Cystine, Tyrosine, and Essential Amino Acid Contents of Selected Foods

CECILE H. EDWARDS,
LOLLA P. CARTER, and
CHARLOTTE E. OUTLAND
Carver Foundation and School of Home Economics, Tuskegee Institute, Ala.

On the basis of fresh weight, chicken gizzard and liver, pork heart, kidney, liver, muscle, and tongue are excellent sources of the essential amino acids. Though pork brain, chitterlings, fatback, and many vegetables and grains are fair to poor sources of amino acids when viewed as individual foods, ingestion at the same meal of foods rated as fair or good may enable an individual to maintain a state of good protein nutrition.

THE PRESENT EMPHASIS on protein quality in contrast to total quantity has stimulated the accumulation of data on the amino acid composition of food. These data are essential as a basis for practical nutrition programs geared to the needs of people in specific regions and in the world at large. Thus, where the choice of a variety of foods is limited by financial resources and food habits, the amino acid contribution of staple foods becomes an important dietary factor.

Pork muscle and organ meats, leafy vegetables, peanuts, yams, rice, corn grits, and meal are commonly consumed in the United States, especially in the southeastern region. In areas where these foods form the foundation of the diet, attention in dietary planning should be given to supplementary relationships of amino acids which may be made possible by ingestion of certain combinations of foods at the same meal. An essential step in this direction is the accumulation of data on the amino acid contents of foods commonly consumed by large population groups.

Development of microbiological methods has permitted the compilation of data on the amino acid content of many foods. These data, however, are incomplete for certain amino acids, notably cystine and tyrosine.

For the most part, data on the amino acid content of egg white and yolk have been obtained by the use of chemical procedures. Schweigert (*27*), using the microbiological assay technique, has reported the arginine, histidine, lysine, and threonine contents of egg white, and Dunn (*4*) has reported the methionine content of egg white and yolk. While data are available on the amino acid content of peanuts, limited data appear for brown rice and pecans, and none have been reported for chicken liver and gizzard. The amino acid content of pork muscle has been investigated by several workers (*2*, *9*, *11*, *27*). Lyman and Kuiken (*17*) have reported the essential amino acid content of pork heart, kidney, liver, and muscle.

In the present investigation, concentrations of the essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine), cystine, and tyrosine have been determined in eight pork muscle and organ meats, chicken liver and gizzard, cabbage, collard, mustard, and turnip greens, corn grits and meal, egg yolk and white, field peas, okra, peanuts, pecans, brown rice, and yams by microbiological procedures.

Preliminary Treatment of Foods

All vegetables were analyzed for moisture immediately after harvest. The varieties, age at harvest, and botanical names are as follows: cabbage (*Brassica oleracea* var. Capitata), headed Copenhagen; collard greens (*Brassica oleracea*), immature Georgia or Southern; mustard greens (*Brassica juncea* var. crispifolia), immature Southern Giant Curl and Tender Green; turnip greens (*Brassica rapa*), immature Purple Top Globe; okra (*Hibiscus esculentus*), immature White Spineless; corn grits and meal (*Zea mays*), fully mature Dixie 18 (dry corn); field peas (*Vigna sinensis*), cowpea, mature green; and yams (*Ipomoea batatas*), mature Louisiana Copperskin and Puerto Rican. Dry corn was used for the preparation of corn grits and meal. The vegetables were grown on plots of the School of Agriculture, Tuskegee Institute. At the time of harvest, they were randomly selected and sampled for analysis by accepted techniques (*22*).

Twenty heads of cabbage were washed with tap water, and visible moisture was removed with a damp cheesecloth. Each head was cut into eight wedges. One slice was removed from each wedge and diced quickly; these were mixed thoroughly and subsamples taken for analysis.

Approximately 5 pounds from original lots of 30 pounds each of collard, mustard and turnip greens were washed with tap water to remove adhering soil. The leaves were wiped free of visible moisture with cheesecloth, deribbed, diced, and mixed quickly. Subsamples of this original sample were taken for assay.

Caps were removed from 100 pods of okra randomly selected from an original 20-pound lot. These were divided into thirds; wedges from each third were mixed, and subsamples taken for analysis.

Four pounds of field peas were randomly selected from a lot of 20 pounds. After they were shelled and mixed, subsamples were analyzed.

The skins were removed from 30 yams randomly selected from an original lot of 25 pounds. One 1-inch longitudinal center slice and one transverse slice were removed from each yam, diced, mixed thoroughly, and sampled for analysis.

In each instance, weighed portions of the remaining foods were immediately frozen.

Samples of corn grits and meal were obtained from a community approximately 20 miles fromTuskegee Institute, where the corn was planted in Norfolk sandy loam soil. It was not degermed, and was ground by the water-mill method.

Corn meal was sifted through a No. 35 U. S. Standard sieve (500 microns), and corn grits were sifted through a No. 10 U. S. Standard sieve (2000 microns).

The sample of brown rice (*Oryza sativa*, Rexolo seed grown in Beaumont, Tex.) was obtained through the courtesy of the Human Nutrition Research Branch, Agricultural Research Service, U. S. Department of Agriculture. The brown rice was hulled and then ground in a Wiley mill, 40-mesh sieve.

The peanuts (*Arachis hypogaea*) were obtained from the Alabama Polytechnic Institute at Auburn, Ala., and were native to Alabama. Approximately 3 pounds were randomly selected from a 50-pound sublot of an original 200-pound lot, hulled and roasted at 320° F. for 40 minutes. They were allowed to cool and chopped in a Waring Blendor. Pecans (*Carya illinoensis*, Stewart variety) were harvested from the orchards of the School of Agriculture, Tuskegee Institute, in the fall of 1952 and were received for analysis in January 1953. The outer shells and center divisions were removed, care being taken that only nut meats remained.

Pork organs and tissues from two sows were obtained within an hour after slaughter. One, of Hampshire and Chester White breed, had been fed kitchen waste and corn, and was 8 months old. The other, of Chester White breed, consumed kitchen waste and grass, and was 9 months old. Both carcasses were inspected by a veterinarian and graded one, medium.

Superficial fat and exterior blood vessels were removed wherever necessary. The fatback contained both fat and skin removed from the underside of the pig. The samples contained little, if any, lean meat, and were cut in proportions similar to those used in cooking procedures in the home. The sample of cooked fatback was prepared by boiling for 1.75 hours.

Chitterlings, the large intestine of the pig, were washed free of contents with a stream of running water. Visible moisture was removed from all organs and tissues with a damp cheesecloth.

Chicken livers and gizzards were obtained within 0.5 hour after slaughter from randomly selected fryers fed a commercial ration containing 18% protein. The birds were from inbred flocks (Dryden, Roselann, Auburn, and Hampton). The organs were wiped free of visible blood; superficial fat and gristle were removed and discarded.

Eggs were obtained from Single-Comb White Leghorn pullets in the first laying year.

Determination of Moisture, Ash, and Total Nitrogen

For determination of moisture, triplicate samples were dried to constant weight in glass weighing bottles in an electric oven at 81° or 105° C. The dry foods were ground in a Wiley mill, 40-mesh sieve, and samples were ashed to constant weight in platinum crucibles in a muffle furnace.

Total nitrogen assays were conducted by the macro-Kjeldahl technique. Prior to digestion with concentrated sulfuric acid in the Kjeldahl procedure, fat was extracted from the fatback, chitterlings, and pecans; these and yams were autoclaved at 15-pound pressure for 2 hours with 50 ml. of 20% sulfuric acid.

Preparation of Hydrolyzates for Amino Acid Assays

Acid hydrolyzates of chicken liver and gizzard, brown rice, and pork cuts (except cooked fatback) were prepared by autoclaving the samples, which contained 1 gram of protein, with 25 ml. of 20% hydrochloric acid for 24 hours at 15-pound pressure, and filtering through Whatman No. 12 paper.

Acid hydrolyzates of other foods were prepared by refluxing the samples with 35 ml. of 20% hydrochloric acid for 24 hours, and filtering the samples at pH 4.0 through a fritted-glass funnel of medium porosity. Samples of brown rice and pork muscle were hydrolyzed by both procedures. Horn and his associates (*12*, *13*) have reported that the presence of humin, obtained after acid hydrolysis of certain foods containing carbohydrate, may be responsible both for high values on immediate assay of hydrolyzates (arginine, isoleucine, lysine, valine) and for apparent losses of amino acids on storage (arginine, histidine, methionine). Filtration of the hydrolyzates at pH 4.0 through a fritted-glass funnel prevented these changes. Values are reported for the refluxed sample of pork muscle in assays of arginine, histidine, leucine, methionine, threonine, tyrosine, and valine, and for the refluxed sample of brown rice in assays of histidine and methionine.

Acid hydrolyzates were used for all amino acid analyses except tryptophan and, in some instances, tyrosine. In foods where the ratio of carbohydrate to protein exceeds 1 to 1, higher values are often obtained when alkaline hydrolyzates are used for tyrosine assay. The exception to this statement in the present study was field peas, a higher value being obtained with the acid hydrolyzate.

Alkaline hydrolyzates were prepared by autoclaving the samples (containing 1 gram of protein) with 16 ml. of 5*N* sodium hydroxide and 100 mg. of L-cysteine hydrochloride for 16 hours at 15-pound pressure, according to the method described by Lyman and Kuiken (*17*). The value obtained was multiplied by 2 to correct for racemization of the amino acid.

Microbiological assays for arginine, histidine, and methionine were conducted immediately after hydrolysis of the foods. Low values for these amino acids are frequently obtained when samples are allowed to stand, even for short periods of time, prior to analysis (*13*).

Microbiological Assays

Microbiological procedures for the 12 amino acids are listed in Table I.

Stock cultures of *Leuconostoc mesenteroides* P-60 and *Streptococcus faecalis* No. 9790 were carried as stab cultures in both (1) yeast extract agar (1% yeast extract, 1% glucose, 0.1% dibasic potassium phosphate, and 1.5% agar); and (2) tomato juice agar (1% tryptone, 1% yeast extract, 1.3% agar, and 20% filtered tomato juice of pH 7.0).

Values obtained by the methods of

Table I. Microbiological Procedures and Assay Organisms

Amino Acid	Procedure	Reference	Assay Organism[a]
Arginine[b,c]	Stokes	(*23*)	*Streptococcus faecalis* 9790
	Barton-Wright	(*1*)	*Leuconostoc mesenteroides* P-60
	Greenhut	(*7*)	*Streptococcus faecalis* 9790
Cystine[d]	Dunn	(*6*)	*Leuconostoc mesenteroides* P-60
	Barton-Wright	(*1*)	*Leuconostoc mesenteroides* P-60
Histidine[d]	Stokes	(*23*)	*Streptococcus faecalis* 9790
	Barton-Wright	(*1*)	*Leuconostoc mesenteroides* P-60
Isoleucine[b]	Stokes	(*23*)	*Streptococcus faecalis* 9790
Leucine[b]	Stokes	(*23*)	*Streptococcus faecalis* 9790
Lysine[b]	Stokes	(*23*)	*Streptococcus faecalis* 9790
	Barton-Wright	(*1*)	*Leuconostoc mesenteroides* P-60
Methionine[b]	Stokes	(*23*)	*Streptococcus faecalis* 9790
	Barton-Wright	(*1*)	*Leuconostoc mesenteroides* P-60
Phenylalanine[b]	Dunn	(*6*)	*Leuconostoc mesenteroides* P-60
	Barton-Wright	(*1*)	*Leuconostoc mesenteroides* P-60
Threonine[b]	Stokes	(*23*)	*Streptococcus faecalis* 9790
Tryptophan[b]	Stokes	(*23*)	*Streptococcus faecalis* 9790
	Dunn	(*6*)	*Leuconostoc mesenteroides* P-60
Tyrosine[d,c]	Dunn	(*6*)	*Leuconostoc mesenteroides* P-60
	Barton-Wright	(*1*)	*Leuconostoc mesenteroides* P-60
Valine[b]	Stokes	(*23*)	*Streptococcus faecalis* 9790
	Dunn	(*6*)	*Leuconostoc mesenteroides* P-60
	Barton-Wright	(*1*)	*Leuconostoc mesenteroides* P-60

[a] American Type Culture Collection.
[b] U. S. Pharmacopeia reference standard.
[c] H. M. Chemical Co.
[d] Nutritional Biochemicals, Inc.

Stokes, Barton-Wright, and Dunn were in good agreement. The data presented in Tables II, III, and IV represent the averages of two to four values obtained from the assay of two or more samples of the same food secured at different times.

Results and Discussion

The average percentages of total nitrogen, moisture, and ash for the 25 foods, calculated on a fresh basis, are given in Table II. Samples of whole plants or leaves have been shown to reflect responses to environmental conditions and seasonal variations by changes in content of moisture, minerals, and nitrogen. It is generally recognized that southern soil compares poorly with soils from other sections of the country, unless properly fertilized. The nitrogen content of plots from which vegetables were secured in the present study ranged from 0.2 to 0.5%. This is considered to be representative of soils in the southeastern region of the United States.

Data on the content of 10 essential amino acids, cystine, and tyrosine in the foods are presented as grams of amino acid per 100 grams of crude protein (calculated to 16% nitrogen) in Table III, and as per cent amino acid in the fresh food in Table IV.

Table II. Total Nitrogen, Moisture, and Ash Contents of Selected Foods

Food	Total Nitrogen[a], %	Moisture[a], %	Ash[a], %
Grains			
Brown rice	1.42	11.75	1.20
Corn grits	1.14	10.83	0.78
Corn meal	1.11	11.30	1.55
Nuts			
Peanuts, roasted	4.48	0.30	1.88
Pecans	1.24	3.10	1.58
Pork			
Brain	1.39	77.90	1.46
Chitterlings	1.38	61.75	0.75
Fatback, cooked	0.97	29.61	0.11
Fatback, raw	2.06	28.85	0.12
Heart	3.17	77.30	0.98
Kidney	2.52	80.10	0.94
Liver	3.36	72.90	1.41
Muscle	3.38	68.40	0.82
Tongue	3.12	68.70	1.08
Poultry and Poultry Products			
Chicken gizzard	3.38	77.84	0.78
Chicken liver	3.28	72.27	1.17
Egg white	1.62	87.19	0.54
Egg yolk	2.64	50.30	1.50
Vegetables			
Cabbage	0.19	86.98	1.03
Collard greens	0.61	86.52	1.40
Field peas	0.99	77.07	1.08
Mustard greens	0.56	88.80	1.13
Okra	0.35	90.59	0.85
Turnip greens	0.74	86.39	1.52
Yams	0.21	67.18	0.80

[a] Calculated as per cent of edible fresh weight of sample.

Evaluation of Foods as Sources of Amino Acids

Whole egg has frequently been used as a basis for the evaluation of the amino acid content of foods (*5, 18*). In the present investigation, egg white and egg yolk were assayed for amino acids. The values reported herein for whole egg were calculated from the data on egg white and egg yolk, using 31 grams of white and 17 grams of yolk as the proportions of these components in whole egg (*24*). All comparisons have been made using whole egg as the standard of protein quality.

Thus, when a food contained 100% or more of the quantity of the specific amino acid in whole egg, the food was rated as an excellent source of that amino acid. Similarly, if the food contained 75 to 99% of the quantity of the amino acid in whole egg, it was rated as a good source. Those foods listed as fair sources contain 50 to 74% of the amino acids in whole egg, whereas poor sources contain less than 50%.

Essential Amino Acids in Food Protein

On the basis of 16% nitrogen, pork muscle and organ meats, with few exceptions, were found to be good or excellent sources of the essential amino acids. Other investigators have shown (*17*) that the histidine content of meats varies, and is lower in all of the organ meats than in muscle tissues. These differences are attributed to the occurrence of histidine in muscle in the nonprotein form of carnosine, the β-alanine peptide of histidine. High histidine values, therefore, may reflect a high carnosine content of the tissue.

Chitterlings, pork liver, and muscle are fair sources of tryptophan, while pork heart is a poor source of this amino acid. Pork muscle appears to be a fair source of arginine, and both muscle and chitterlings are fair sources of leucine. Brain is a poor source of leucine and valine. Tongue is a fair supplier of methionine.

In contrast, the protein of fatback is rated fair or poor in seven of the essential amino acids. Both raw and cooked fatback are excellent sources of arginine and lysine, raw fatback is an excellent provider of leucine, and cooked fatback is a good source of valine.

The proteins of brown rice, peanuts, field peas, pecans, and collard and turnip greens are excellent sources of both arginine and histidine, whereas mustard greens and cabbage are rated as excellent providers of arginine. Corn grits, brown rice, pecans, and field peas are excellent suppliers of isoleucine. In contrast to other vegetables, field peas are an excellent source of lysine, and turnip greens are an excellent source of tryptophan. Corn grits and meal are excellent sources of both leucine and histidine.

The vegetables and nuts analyzed in the present study were frequently found to be poor sources of methionine. In this category are peanuts, cabbage, collard and mustard greens, field peas, and yams. Cabbage, peanuts, and collard and mustard greens are poor providers of leucine; this is also true of corn with respect to lysine. Corn meal, cabbage, and peanuts are poor sources of tryptophan; cabbage is poor in valine content, and collard greens are poor in both phenylalanine and threonine.

The proteins of chicken liver and gizzard are excellent to good sources of all the essential amino acids, with two exceptions. Chicken gizzard appears to be only a fair source of methionine and tryptophan.

In an effort to obtain additional information which might explain the low tryptophan content of fatback, total nitrogen and tryptophan were determined in raw and cooked fatback, and tryptophan in fat-extracted raw and cooked fatback. The samples for these determinations were purchased on the local market, and were similar in weight to those for which data are presented in this report. The samples prior to cooking were cut similarly to those analyzed in the raw state.

On the basis of 16% nitrogen, the tryptophan contents of the samples of raw and cooked fatback were in excellent agreement with earlier analyses (raw fatback 0.16% *vs.* 0.14%, cooked fatback 0.49% *vs.* 0.49%). The values for tryptophan in the fat-extracted samples were somewhat higher (0.23% for raw fatback, and 0.59% for cooked fatback) on the basis of 16% nitrogen. The total nitrogen contents of the samples purchased on the local market were 0.31 and 0.15% for raw and cooked fatback, respectively, and the tryptophan contents of the samples on the basis of the fresh food were 0.003% for raw fatback and 0.004% for cooked fatback. The tryptophan content of fat-extracted samples was also very low, being 0.004 and 0.005%, respectively, for the raw and cooked samples.

These data suggest that differences in the total nitrogen and amino acid content of fatback on the fresh basis may be attributed to variations in the proportion of fat to skin in the samples. In such foods, where the proportion of protein to nonprotein constituents may vary from sample to sample, the definition of an "average sample" poses an analytical problem.

Essential Amino Acids in Fresh Foods

Fresh pork heart, kidney, liver, muscle, and tongue are excellent sources of the essential amino acids, with few excep-

Table III. Amino Acids in Selected Foods[a]

Food	Arginine, %	Cystine, %	Histidine, %	Isoleucine, %	Leucine, %	Lysine, %	Methionine, %	Phenylalanine, %	Threonine, %	Tryptophan, %	Tyrosine, %	Valine, %
Grains												
Brown rice	8.6	0.9	2.5	4.5	9.0	4.5	2.2	4.6	3.2	1.1	5.8[b]	6.4
Horn (*13*)	8.4	...	2.4	4.6	7.9	3.9	2.1	4.8	3.7	...	...	6.2
Lyman (*17*)	...	...	...	...	...	...	...	4.9	...	1.5	...	...
Corn grits	5.8	2.2	2.4	6.1	11.6	2.7	1.9	3.2	4.3	1.0	6.6[b]	4.7
Corn meal	5.0	1.8	2.3	4.1	11.9	2.2	2.3	5.0	4.7	0.8	4.0[b]	4.7
Lyman (*17*)	4.8	...	2.6	...	11.9	...	2.3	...	3.6	...	...	...
Greenhut (*9*)	...	...	...	...	...	...	...	...	4.7	...	...	...
Nuts												
Peanuts, roasted	10.7	1.0	2.1	3.5	6.5	2.8	1.0	5.4	2.8	0.9	4.6[c]	4.6
Hirsch (*10*)	8.7	...	2.8	4.0	4.7	3.9	0.9	4.6	2.6	1.0	...	4.9
Kuiken (*14*)	11.3	...	2.2	...	...	3.2	1.0	5.1	2.7	1.2	...	...
Lyman (*16*)	...	...	...	3.4	...	...	...	...	...	...	...	4.0
Sauberlich (*20*)	11.0	...	2.6	...	...	1.8	0.8	...	...	...	...	...
Schweigert (*21*)	10.6	...	1.8	3.9	6.7	3.0	...	...	3.8	...	...	4.6
Pecans	10.4	2.1	3.0	4.9	8.2	5.4	1.7	5.3	4.0	1.4	2.7[b]	3.5
Pork												
Brain	5.3	1.6	2.3	4.1	4.3	6.2	2.3	4.7	5.6	1.5	4.0[c]	1.6
Chitterlings[d]	16.4	1.3	2.0	3.6	5.3	7.8	2.3	4.2	4.6	1.1	2.7[c]	5.4
Fatback, cooked[e]	11.0	0.7	1.4	2.5	4.6	8.5	1.6	3.5	3.0	0.5	1.9[c]	5.3
Fatback, raw[e]	9.7	1.1	0.9	2.8	9.4	8.1	1.4	4.0	3.6	0.2	1.4[c]	4.3
Heart	6.9	1.0	1.8	4.8	8.0	8.9	2.3	4.6	4.1	0.9	2.9[c]	5.8
Lyman (*17*)	6.7	...	2.6	4.9	9.1	8.2	2.4	4.4	4.6	1.3	...	5.7
Kidney	6.8	1.0	2.2	4.4	8.3	7.0	2.3	4.6	4.3	1.4	2.6[c]	6.6
Lyman (*17*)	6.4	...	2.6	4.7	8.6	6.8	2.1	4.6	4.4	1.4	...	6.0
Liver	6.7	1.1	1.9	5.2	9.6	6.8	2.4	4.6	4.9	1.1	3.3[c]	6.2
Lyman (*17*)	6.1	...	2.8	5.2	9.6	7.1	2.2	5.4	4.4	1.5	...	6.4
Muscle	4.5	1.2	2.9	5.3	7.0	8.1	2.5	4.2	4.5	1.3	3.7[c]	5.2
Beach (*2*)	...	1.1	2.2	...	...	8.7	3.4	4.0	...	1.3	4.4	...
Greenhut (*9*)	...	...	...	...	...	...	...	3.7	4.4	1.3	...	...
Horn (*11*)	6.4	...	3.2	5.0	7.3	8.6	2.6	3.9	4.9	...	...	5.1
Lyman (*17*)	6.4	...	3.8	5.1	8.6	8.7	2.4	4.2	4.5	1.2	...	5.5
Schweigert (*21*)	...	...	3.2	...	...	...	2.5	...	...	...	3.0	5.0
Tongue	6.1	1.5	2.0	5.0	7.4	10.2	1.9	4.6	4.9	1.4	3.1[c]	5.6
Lyman (*17*)	6.6	...	2.8	5.0	8.8	8.6	2.4	4.6	4.7	1.2	...	5.6
Poultry and Poultry Products												
Chicken gizzard	9.5	1.0	1.7	5.1	8.6	7.6	2.2	5.2	4.8	1.0	3.0[c]	5.9
Chicken liver	8.9	2.0	1.9	4.8	9.5	8.1	2.5	4.5	5.9	1.4	3.3[c]	5.9
Egg white	6.6	1.7	2.1	4.6	9.9	6.2	4.0	6.0	4.7	1.8	5.1[c]	7.1
Dunn (*4*)	...	...	...	...	...	...	3.7	...	...	...	...	...
Schweigert (*21*)	6.2	...	2.1	...	...	6.6	...	...	3.5	...	...	...
Egg yolk	6.7	1.6	1.9	4.0	8.5	5.6	1.9	4.6	5.4	1.6	4.8[c]	5.9
Dunn (*4*)	...	...	...	...	...	...	2.0	...	...	...	...	...
Vegetables												
Cabbage	7.8	1.6	1.6	2.6	4.5	3.3	0.5	3.2	2.6	0.8	2.1[b]	2.8
Lyman (*17*)	7.3	...	2.1	3.1	3.7	3.7	1.3	1.9	2.8	0.9	...	4.0
Collard greens	7.4	1.5	2.2	1.4	3.7	4.7	1.1	2.3	1.5	1.2	3.9[b]	3.7
Field peas	7.2	1.5	3.2	5.3	6.4	6.2	1.5	5.0	3.8	1.2	4.1[c]	5.2
Mustard greens	7.3	1.5	1.8	3.3	2.7	4.8	1.0	3.2	2.6	1.6	5.3[b]	4.7
Okra	6.4	1.1	1.8	3.8	5.7	4.5	1.7	3.6	3.6	1.4	4.4[b]	4.6
Lyman (*17*)	6.4	...	2.1	3.5	5.0	4.6	1.5	3.2	3.6	1.3	...	4.6
Turnip greens	7.7	1.5	2.5	2.6	5.6	4.1	2.6	4.7	4.3	1.9	3.6[b]	4.3
Yams	3.4	1.6	1.6	4.0	5.7	4.1	1.1	5.4	3.4	1.8	4.5[b]	5.2
Lyman (*17*)	2.9	...	1.4	3.6	4.8	4.3	1.7	4.3	3.8	1.8	...	5.6
Hirsch (*10*)	5.2	...	2.4	5.1	5.6	5.5	2.6	6.1	5.7	2.1	...	9.3
Whole egg[f]	6.5	1.7	2.1	4.4	9.4	6.0	3.1	5.6	5.0	1.9	5.0	6.7

[a] All results expressed in grams per 100 g. crude protein, calculated to 16% nitrogen.
[b] Alkaline hydrolyzate used in tyrosine assay.
[c] Acid hydrolyzate used in tyrosine assay.
[d] Washed, large intestine of pig.
[e] Fat and skin from underside of pig, no lean meat.
[f] Calculated from data on egg white and yolk, using 31 g. white and 17 g. yolk as components of whole egg.

Table IV. Amino Acids in Selected Foods

(Calculated on fresh basis)

Food	Arginine, %	Cystine, %	Histidine, %	Isoleucine, %	Leucine, %	Lysine, %	Methionine, %	Phenylalanine, %	Threonine, %	Tryptophan, %	Tyrosine, %	Valine, %
Grains												
Brown rice	0.76	0.08	0.22	0.40	0.79	0.40	0.20	0.41	0.28	0.10	0.52[a]	0.56
Corn grits	0.42	0.15	0.17	0.43	0.82	0.19	0.14	0.23	0.30	0.07	0.47[a]	0.33
Corn meal	0.34	0.12	0.16	0.29	0.83	0.15	0.16	0.34	0.33	0.06	0.28[a]	0.32
Nuts												
Peanuts, roasted	2.99	0.29	0.60	0.97	1.81	0.77	0.28	1.52	0.79	0.25	1.30[b]	1.30
Pecans	0.80	0.16	0.23	0.38	0.63	0.42	0.13	0.41	0.31	0.11	0.21[a]	0.27
Pork												
Brain	0.46	0.14	0.20	0.36	0.37	0.54	0.20	0.41	0.48	0.13	0.34[b]	0.14
Chitterlings	1.41	0.11	0.17	0.31	0.46	0.67	0.19	0.36	0.40	0.09	0.23[b]	0.46
Fatback, cooked	0.67	0.04	0.09	0.15	0.28	0.51	0.10	0.21	0.18	0.03	0.11[b]	0.32
Fatback, raw	1.25	0.14	0.12	0.36	1.21	1.05	0.18	0.52	0.46	0.02	0.18[b]	0.55
Heart	1.37	0.20	0.35	0.94	1.58	1.77	0.46	0.91	0.81	0.18	0.58[b]	1.15
Kidney	1.08	0.16	0.29	0.69	1.31	1.11	0.37	0.72	0.68	0.22	0.41[b]	1.04
Liver	1.40	0.24	0.40	1.08	2.02	1.42	0.50	0.96	1.04	0.23	0.73[b]	1.31
Muscle	0.95	0.26	0.61	1.12	1.47	1.71	0.53	0.89	0.94	0.28	0.78[b]	1.10
Tongue	1.18	0.29	0.38	0.98	1.43	1.98	0.36	0.90	0.95	0.28	0.60[b]	1.10
Poultry and Poultry Products												
Chicken gizzard	2.01	0.20	0.36	1.07	1.82	1.60	0.47	1.10	1.00	0.22	0.62[b]	1.25
Chicken liver	1.82	0.41	0.39	0.99	1.95	1.65	0.52	0.92	1.21	0.28	0.67[b]	1.22
Egg white	0.67	0.17	0.21	0.46	1.01	0.63	0.41	0.60	0.47	0.18	0.51[b]	0.72
Egg yolk	1.10	0.27	0.32	0.66	1.40	0.92	0.32	0.76	0.89	0.26	0.79[b]	0.97
Vegetables												
Cabbage	0.09	0.02	0.02	0.03	0.05	0.04	0.01	0.04	0.03	0.01	0.03[a]	0.03
Collard greens	0.28	0.06	0.08	0.05	0.14	0.18	0.04	0.09	0.06	0.04	0.15[a]	0.14
Field peas	0.45	0.09	0.20	0.33	0.39	0.38	0.09	0.31	0.23	0.08	0.25[b]	0.32
Mustard greens	0.25	0.05	0.06	0.12	0.09	0.17	0.04	0.11	0.09	0.06	0.18[a]	0.17
Okra	0.14	0.02	0.04	0.08	0.12	0.10	0.04	0.08	0.08	0.03	0.10[a]	0.10
Turnip greens	0.36	0.07	0.12	0.12	0.26	0.19	0.12	0.22	0.20	0.09	0.17[a]	0.20
Yams	0.04	0.02	0.02	0.05	0.08	0.05	0.01	0.07	0.05	0.02	0.06[a]	0.07
Whole egg[c]	0.83	0.21	0.25	0.52	1.15	0.75	0.38	0.67	0.63	0.21	0.60	0.79

[a] Alkaline hydrolyzate used in tyrosine assay.
[b] Acid hydrolyzate used in tyrosine assay.
[c] Calculated from data on egg white and yolk, using 31 g. white and 17 g. yolk as components of whole egg.

tions. Pork kidney and tongue are rated as good sources of methionine, and heart is a good source of tryptophan. In contrast, pork brain, chitterlings, and fatback are generally fair to poor sources of the ten essential amino acids. Brain is a good source of histidine and threonine; chitterlings are rated as a good supplier of lysine, and excellent with respect to arginine. Cooked fatback is a good source of arginine, and raw fatback, though an excellent source of arginine, leucine, and lysine, is rated as good in phenylalanine content.

Roasted peanuts compared well with the pork cuts, being an excellent source of all amino acids except methionine. In contrast, pecans were rated poor to fair in all essential amino acids except arginine and histidine, being a good source of these nutrients.

Chicken gizzard and liver, without exception, were found to be excellent sources of all the essential amino acids.

The vegetables and grains analyzed in the present study were generally found to be fair or poor sources of the essential amino acids. Brown rice and field peas represent good sources of histidine; brown rice and corn grits are good suppliers of isoleucine; brown rice is a good source of arginine.

Cystine and Tyrosine in Food Protein and Fresh Food

The supplementary relationships of (1) cystine and methionine and (2) tyrosine and phenylalanine have been demonstrated to be of importance in animal nutrition. The ability of the animal organism to form cystine from methionine is well established. Though methionine can be synthesized from homocysteine, the latter has not been found in foods.

Phenylalanine and tyrosine also have a close metabolic relationship. Dietary needs for tyrosine can be readily supplied by dietary phenylalanine, as established by growth studies with young rats and by maintenance of nitrogen equilibrium in the adult human (*19*). Experimental evidence, however, has not demonstrated the conversion of tyrosine into phenylalanine.

The proteins of pork muscle and organ meats, with the exception of fatback, are good to fair sources of cystine and tyrosine. Raw and cooked fatback are poor sources of tyrosine, whereas cooked fatback is poor in cystine content.

The proteins of brown rice, corn grits, and mustard greens are excellent sources of tyrosine, and pecans, corn grits, and meal are excellent suppliers of cystine. With the exception of cabbage, all other vegetables, grains, and nuts are good to fair sources of cystine and tyrosine. The protein of cabbage is a poor source of tyrosine.

On the basis of fresh food, chicken liver and gizzard, pork heart, kidney, liver, muscle, and tongue usually are rated excellent or good with respect to cystine and tyrosine. Brown rice and corn grits are rated as good sources of tyrosine, whereas corn grits and meal are fair sources of cystine.

Supplementary Relationships Though chitterlings provide only fair amounts of the amino acids on a fresh basis, in southern diets this food is usually eaten with slaw and cornbread. Sweet potatoes and greens often complete the menu. Thus, supplementary relationships may operate to enable the individual to utilize the amino acids in chitterlings when this food replaces meat in the diet.

Fatback is extensively used in southern diets to flavor greens and other vegetables during the cooking process. In rural areas of the South, it is fried crisp and often replaces the meat component of the diet. Fried "skins," which are eaten in much the same way as salted peanuts and pretzels, are readily available in food stores all over the country. Cooked fatback was consistently lower in amino acids than the raw material. The concentration of tryptophan is negligible in both the raw and cooked food.

Cannon (*3*) and Geiger (*7, 8*) in studies with rats, and Leverton and Gram (*15*) in studies with college women, have substantiated the need for supplying adequate amounts of all the essential amino acids simultaneously for maintenance of nitrogen balance.

Though many of the vegetables analyzed in the present study are fair to poor sources of the amino acids when viewed as individual foods on the basis of fresh weight, simultaneous ingestion of these foods with others commonly found in southern diets, such as pork organs and tissues, chicken, and peanuts, may enable the individual to maintain a state of good protein nutrition where limited funds and food habits restrict the choice of a variety of more expensive foods of higher biological value. The careful planning of diets to include two or more of these foods as components of the same meal may enable the body to effect supplementary relationships between amino acids, and thus favor utilization of the nutrients in body processes.

Thus, if a typical southern dinner contained mustard greens cooked with fatback, baked yams, field peas, and cornbread (Meal A), the individual would be more likely to utilize the amino acids in the meal than if the only foods eaten were cabbage cooked with fatback and cornbread.

Similarly, in a meal containing only chitterlings, cole slaw, yams, and cornbread (Meal B), the quantities of amino acids would contribute substantially to the daily requirements for these nutrients, because of supplementary relationships which would exist among the amino acids in these foods.

The quantity of methionine in Meals A and B is less than the minimum daily requirement suggested by Rose (*19*). As the suggested meals represent only one of two or three which would ordinarily be consumed during the day, one might expect the remaining quantity of methionine to be obtained from the other meal(s).

Based on 4-ounce servings of each food, the contributions of Meals A and B with regard to eight essential amino acids, cystine, and tyrosine are given in Table V.

Table V. Comparison of Amino Acids in Selected Southern Meals with Minimum Daily Requirements

Amino Acid	*Meal A[a], G.*	*Meal B[b], G.*	*Minimum Daily Requirement (19), G.*
Isoleucine	1.11	0.81	0.70
Leucine	1.98	1.70	1.10
Lysine	1.50	1.11	0.80
Methionine	0.46	0.44	1.10
Phenylalanine	1.21	0.96	1.10
Threonine	1.03	0.95	0.50
Tryptophan	0.29	0.21	0.25
Valine	1.41	1.05	0.80
Cystine	0.38	0.31	...
Tyrosine	1.04	0.73	...

[a] 4-ounce (113.4 gram) servings of mustard greens, yams, field peas, fatback, and cornbread (cornmeal, egg, milk, baking powder, salt, sugar, and shortening).

[b] 4-ounce (113.4 gram) servings of yams, cole slaw, chitterlings, and cornbread.

The evaluation of amino acids in foods on the basis of supplementary relationships is of importance, as practical nutrition is concerned not with the amino acid composition of individual foods, but rather with the protein quality of diets.

Summary

Concentrations of 10 essential amino acids, cystine, and tyrosine, total nitrogen, moisture, and ash have been determined in 25 selected foods, which have been rated as excellent, good, fair, or poor sources of the amino acids.

Chicken liver, gizzard, pork heart, kidney, liver, muscle, and tongue are rated as excellent or good sources of the amino acids, on the basis of both food protein and the fresh food. The vegetables and grains analyzed in the present study are fair to poor sources of the essential amino acids on a fresh weight basis.

Possible supplementary relationships of the amino acids in practical dietary planning have been explored

Acknowledgment

The authors wish to express appreciation to R. A. Munday, B. D. Mayberry, and J. A. Walls for their assistance in the collection of samples for assay.

Literature Cited

(1) Barton-Wright, E. C., *Analyst*, **71,** 267 (1946).
(2) Beach, E. F., Munks, B., and Robinson, A., *J. Biol. Chem.*, **148,** 431 (1943).
(3) Cannon, P. R., *Federation Proc.*, **7,** 391 (1948).
(4) Dunn, M. S., in Block, R. J., and Bolling, D., "Amino Acid Composition of Proteins and Foods," 2nd ed., Charles C Thomas, Springfield, Ohio, 1951.
(5) Dunn, M. S., *Food Technol.*, **1,** 269 (1947).
(6) Dunn, M. S., Shankman, S., Camien, M. N., Frankl, W., and Rockland, L. B., *J. Biol. Chem.*, **156,** 703 (1944).
(7) Geiger, E., *J. Nutrition*, **34,** 97 (1947).
(8) *Ibid.*, **36,** 813 (1948).
(9) Greenhut, I. T., Schweigert, B. S., and Elvehjem, C. A., *J. Biol. Chem.*, **162,** 69 (1945).
(10) Hirsch, J. S., Niles, A. D., and Kemmerer, A. R., *Food Research*, **17,** 442 (1952).
(11) Horn, M. J., private communication.
(12) Horn, M. J., Blum, A. E., Gersdorff, C. E. F., and Warren, H. W., *Cereal Chem.*, **32,** 64 (1955).
(13) Horn, M. J., Blum, A. E., Gersdorff, C. E. F., and Warren, H. W., *J. Biol. Chem.*, **203,** 907 (1953).
(14) Kuiken, K. A., and Lyman, C. M., *J. Nutrition*, **39,** 359 (1945).
(15) Leverton, R. M., and Gram, M. R., *Ibid.*, **39,** 57 (1949).
(16) Lyman, C. M., and Kuiken, K. A., *J. Biol. Chem.*, **151,** 615 (1943).
(17) Lyman, C. M., and Kuiken, K. A., Texas Agr. Expt. St. Bull. **708** (1949).
(18) Mitchell, H. H., and Block, J., *J. Biol. Chem.*, **16,** 599 (1946).
(19) Rose, W. C., *Federation Proc.*, **8,** 546 (1949).
(20) Sauberlich, H. E., Pearce, E. L., and Baumann, C. A., *J. Biol. Chem.*, **175,** 29 (1948).
(21) Schweigert, B. S., in Block, R. J., and Bolling, D., "Amino Acid Composition of Proteins and Foods," 2nd ed., Charles C Thomas, Springfield, Ohio, 1951.
(22) *Southern Coop. Ser. Bull.*, No. **10** (1951).
(23) Stokes, J. L., Gunness, M., Dwyer, I. M., and Caswell, M. C., *J. Biol. Chem.*, **160,** 35 (1945).
(24) Watt, B. K., and Merrill, A. L., U. S. Dept. Agr., Washington, D. C., "Agriculture Handbook," No. 8, (1950).

Received for review May 16, 1955. Accepted August 1, 1955. Presented before the Division of Analytical Chemistry, American Chemical Society, *at the Joint Session of the Southeastern and Southwestern Regions, New Orleans, La., December 12, 1953. Research supported in part by the U. S. Department of Agriculture, through a contract sponsored by the Human Nutrition Research Branch, Agricultural Research Service.*