Wong, T. C., Luh, B. S., Whitaker, J. R., *Plant Physiol.* **48**, 24 (1971).
Wrolstad, R. E., Heatherbell, D. A., *J. Sci. Food Agric.* **25**, 1221 (1974).

Received for review December 6, 1976. Accepted July 14, 1977.

This work was conducted at the Division of Food Technology, Agricultural Research Organization, The Volcani Center, Bet Dagan, Israel, as part of research for a dissertation submitted by A. Golan in partial fulfillment of the requirements for the M.Sc. Degree at the Hebrew University of Jerusalem. Contribution from the Agricultural Research Organization, The Volcani Center, Bet Dagan, Israel, 1976 Series, No. 284-E.

# Amino Acid Composition of Red Pepper

Aristides H. Kehayoglou* and Christos I. Manoussopoulos

The amino acid composition of the Greek "sweet" and "hot" red pepper (powdered whole fruit) and that of the dehydrated pericarp, seeds, and stem of the "sweet" and "hot" red fruit of *Capsicum* was obtained by an automatic amino acid analyzer. Data not previously reported are presented. The amino acid composition of the seeds with respect to that of the pericarp and stem showed characteristic differences. No characteristic differences in amino acid composition between "sweet" and "hot" corresponding species were noticed. Comparison of the amino acid composition of the "sweet" pericarp with that of the pericarp of a similar Italian variety showed several differences, whereas the amino acid compositions of the seeds of this pepper and those of a pepper of American origin were approximately similar with a few exceptions. Three unidentified peaks eluted between cysteic acid and hydroxyproline (aspartic acid) with maximum absorbance at 440 nm are discussed.

In a previous paper (Tsatsaronis and Kehayoglou, 1964), the protein (N × 6.25) content of the Greek "sweet" (paprika) and "hot" red pepper (powdered whole fruit) as well as that of the dehydrated components (pericarp, seeds, stem) of the "sweet" and "hot" red fruit of *Capsicum* was reported among other analytical constants. In this paper the amino acid composition of these products was determined by an amino acid analyzer to obtain data not previously reported and to examine possible differences among the various parts of the fruit and between "sweet" and "hot" species. Knowledge of the amino acid composition of these products is also of interest in evaluating their nutritional value even though their contribution to the protein content of the diet is not at a high level. However, the use of their by-products (e.g., defatted seeds) as an animal feed might enhance their contribution to protein intake.

The amino acid composition of "sweet" and "hot" red pepper (powdered whole fruit) and that of the dehydrated stem with calyxes of the "sweet" and "hot" fruit of *Capsicum* is originally reported in this study, as well as some supplementary data for the amino acid composition of pericarp and seeds.

Previous studies of the amino acid composition of the fruit of *Capsicum* were only for the fresh pericarp of various Italian varieties and did not include hydroxyproline and tryptophan (Bottazzi et al., 1968), or were for seeds of *Capsicum frutescens* of American origin and did not include cystine and tryptophan (Van Etten et al., 1963), whereas the amino acid composition of Spanish paprika was partly determined by paper chromatography (Navarro et al., 1962).

The results of this study are also compared with those in literature.

## EXPERIMENTAL SECTION

**Samples.** Several representative samples of the Greek "sweet" and "hot" red pepper (powdered whole fruit) and those of the dehydrated components (pericarp, seeds, stem with calyxes) of the "sweet" and "hot" red fruit of *Capsicum* were obtained from large quantities from the two main processing plants in Greece located in the Almopia region. The products were composites of typical varieties of Almopia, from the 1972 crop, and recently processed. The fruit components were ground to pass through a 30-mesh (0.5 mm) screen. The pericarps were dried at 60 °C for grinding.

**Methods.** The weight loss at 65 °C for 48 h was taken as the samples' moisture content to calculate the amino acid content on a dry weight basis.

*Hydrolysis with Hydrochloric Acid.* Hydrolysis was essentially as described by Tkachuk and Irvine (1969) and Robbins and Pomeranz (1972): 5 mL 6 N HCl was added to 40–50 mg of sample and heated at 110 ± 1 °C for 24 h in a forced-draft oven. The hydrolysate was filtered (Jamalian and Pellet, 1968) through a sintered glass disk and was concentrated to dryness. The residue was redissolved in water, concentrated to dryness three times, and then redissolved in a pH 2.2 citrate buffer (0.2 N $Na^+$), and the solution was made up to 25 mL.

*Performate Oxidation.* Samples (40 mg) were oxidized with performic acid according to the procedure of Moore (1963) and then hydrolyzed with 4 mL of 6 N HCl as reported above.

*Alkaline Hydrolysis.* Hydrolysis of a 100–mg sample with octahydrate barium hydroxide (1.5 g) and 1 mL of distilled water was carried out in an evacuated, sealed tube at 110 ± 1 °C in a forced-draft oven for 16 h. The cooled hydrolysate was neutralized (Miller, 1967) with 6 N HCl until colorless to phenolpthalein. The solution was transferred by washing with 10 mL of $H_2O$ to a centrifuge tube, and barium ions were precipitated by a solution of 10% sodium sulfate. The tube was centrifuged, and the supernatant was decanted to a 25-mL volumetric flask. The residue was twice resuspended in 5 mL of water and then recentrifuged, and the washings were added to the flask and then made up to volume. The solutions were kept in a deep-freeze and used for determination of tryptophan as soon as possible.

Laboratory of Organic Chemical Technology and Food Chemistry, University of Thessaloniki, Greece.

Table I. Amino Acid Composition of Greek "Sweet" and "Hot" Red Pepper (Mean Values and Standard Deviations in g/100 g Dry Weight Basis)

| Amino acid | Red pepper | |
|---|---|---|
| | "Sweet" | "Hot" |
| Lysine | 0.68 ± 0.01 | 0.62 ± 0.07 |
| Histidine | 0.28 ± 0.04 | 0.28 ± 0.15 |
| Ammonia | 0.17 ± 0.04 | 0.19 ± 0.06 |
| Arginine | 0.75 ± 0.02 | 0.81 ± 0.09 |
| Hydroxyproline | 0.24 ± 0.02 | 0.21 ± 0.01 |
| Aspartic acid | 1.62 ± 0.15 | 1.41 ± 0.20 |
| Threonine | 0.48 ± 0.05 | 0.44 ± 0.07 |
| Serine | 0.55 ± 0.06 | 0.48 ± 0.09 |
| Glutamic acid | 1.67 ± 0.25 | 1.55 ± 0.29 |
| Proline | 0.72 ± 0.06 | 0.61 ± 0.11 |
| Glycine | 0.53 ± 0.05 | 0.51 ± 0.08 |
| Alanine | 0.53 ± 0.06 | 0.44 ± 0.08 |
| Cystine | 0.29 ± 0.02 | 0.38 ± 0.05 |
| Valine | 0.53 ± 0.05 | 0.53 ± 0.06 |
| Methionine | 0.29 ± 0.03 | 0.33 ± 0.06 |
| Isoleucine | 0.44 ± 0.02 | 0.43 ± 0.07 |
| Leucine | 0.71 ± 0.05 | 0.68 ± 0.09 |
| Tyrosine | 0.28 ± 0.03 | 0.27 ± 0.04 |
| Phenylalanine | 0.44 ± 0.05 | 0.40 ± 0.06 |
| Tryptophan | 0.27 ± 0.03 | 0.24 ± 0.02 |
| N recovered[a] | 1.69 ± 0.16 | 1.62 ± 0.29 |
| N by Kjeldahl | 2.26 ± 0.26 | 2.20 ± 0.16 |

[a] Accounted for amino acids and ammonia.

*Amino Acid Analysis.* Amino acid analyses were by the method of Spackman et al. (1958) with a JEOL Model JLC-5AH automatic amino acid analyzer using two columns (15 and 70 cm) filled with JEOL LC-R-1 resin.

Aliquots of a standard solution (0.1 μmol/mL for each of the amino acids) were run in duplicate for calibration. Ammonia was determined by comparing its peak area to that of 0.1 μmol/mL of glycine, since these compounds afford practically equivalent absorption areas at 570 nm (JEOL Co., Instructions Manual).

All amino acids, except cystine, methionine, and tryptophan, and ammonia were determined after 24 h of acid hydrolysis. Cystine and methionine were determined after performic acid oxidation. Tryptophan was determined after alkaline hydrolysis on the short column using a pH 5.29 citrate buffer solution (Na 0.35 N), containing 0.5% benzyl alcohol, for best separation from lysine (flow rate, 69 mL/h).

## RESULTS AND DISCUSSION

The mean values and standard deviations of the amino acid contents resulting from the analyses of several samples of "sweet" and those of "hot" red pepper are summarized in Table I. Similarly, the amino acid composition of pericarp, seeds, and stem (with calyxes) of the "sweet" and "hot" red fruit of *Capsicum* is summarized in Table II.

No consistent or significant differences in amino acid contents between "sweet" and "hot" corresponding products (red pepper, pericarps, seeds, or stems) could be established. However, the mean values of most amino acid contents were slightly higher for the "sweet" than for the "hot" species (Tables I and II). These differences between "sweet" and "hot" red pepper (powdered whole fruit) are due to their different percentages in pericarp, seeds, and stem (Tsatsaronis and Kehayoglou, 1964) and to the different amino acid compositions of these components, as well as to the slightly different amino acid compositions of the corresponding parts of the "sweet" and "hot" fruit (Table II).

Among the three fruit components for both species, the seeds contained much more glutamic acid, arginine, serine, glycine, and the essential amino acids lysine, threonine, valine, isoleucine, leucine, and phenylalanine. Aspartic acid, which was approximately equally distributed in the three fruit components, is the major amino acid in the pericarp and stem and second to glutamic acid in the seeds.

The amino acid composition of the stem resembled the amino acid composition of the pericarp rather than of the seeds. An analogous observation was made by Tsatsaronis and Kehayoglou (1971) for fatty acid composition of pericarp, seeds, and stem oils. Main differences in the amino acid composition of stem and pericarp were the higher content of lysine and hydroxyproline and the lower content of methionine and tryptophan in the stem.

The amino acid composition of the seeds of the "sweet" red fruit of *Capsicum* in this study is comparable to the composition of the seeds of American origin (Van Etten et al., 1963) except for the much higher aspartic acid

Table II. Amino Acid Composition of Pericarp, Seeds, and Stem of "Sweet" and "Hot" Dehydrated Fruit of *Capsicum* (Mean Values and Standard Deviations in g/100 g Dry Weight Basis)

| Amino acid | Pericarp | | Seeds | | Stem + calyxes | |
|---|---|---|---|---|---|---|
| | "Sweet" | "Hot" | "Sweet" | "Hot" | "Sweet" | "Hot" |
| Lysine | 0.48 ± 0.07 | 0.40 ± 0.05 | 1.01 ± 0.03 | 1.01 ± 0.08 | 0.77 ± 0.08 | 0.64 ± 0.03 |
| Histidine | 0.30 ± 0.06 | 0.21 ± 0.04 | 0.37 ± 0.03 | 0.44 ± 0.05 | 0.27 ± 0.04 | 0.21 ± 0.01 |
| Ammonia | 0.19 ± 0.03 | 0.17 ± 0.03 | 0.17 ± 0.02 | 0.22 ± 0.05 | 0.16 ± 0.01 | 0.18 ± 0.03 |
| Arginine | 0.46 ± 0.03 | 0.40 ± 0.04 | 1.49 ± 0.01 | 1.58 ± 0.12 | 0.43 ± 0.03 | 0.41 ± 0.02 |
| Hydroxyproline | 0.17 ± 0.03 | 0.14 ± 0.02 | 0.30 ± 0.03 | 0.28 ± 0.01 | 0.38 ± 0.02 | 0.28 ± 0.01 |
| Aspartic acid | 1.52 ± 0.15 | 1.47 ± 0.13 | 1.62 ± 0.15 | 1.23 ± 0.14 | 1.68 ± 0.20 | 1.54 ± 0.16 |
| Threonine | 0.35 ± 0.06 | 0.34 ± 0.01 | 0.58 ± 0.02 | 0.54 ± 0.05 | 0.31 ± 0.05 | 0.35 ± 0.05 |
| Serine | 0.37 ± 0.05 | 0.38 ± 0.01 | 0.73 ± 0.03 | 0.62 ± 0.06 | 0.48 ± 0.06 | 0.41 ± 0.04 |
| Glutamic acid | 1.05 ± 0.12 | 0.95 ± 0.11 | 2.57 ± 0.12 | 2.37 ± 0.19 | 1.25 ± 0.19 | 1.07 ± 0.07 |
| Proline | 0.60 ± 0.03 | 0.56 ± 0.05 | 0.90 ± 0.10 | 0.82 ± 0.08 | 0.83 ± 0.07 | 0.63 ± 0.02 |
| Glycine | 0.37 ± 0.04 | 0.45 ± 0.04 | 0.69 ± 0.03 | 0.61 ± 0.06 | 0.46 ± 0.06 | 0.37 ± 0.05 |
| Alanine | 0.41 ± 0.03 | 0.42 ± 0.04 | 0.65 ± 0.03 | 0.60 ± 0.06 | 0.45 ± 0.06 | 0.38 ± 0.05 |
| Cystine | 0.26 ± 0.09 | 0.41 ± 0.08 | 0.34 ± 0.04 | 0.38 ± 0.04 | 0.31 ± 0.05 | 0.33 ± 0.05 |
| Valine | 0.46 ± 0.05 | 0.43 ± 0.05 | 0.73 ± 0.08 | 0.68 ± 0.07 | 0.58 ± 0.06 | 0.37 ± 0.04 |
| Methionine | 0.31 ± 0.08 | 0.37 ± 0.05 | 0.27 ± 0.02 | 0.29 ± 0.01 | 0.19 ± 0.03 | 0.24 ± 0.01 |
| Isoleucine | 0.34 ± 0.03 | 0.34 ± 0.03 | 0.55 ± 0.06 | 0.53 ± 0.07 | 0.36 ± 0.03 | 0.32 ± 0.03 |
| Leucine | 0.54 ± 0.06 | 0.57 ± 0.04 | 0.91 ± 0.07 | 0.85 ± 0.09 | 0.58 ± 0.08 | 0.49 ± 0.06 |
| Tyrosine | 0.22 ± 0.04 | 0.16 ± 0.05 | 0.34 ± 0.03 | 0.34 ± 0.01 | 0.22 ± 0.04 | 0.19 ± 0.02 |
| Phenylalanine | 0.33 ± 0.06 | 0.28 ± 0.05 | 0.64 ± 0.08 | 0.62 ± 0.04 | 0.37 ± 0.04 | 0.29 ± 0.04 |
| Tryptophan | 0.29 ± 0.06 | 0.23 ± 0.04 | 0.25 ± 0.03 | 0.25 ± 0.02 | 0.18 ± 0.02 | 0.14 ± 0.02 |
| N recovered* | 1.34 ± 0.17 | 1.27 ± 0.15 | 2.29 ± 0.13 | 2.33 ± 0.22 | 1.47 ± 0.16 | 1.29 ± 0.12 |
| N (Kjeldahl) | 2.14 ± 0.37 | 1.87 ± 0.34 | 2.86 ± 0.10 | 2.83 ± 0.19 | 1.77 ± 0.23 | 1.75 ± 0.28 |

[a] Accounted for amino acids and ammonia.

(2.32%) and lower lysine (0.77%), arginine (1.15%), and proline (0.77%) content in the American pepper.

The amino acid content of the pericarp of the "sweet" fruit in this study was generally lower than in the pericarp of the Italian variety *Corno di due* (Bottazi et al., 1968) which is similar in the shape and size of the fruit. Exceptions were histidine, proline, alanine, methionine, and isoleucine, which were higher in our samples. These differences could be due to climatic and cultivating conditions since, among other factors, fertilizing influences the amino acid composition of *Capsicum* (Tsonev and Chalukova, 1969, 1972).

Finally, we wish to report three unidentified yet reproducible peaks with maximum absorbance higher at 440 nm than at 570 nm. Their positions were before hydroxyproline (aspartic acid) or between cysteic acid and hydroxyproline in the peroxidized samples. Unidentified peaks with maximum absorbance at 440 nm, before aspartic acid, were also observed for several plant hydrolysates (Van Etten et al., 1963). A possible attribution of such peaks to breakdown products of carbohydrate content (Ewart, 1967) is not likely in the present case, as the size of these peaks was not related to the sugar content of the samples (Tsatsaronis and Kehayoglou, 1964). To indicate the relative sizes of these peaks they were integrated and computed as proline. Thus, the following mean values (g/100 g of dry sample) for both "sweet" and "hot" species were obtained: 0.30, 0.27, 0.09 for red peppers; 0.31, 0.34, 0.26 for pericarps; 0.28, 0.27, 0.06 for seeds; and 0.56, 0.33, 0.26 for stems. These peaks, however, were disregarded in the results given in Tables I and II since the peaks have not yet been identified.

LITERATURE CITED

Bottazzi, F., Quagliariello, G., Niceforo, A., *Quad. Nutr.* **28**(6), 439 (1968).
Ewart, J. A. D., *J. Sci. Food Agric.* **18**, 548 (1967).
Jamalian, J., Pellett, P. L., *J. Sci. Food Agric.* **19**, 378 (1968).
JEOL Co. Ltd., "Instructions JLC-5AH Amino Acid Analyzer", Tokyo, Japan.
Miller, E. L., *J. Sci. Food Agric.* **18**, 381 (1967).
Moore, S., *J. Biol. Chem.* **238**, 235 (1963).
Navarro, F., Rodriguez, A., Sancho, J., *Anal. Real Soc. Espan. Fis. Quim. (Madrid), Ser. B.* **58**, 571 (1962); *Chem. Abstr.* **58**, 5982 (1963).
Robbins, G. S., Pomeranz, Y., *Cereal Chem.* **49**, 240 (1972).
Spackman, D. H., Stein, W. H., Moore, S., *Anal. Chem.* **30**, 1190 (1958).
Tkachuk, R., Irvine, G. N., *Cereal Chem.* **46**, 206 (1969).
Tsatsaronis, G. C., Kehayoglou, A. H., *Chem. Chron. A* **29**, 25 (1964); *Chem. Abstr.* **61**, 3623 (1964).
Tsatsaronis, G. C., Kehayoglou, A. H., *J. Am. Oil Chem. Soc.* **48**, 365 (1971).
Tsonev, D., Chalukova, M., *Agron. Fak. Ser. Rastenievud (Sofia)* **21**, 111, (1969); *Chem. Abstr.* **76**, 71452 (1972).
Tsonev, D., Chalukova, M., *Pochvozn. Agrokhim.* **7**, 81 (1972); *Chem. Abstr.* **77**, 74195 (1972).
Van Etten, C. H., Miller, R. W., Wolf, I. A., Jones Q., *J. Agric. Food Chem.* 11, 399 (1963).

Received for review January 17, 1977. Accepted July 18, 1977.

# Mineral and Proximate Composition of Pacific Coast Fish

Dennis T. Gordon* and G. Louis Roberts

The mineral and proximate composition of 14 marine species from the Pacific Coast Fishery and as going into the human food chain were determined. Mineral analysis was accomplished by atomic absorption spectrometry for K, Ca, Mg, Na, Fe, Cu, Zn, and Mn. Phosphorus levels were determined by emission spectroscopy and S gravimetrically after sample combustion in an oxygen bomb. Mean Na and K levels found in white flesh finfish were, respectively, 52 ± 15 mg/100 g and 348 ± 47 mg/100 g wet weight. Magnesium, P, and S levels in finfish, mollusks, and crustaceans were determined to be fairly constant, averaging, respectively, 25 ± 4 mg/100 g, 177 ± 47 mg/100 g, and 225 ± 43 mg/100 g. The only other mineral displaying such uniformity between species was Mn at 22 ± 9 μg/100 g. Oysters were the exception and were found to contain on the average of 643 μg/100 g. Much lower iron levels, 0.31 ± 0.08 mg/100 g were found in white flesh finfish than previously reported. Copper and Zn averaged, respectively, 29 ± 8 μg/100 g and 0.28 ± 0.04 mg/100 g in finfish with higher amounts in mollusks and crustaceans. Calcium is very low in finfish and oysters, 8 ± 2 mg/100 g, two to three times higher in crustaceans, and extremely high in canned salmon, 251 mg/100 g.

Seafoods do not play a major role in the dietary habits of Americans based on a 5.5 kg per capita consumption (National Marine Fisheries Service, 1975). The extent to which this figure is underestimated in selected geographical regions is unknown. In line with this lack of a more thorough detailing of seafood consumption is the lack of nutritional information on the mineral composition of finfish, mollusks, and crustaceans. This is evidenced by the blanks existing in Agriculture Handbook No. 8 (Watt and Merrill, 1963) on minerals in seafoods. While current reviews have brought together a magnitude of information on the proximate composition (Stansby and Hall, 1967; Sidwell et al., 1974; Stansby, 1976) and fatty acid composition (Exler et al., 1975; Exler and Weihrauch, 1976) of marine foods, reported mineral levels are only for two or three elements on a very select species basis; the work of Thurston (1958, 1960) on Na and K levels not withstanding. Nilson and Coulson (1939) published the latest comprehensive study on six minerals, Ca, Mg, P, Fe, Cu,

Department of Food Science and Technology, Oregon State University Seafoods Laboratory, Astoria, Oregon 97103.