wet weight basis) of the skin samples.

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Table III. Amino Acid Composition[a–c] of Tomato Processing Wastes

	composition	
amino acid	tomato seeds (fat-free)	tomato skins (fat-free)
Lys	4.19	7.19
His	1.32	1.98
Arg	4.45	3.83
Asp	6.15	8.62
Thr	3.24	3.01
Ser	2.53	3.57
Glu	12.81	11.87
Pro	2.33	1.81
Gly	2.38	5.64
Ala	2.53	3.67
Cys	0.29	0.39
Val	3.00	7.07
Met	0.95	1.08
Ile	1.98	2.95
Leu	3.88	5.49
Tyr	3.94	5.14
Phe	2.50	4.51
Trp		

[a] Data are average of duplicate analyses. [b] Grams per 16 g of nitrogen. [c] Tryptophan was not determined.

Table IV. Comparison of Chemical Score Values of Essential Amino Acids of Tomato Processing Wastes (Seeds and Skins) with Those of Whole Wheat Grain[a]

	tomato processing wastes		
essential amino acids (EAA)[a]	seeds	skins	wheat[b] (whole grain)
leucine	43.8	61.7	74.2
isoleucine	34.5	50.9	65.5
cysteine and methionine	21.8	25.8	59.7
valine	40.5	95.5	63.5
phenylalanine	44.6	80.5	80.4
lysine	62.7	107.3	40.3
histidine	62.9	94.3	95.2
threonine	64.8	60.2	58.0
tyrosine			

[a] Data for EAA in the reference protein (whole egg) and the method used for calculation of the chemical score were reported by Osborne and Voogt (1978). [b] Chemical score values were based on data of the amino acid composition of whole wheat grain reported by Hepburn et al. (1960).

Table V. Fatty Acids Composition (% Fatty Acids Basis)[a] of Seed Lipids of Tomato Processing Wastes

fatty acid	% fatty acids
palmitic acid	12.28 ± 2.48[b]
stearic acid	3.95 ± 0.58
oleic acid	81.34 ± 1.41
arachidic acid	1.34 ± 0.43

[a] Individual fatty acids were quantified by the method of triangulation. [b] Mean ±SD. [c] Data are average of duplicate analyses.

Table VI. Carotenoid Composition[a,b] of Tomato Fruit,[c] Tomato Processing Wastes, and Tomato Paste

carotenoids	whole mature fruit	tomato seeds	tomato skins	tomato seeds	tomato paste
phytoene	trace	0	trace	0	2.29
phytofluene	trace	0	trace	0	1.86
β-carotene	0.13	0.19	0.30	0	1.06
lycopene	3.35	0.04	11.98	0	16.79

[a] Milligrams of individual carotenoids per 100 g of wet sample. [b] Data are the average of two determination on separate samples. [c] Fresh tomatoes used as raw material in normal processing for production of tomato pastes.

Table VII. Mineral Composition[a–c] of Tomato Processing Wastes, Rice, Wheat, and Barley

	source				
element	tomato seeds	rice[d]	wheat[d]	barley[d]	tomato skins
calcium	153	20	51	50	338
copper	5	0.5	0.7	0.5	8
chromium	<1				<1
iron	25	6.7	5	5	28
magnesium	400	180	157	180	238
manganese	13.2	2.1	4	2	2.4
nickel	0.9	0.17	0.14	0.02	1.6
potassium	650	400	453	580	325
rubidium	0.8	0.12			<0.5
sodium	200	20	24	77	325
strontium	1.7	0.18			6
zinc	12	3.7	5	3.7	3

[a] Milligrams per 100 g of fat-free seed and skin powders. [b] Data are an average of duplicate analyses. [c] Phosphorus and sulfur were not determined. [d] Data were reproduced from Kent (1978). [e] The lipid content of wheat and barley is 1–2% (Kent, 1978).

Data shown in Table II indicate the crude protein ($N \times 6.25$) in the full fat and the fat-free samples were 31.6% and 39.6%, respectively, and 10.7% in the fat-free skin samples. The extraction of seed lipids by refluxing with hexane gave total lipid concentration of 27.1%. Further extraction of the hexane-extracted flour with chloroform–methanol (2:1 v/v) gave an additional lipid concentration of 3.5%. This may be due to the fact that neutral lipids were extracted by hexane while waxy materials and polar lipids were extracted by the chloroform–methanol mixture. Table III shows the amino acids composition of tomato seeds and skins. It can be seen that in both seeds and skins the amino acids glutamic acid and aspartic acid were the most predominant amino acids. The major essential amino acids in seeds were found to be lysine, tyrosine, leucine, threonine, valine, and phenylalanine. Lysine, valine, leucine, tyrosine, and phenylalanine were the most predominant essential amino acids of tomato skins. Methionine and cysteine were the least abundant amino acids in both seeds and skins. Table IV shows the chemical scores for the essential amino acids of tomato seeds and skins. Fatty acids composition of tomato seed lipids is shown in Table V. Oleic acid was the major fatty acid and amounted to 81.34% of the total recovered fatty acids, followed by palmitic acid (12.28%), stearic acid (3.95%), and arachidic acid (1.34%). The coloring materials of tomato fruits, tomato paste, and tomato skins are shown in Table VI. From the results it can be observed that the hydrocarbon carotenoid "lycopene" (bright red in color) was the main pigment and amounted to 12 mg/100 g of wet skin. Elemental compositions of tomato seed and skin are shown in Table VII. The data indicate that K, Mg, Na, and Ca are the major elements in tomato seeds, followed by Fe, Mn, Zn, and Cu. In tomato skins however, Ca, Mg, K, and Na are the major elements, followed by Fe, Cu, Sr, and Zn.

DISCUSSION

Amino Acid Composition of Tomato Seeds. Increasingly frequent food and feed shortages and increases in their price, as well as environmental pressures, are the basis of worldwide interest in reusing food industry wastes. In this manner, solid waste from tomato processing plants contain a large amount of protein. Thus the results in Table II show that from the hexane-extraction method, the approximate composition of the residue is about 40% crude protein ($N \times 6.25$). The results of amino acid analyses (Table III) indicate that with the exception of tryptophan (which is not determined), all essential amino acids are present in tomato seed. Data in Table IV reveal that the most limiting amino acids (based on analytical evidence) in defatted tomato seed flour are the sulfur amino acids, cysteine and methionine (chemical score, 21.8), isoleucine (34.5) valine (40.5), leucine (48.8), and phenylalanine (44.6), while threonine, histidine, and lysine were found to be the most abundant essential amino acids of tomato seed with chemical scores 64.8, 62.9, and 62.7, respectively. Finally, with the exception of lysine and threonine, the essential amino acid scores of tomato seed are rather poor compared to those of whole wheat grain (Table IV). Nevertheless, the importance of tomato seed protein may be justified from the viewpoint that it represents a byproduct from tomato processing plants, and its protein (40%) is more than double the amount found in most wheat varieties. On the other hand the justification of tomato seed protein importance should be evaluated in relation to some other parameters such as the digestibility of the products.

Lipids and Fatty Acids of Tomato Seeds. The demand for edible fat is continuing to increase particularly in those countries which have had inadequate supplies of this commodity (Ratledge, 1976). On the other hand, requirements of industry for fat for technical purposes usually place a large strain on the balance of payments in many countries. Therefore due to an increase in World population and limitation in the conventional agicultural products, the need for additional oil sources is universally recognized. Seed fraction obtained as tomato processing waste was found to comprise more than 50% (wet weight basis) of total solid wastes (Table I). The seed was found to contain 27.3% (dry wet basis) hexane-extracted lipids (Table II). The results of the gas chromatographic analysis of the methyl esters of tomato seed lipids (Table V) reveal that tomato seed is characterized with its high content of monounsaturated fatty acids, namely, oleic acid ($C_{18:1}$, 81.34%). Although this edible fatty acid is of low nutritional value compared to the polyunsaturated fatty acids, especially linoleic acid ($C_{18:2}$) which is predominant in croups like safflower, sunflower, corn, etc., nevertheless, oleic acid can be used as a soap base and manufactured for oleate ointments, cometics, polishing compounds, lubricants, and food-grade additives, etc.

Mineral Composition of Tomato Seeds. The results in Table VII represent the elemental composition of defatted tomato seed flour. The elements K, Mg, Na, and Ca are the major elemental components. Other less abundant elements seem to be Fe, Mn, Zn, and Cu. It can also be noticed that the levels of all elements presented in Table VII are higher in tomato seed when compared with those of rice, wheat, and barley.

Amino Acid Composition of Tomato Skins. The total crude protein content ($N \times 6.25$) of defatted (pigment-free) tomato skins was found to be (10.7%, Table II). Amino acid composition and the chemical scores for the essential amino acids are presented in Tables III and IV, respectively. Data in Table IV indicate that the most limiting amino acids (based on analytical evidence) are the sulfur amino acids cysteine and methionine (chemical score, 25.8), isoleucine (50.9), threonine (60.2), and leucine (61.7). On the other hand, tomato skin seems to be rich in lycine (chemical score 107.3), valine (95.5), histidine (94.3), and phenylalanine (80). No data in the literature on the amino acid composition of tomato skins were available for comparative purposes.

Mineral Composition of Tomato Skins. The elemental composition of fat-free tomato skin flour is shown in Table VII. The elements Ca, K, Na, and Mg seem to be the predominent elements, while Fe, Cu, Sr, Zn, Mn, and Ni are much less abundant on quantitative consideration if compared to the major elements.

Coloring Compounds of Tomato Skins. The national cancer institute (Anon, 1978) released a report which concluded that *p*-cresidine, basic to the manufacture of FD&C No. 40, one of the two (FD&C red No. 40 and No. 3) remaining red food colors on the GRAS list, is carcinogenic in rats and mice in the NICs bioassay program. As a consequence of intensified safety awareness and restrictions imposed on artificial colors for use in foods, considerable attention has been focused in recent years on natural colors (Saguy, 1979). According to Huschke (1981), artificial colors are defined as those compounds which do not occur as such in nature or in our daily food and which are only manufactured synthetically. Natural colors on the other hand are those which occur naturally in our daily food and are produced either by extraction from foods or synthetically. In the later case the resulting colors are also called "nature identical". The main groups of natural coloring substances in food are carotenoids, anthocyanins, porphyrins, and chlorophylls (Klaui, 1981), and carotenoids are considered to be the most important groups (Coulson, 1980). Lycopene (bright red carotenoid pigment) is considered to be the major coloring principle of red tomato cultivars. On the other hand, the carotenoids that impart a desirable color to foods are based structurally on the α- and β-carotenes and lycopene (Eskin, 1979). Forssberg et al. (1959) have reported that adminstration of lycopene up to at least 2 mg per 20 g of mouse body weight did not cause any demonstrable harmful effect.

The results presented in Table I indicate that tomato skins comprise more than 40% of total solid tomato processing wastes. The results presented in Table VI show that tomato skins yield about 71% of the lycopene found in tomato pastes. Finally it is clear that a large quantity of natural color is normally disposed in tomato processing "as wastes". This waste may offer potential as a natural source for coloring material which may be used for various food purposes with the understanding that the other technical requirements are reasonably met.

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Registry No. Ca, 7440-70-2; Cu, 7440-50-8; Cr, 7440-47-3; Fe, 7439-89-6; Mg, 7439-95-4; Mn, 7439-96-5; Ni, 7440-02-0; K, 7440-09-7; Rb, 7440-17-7; Na, 7440-23-5; Sr, 7440-24-6; Zn, 7440-66-6; lycopene, 502-65-8; phytoene, 540-04-5; phytofluene, 27664-65-9; β-carotene, 7235-40-7.

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Elements in Major Raw Agricultural Crops in the United States. 3. Cadmium, Lead, and Eleven Other Elements in Carrots, Field Corn, Onions, Rice, Spinach, and Tomatoes

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Six raw agricultural crops (carrots, field corn, onions, rice, spinach, and tomatoes) were collected from major U.S. growing areas uncontaminated by human activities other than normal agricultural practices. Handling, preparation, and analysis of the 1215 samples were performed under carefully controlled conditions. Cadmium and lead were determined by differential pulse anodic stripping voltammetry and Ca, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, and Zn by inductively coupled plasma emission spectroscopy. Mean Cd concentrations in carrots, field corn, onions, rice, spinach, and tomatoes were 0.028, 0.012, 0.011, 0.012, 0.065, and 0.017 μg/g (wet weight), respectively; mean Pb concentrations in these crops were 0.009, 0.022, 0.005, 0.007, 0.045, and 0.002 μg/g wet weight, respectively.

INTRODUCTION

The Food and Drug Administration (FDA) requires detailed information on the levels of elements in agricultural crops in the food chain to assess the toxicological and nutritional significance of human and animal intake of these elements. The normal "background" concentrations of the toxic elements, such as Pb and Cd, must be known to develop limitations on the intake of these elements from foods. Information on background levels provides guidance in evaluating the effect of soil additions, such as phosphatic fertilizers and sewage sludge containing Cd and Pb, as well as the effect of commercial food handling and processing steps, which can result in food contamination.

FDA, the Environmental Protection Agency (EPA), and the U.S. Department of Agriculture (USDA) share a particular interest in the application of sewage sludge to croplands with respect to the benefits of its use and its potential to contaminate the environment and the food supply. In 1979, questions concerning sludge use (Jelinek and Braude, 1978) brought the three agencies together in an agreement to develop data on the background levels of Cd, Pb, and other elements in selected crops and soils collected throughout the United States from major crop production areas uncontaminated by human activities other than normal agricultural practices (*Fed. Regist.*, 1979). Cadmium and lead were of primary concern because of their toxicity and potential for accumulation in food plants. Cadmium was of particular importance to FDA because the estimated Cd burden from food intake in the United States was approaching the joint Food and Agriculture Organization/World Health Organization (FAO/WHO) provisional tolerable weekly intake (Fox, 1976). Levels of other elements were of interest because animal nutrition studies suggest that elemental interactions affect the toxicity of dietary Cd (Fox, 1974). Also, data were unavailable for nutritional elements obtained from an extensive, controlled sampling of raw agricultural products representing major crop production regions of the United States.

Crop types were selected for this study on the basis of market volume, type of usage (human or animal), and potential for accumulation of toxic elements. Results for the six crops collected during the first phase of the study (lettuce, peanuts, potatoes, soybeans, sweet corn, and wheat) were reported previously by Wolnik et al. (1983a, 1983b). Results for carrots, field corn, onions, rice, spinach, and tomatoes are reported here. Correlations between crop element levels and corresponding soil element levels (determined by USDA), crop species, and other factors that may influence mineral uptake are currently being evaluated and will be discussed in future publications.

MATERIALS AND METHODS

Site Selection. As shown in Figure 1, samples of the crops were collected in several of the major production areas of the United States. The limitations imposed on site selection to minimize the effects of contamination caused by human activity are described in part 1 (Wolnik et al., 1983a).

Crop Sampling. All crops were taken directly from the field and were obtained in sufficient quantities to provide a representative sample, such as 40 carrots, 5 ears of field corn, 25 onions, 200 heads of rice, 1000 leaves of spinach,

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