PROTEIN NUTRITIVE VALUE OF SELECTED PRESENT AND POTENTIAL MEAT EXTENDERS

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The high nutritive value of lean beef protein was used as the criterion for evaluating the relative quality of mixtures of meat and other animal and/or plant proteins. The nutritive value of selected animal and plant proteins, present or potential meat extenders, and their combinations with lean beef is under study. Available data from this study are reported here.

The protein nutritive value of partially defatted chopped beef and partially defatted beef fatty tissue is reviewed (Happich et al., 1975), and analytical data on bovine blood and its fractions, beef by-products that have possible uses in meat products, are discussed.

Protein efficiency ratios (PER) were determined for the proteins of whey, fish, soy, and liquid cyclone process cottonseed protein concentrates individually and in combinations with lean beef. All of the combinations had PER values equal to or higher than 2.5, the assigned PER for casein, a protein standard of high quality.

The use of soy proteins in meat products is expanding rapidly. The PER values and amino acid analyses of samples of textured

vegetable protein, meat patties with textured vegetable protein, and a soy protein concentrate were determined. Combinations of lean beef and a soy protein concentrate in 80:20, 70:30, or 60:40 protein ratios, respectively, had PERs that were not significantly different from each other or from the PER of casein.

Cattlehide collagen, a potential food texturizing and binding agent, has little nutritional value when fed as the only source of protein. PER values of collagen in combinations with lean beef and of lean beef-collagen combinations with either a whey or soy protein concentrate indicate parameters for adding collagen as a texturizing agent in designing new meat products with a PER of 2.5. The data also indicate that the whey concentrate proteins supplemented the lean beef-collagen proteins to a greater degree than the soy proteins did. PER values of lean beef-collagen-whey protein combinations were 2.4 or higher.

INTRODUCTION

The protein nutritive value, palatability, and consumer acceptance of red meat are high and these factors have made red meat the chief source of animal protein food in this country. At present, about two-thirds of food-grade protein used in the United States comes from animal sources (Bird, 1974). Currently there is a growing use of plant proteins as extenders in ground meat and meat products. It has been predicted that in the next several decades we will obtain one-half to two-thirds of our food-grade protein from plant-derived sources (Bird, 1974). Blending lean beef with other animal and/or plant proteins that have supplementary amino acid compositions can produce nutritious, economical, and palatable meat products. One of our research objectives is to develop the best possible of such products that will have consumer acceptance.

A second objective is to utilize cattlehide collagen as a texturizer. We believe that small amounts will improve commonly encountered textural deficiencies in some plant protein-meat products.

These investigations involve nutritional, processing, and organoleptic aspects. This paper will be limited to the protein nutritional aspects.

Presently we are studying a number of animal and plant proteins as potential meat extenders and obtaining data on the protein nutritive value of these proteins individually and in combination with lean beef proteins to obtain parameters for designing new nutritious meat products.

EXPERIMENTAL PROCEDURES

Preparation of Samples

Lean beef, the semitendinous muscle, commonly called eye of the round, was selected as the meat to be blended with meat extenders and as a reference protein in our studies. The lean beef, partially defatted chopped beef, partially defatted beef fatty tissue, and collagen, were freeze-dried and ground for use in rat feeding studies as described by Happich et al. (1975).

Bovine whole blood was obtained from a nearby slaughterhouse. Approximately 8 gallons were collected in a stainless steel milk can containing a solution of 66 g of citric acid (0.2% on blood volume) in 100 ml of water and mixed well to prevent clotting. The blood was cooled immediately and held in a cold room at 2-3°C until the following day. About 6 lb of whole blood were weighed into each of 6 stainless steel drying trays which were covered with plastic wrap and stored in a freezer. The frozen blood was freeze-dried in a Stokes shelf dryer at a vacuum of about 0.5 mm mercury and a shelf temperature of 100°F. Drying time of 24-32 hr was necessary. About 2850 g of dried whole blood was obtained. There was some loss because blood foamed out of the pans as the dryer was evacuated. The dried whole blood was ground in a Wiley Mill to pass a 2-mm screen, mixed well, and sampled for analysis and rat feeding studies.

A second sample of bovine blood, about 8 gallons, was collected

and allowed to clot. It was cooled and held overnight at 2-3°C. The following day the serum was removed from the clot by first separating the clot into large pieces, hanging the clotted material in a cheesecloth bag, and allowing the serum to drain. The serum was pink to light red in color. It was frozen in 8 stainless steel dryer trays (about 3 lb per tray) and freeze-dried in about 16 hr as described above for whole blood. The yield of dried serum was 807 g, 7.3% of the serum processed. The dried serum was ground to pass a 2-mm screen with a mortar and pestle to keep losses minimal. It was well mixed and sampled for analysis and rat feeding tests.

Dried commercial samples of textured vegetable protein and meat patties with textured vegetable protein were received from the Food and Nutrition Service of USDA for amino acid analyses. These samples of meat patties with textured vegetable protein were extracted with petroleum ether to reduce residual lipids and thoroughly dried before amino acid determinations. Ash, moisture, and nitrogen were determined on these aliquots and on the aliquots of the 4 samples of textured vegetable protein used for amino acid analysis.

Commercial samples of a whey protein concentrate (Enrpro 50), a soy protein concentrate (Promosoy-100), and a whole fish protein concentrate were obtained. A sample of fish protein concentrate prepared from whole hake was obtained from National Marine Fisheries Service, U.S. Department of Commerce (Sidwell, 1970). A sample of liquid cyclone process cottonseed protein flour, a deglanded cottonseed protein concentrate, was obtained from the Southern Regional Research Center (Vix, 1971). Proximate analyses were determined on all the above samples. Amino acid analyses were determined on the whey and soy protein concentrates.

Chemical Analyses

Official methods of the AOAC (1970) were used to determine moisture, ash, fat (petroleum ether extraction), and Kjeldahl nitrogen. Percentage protein was calculated from the total nitrogen

using the factor for the protein(s) analyzed, i.e., N x 6.25 for meat, partially defatted products, blood, fish, soy, and cottonseed protein and N x 6.38 for whey protein.

Amino acid analyses were determined in duplicate using the Piez-Morris system (1960) in collaboration with Dr. Stephen Feairheller and Miss Maryann Taylor of the Eastern Regional Research Center unless otherwise indicated. In preparation for amino acid analyses, samples containing more than 1% fat were extracted with petroleum ether. The residual solvent was removed from the sample by evaporation at room temperature and finally under vacuum. The samples were then dried in a vacuum oven at 50°C followed by hydrolysis with 6 N HCl for 24 hr. Tryptophan was determined on separate samples of meat, partially defatted products, or collagen after hydrolysis with methanesulfonic acid (Liu and Chang, 1971). Samples of textured vegetable protein, meat patties with textured vegetable protein, whey, and soy protein concentrates containing appreciable amounts of carbohydrates were hydrolyzed with barium hydroxide (Knox et al., 1970) in preparation for analysis of tryptophan. Each amino acid was calculated as grams of amino acid residue per 100 grams of total amino acid residues.

Protein Efficiency Ratios

PER values, unless otherwise indicated, were determined in collaboration with Dr. Albert Booth at the Western Regional Research Laboratory, ARS, USDA, on the partially defatted products, lean beef, collagen, and on the whey, soy, fish, and liquid cyclone process cottonseed protein concentrates individually, and on combinations of these proteins, using the method of Derse (1965). PER values were determined by feeding rats a diet containing 10% protein (N x 6.25, except N x 6.38 for whey and N x 5.32 for collagen), supplied by the test protein only, for 4 weeks. Rats of the Sprague-Dawley strain (5 per group) were used. Casein was fed as the protein in the control diet. The PER values were corrected to that of casein at 2.5 using the following equation:

$$\text{Corrected PER} = \frac{\text{determined PER of test protein} \times 2.5}{\text{determined PER of reference standard casein}}$$

Standard deviation was determined and Duncan Multiple Range tests were calculated on the actual PER values before correction to 2.5.

RESULTS AND DISCUSSION

The proximate composition of lean beef, the reference protein, is shown in Table 1. It is high in protein and low in fat. Meat also contains essential minerals and vitamins and an analysis is included in Table 1 for beef with low fat (Watt and Merrill, 1963). The PER was 2.8 when corrected to casein at 2.5 for two separately prepared freeze-dried samples (see Tables 3 and 9). The casein PER test is the only official method available for regulatory purposes.

Protein content, probable first limiting amino acid, and PER value of four animal and three plant proteins that are present or potential meat extenders are listed in Table 2. Included are two beef by-product proteins that have possible value as human food, bovine blood plasma and partially defatted beef fatty tissue, a protein-fat residue from low temperature rendering (under 120°F). These by-products will be discussed in more detail.

Alfalfa white leaf protein concentrate, a new research product of the Western Regional Research Laboratory, is a white protein concentrate from the expressed juice of alfalfa leaves (Edwards et al., 1973).

Partially Defatted (PD) Chopped Beef and PD Beef Fatty Tissue

A study in cooperation with Animal and Plant Health Inspection Service, USDA, related to our collagen investigations, yielded new protein nutritional data on PD chopped beef and PD beef fatty tissue (Happich et al., 1975). They are now used to a limited extent as food components and have the potential for much greater use. Partially defatted beef fatty tissue is allowed in meat

TABLE 1

COMPOSITION OF LEAN BEEF
100 GRAMS, EDIBLE PORTION

Component, g		Mineral, mg[a]		Vitamin, mg[a]	
Water	72.6	Calcium	12	Thiamine	0.09
Protein	21.8	Phosphorus	203	Riboflavin	0.18
Fat	4.6	Iron	3	Niacin	4.80
Ash	1.1	Magnesium	22	Vitamin A value[b]	20

[a]Mineral and vitamin values taken from Watt and Merrill, 1963, p. 15, No. 352.

[b]International units.

products in limited quantities. The nutritional value of these relatively new commercial food components was evaluated measuring the protein quality individually and in combination with other food proteins (Happich et al., 1975) and is reviewed here. Two PD chopped beef, 1 PD cured cooked chopped beef, and 3 PD beef fatty tissue residues were analyzed. They came from six different establishments. The residues were approximately 90% digestible and contained all of the essential amino acids although tryptophan was present only in traces in the beef fatty tissue residues. Collagen is the principal protein of the beef fatty tissue residues.

The essential amino acid composition of typical samples of lean beef, a PD chopped beef, a PD beef fatty tissue, and collagen is given in Table 3. The data are amino acid residues per 100 grams of total amino acid residues. The variation in the percent of each amino acid in the samples of lean beef, the partially defatted products, and collagen is evident, with lean beef containing the highest quantities and collagen the lowest.

Cystine and tyrosine are not essential in the diet but are included because they can replace part of the methionine and phenylalanine requirement, respectively (Rose and Wixom, 1955b; Rama Rao et al., 1961).

TABLE 2

PER Data on Selected Animal and Vegetable Protein Products

Product	Protein %[c]	Probable first limiting amino acid	PER[d]
PD beef fatty tissue[a,b]	48.3-51.5	TRP	1.1-1.7
Cattle blood plasma		MET or ILEU	2.2[e]
Protein concentrates:			
Whey[b]	58.0	TRP	2.7
Fish	96.0	MET	2.8
Whole fish[b]	91.5	MET	2.6
Soy[b]	67.4	MET	2.2
LCP cottonseed[a]	65.0	ILEU or MET	2.0
Alfalfa, white leaf	90.0	MET	2.5[f]

[a]Product code: PD, partially defatted; LCP, liquid cyclone process.

[b]Commercially available.

[c]Moisture-free basis.

[d]All PER values, except cattle blood plasma, corrected to that of casein at 2.5.

[e]Young et al., 1973.

[f]Kohler, private communication, 1974.

The protein efficiency ratio of lean beef and each partially defatted product is directly proportional to and correlates with the total essential amino acids in the protein. The correlation coefficient for this relation in lean beef and the 6 partially defatted products is 0.97. In all products each essential amino acid, except valine, and tryptophan which could not be calculated, shows a correlation with the PER values. These correlation coefficients range from 0.92 to 0.98. The quality of the protein in the PD beef fatty tissue residues is surprisingly high, PERs range from 1.1 to 1.7, and the data indicate that small amounts of tryptophan had a strikingly beneficial effect.

TABLE 3

Essential Amino Acid Composition and PER Value of Proteins of Lean Beef, Partially Defatted Chopped Beef, Partially Defatted Beef Fatty Tissue, Collagen, and a Whey Protein Concentrate[a]

Amino acid	Lean beef	Partially defatted		Collagen	Whey
		Chopped beef	Beef fatty tissue		
Histidine	3.6	3.0	1.9	0.8	2.1
Isoleucine	5.0	4.1	2.7	1.6	6.1
Leucine	8.3	7.2	5.7	3.0	10.4
Lysine	8.8	7.9	5.2	3.7	7.7
Methionine	2.6	1.9	1.2	0.7	1.5
1/2 cystine	1.3	1.0	1.1	0.0	2.2
Phenylalanine	4.9	4.2	3.6	2.1	3.9
Tyrosine	3.9	3.1	2.2	0.9	3.7
Threonine	4.4	3.8	3.2	1.9	6.4
Tryptophan	1.3	0.6	Trace	0.0	0.9[c]
Valine	5.5	4.6	4.9	2.3	5.7
Total	49.6	41.4	31.7	17.0	50.6
PER[b]	2.8	2.4	1.7	0	2.7

[a]Data taken from Happich et al. (1975). Grams of amino acid residue per 100 grams of total amino acid residues.

[b]PER values corrected to that of casein at 2.5.

[c]Estimated from the manufacturers' analysis of the whey protein concentrate.

TABLE 4

PER Data on Two Beef Fatty Tissue Proteins and Mixtures with Proteins from Other Sources[a,b]

PDBFT[c] %	Lean beef %	Whey PC[c] %	Soy PC[c] %	PER[d] #1	PER[d] #3
100	--	--	--	1.1	1.7
33	67	--	--	2.4	2.5
33	--	67	--	2.6	2.7
33	--	--	67	2.0	2.0
25	25	25	25	2.5	2.6

[a]Proteins, singly or in mixture, fed as 10% of diet.

[b]Data taken from Happich et al. (1975).

[c]Product code: PDBFT, partially defatted beef fatty tissue; PC, protein concentrate.

[d]PER values corrected to that of casein at 2.5.

PER data for two of these beef fatty tissue residues and for combinations of each with lean beef, whey protein concentrate, or soy protein concentrate are given in Table 4. The PER value of one beef fatty tissue was 1.1 and the other was 1.7 (the other one analyzed and not shown here was 1.68). When either of these two, #1 (1.1) or #3 (1.7), was combined in a 33:67 protein ratio with the whey protein concentrate or the soy protein concentrate, the PER value was considerably higher than that for the beef fatty tissue alone. The PER values of the combinations with lean beef or whey concentrate proteins approach or are higher than that of casein, the standard. The essential amino acid composition and PER of the whey and the soy protein concentrates which were blended with the partially defatted beef fatty tissue and with other protein products reported in this paper, are given in Tables 3 and 9, respectively. The data indicate that the proteins of lean beef and the whey concentrate supplement the beef fatty tissue proteins to a greater degree than the proteins of the soy concentrate. This is

due to the higher methionine and total sulfur amino acid content in lean beef and the whey protein concentrate.

Mixtures with 25% of the protein supplied by a beef fatty tissue and 25% supplied by each of 3 other proteins, lean beef, a whey, and a soy concentrate, had PER values of at least 2.5.

Bovine Blood

Whole bovine blood contains about 17% protein distributed in two principal fractions, a solid fraction composed of blood cells and a liquid fraction, plasma (American Meat Institute, 1950).

The solid fraction is made up of red cells, white cells, and platelets and contains 32% hemoglobin. Hemoglobin may be separated into the heme pigment and the protein globin by chemical procedures (Tybor et al., 1973).

Plasma contains 3 protein fractions: fibrinogen, albumins, and globulins. It also contains salts, fat-like bodies, and other substances such as sugar and vitamins in small quantities. Serum is the liquid fraction remaining after removal of fibrinogen from plasma.

Bovine blood is now dried and diverted to animal feed or fertilizer. It is potentially edible if handled correctly and represents an annual supply of 220 million pounds of protein available for food utilization. Freeze-dried samples of citrated whole blood and of serum were prepared. The latter was separated from freshly collected and clotted blood. Their proximate compositions are given in Table 5. PER tests are in progress at this time.

Literature data on the amino acid composition of whole beef blood and globin show them to be very low in isoleucine (Table 6). Beef blood plasma and serum contain larger amounts of isoleucine. All fractions appear to be low in methionine but contain some cystine. All fractions are high in leucine, lysine, phenylalanine, tryptophan, and valine as compared with casein or whole egg protein.

Blood fractions have not been used to any extent as food components in the United States. In 1970 Pals reported on a dried

TABLE 5

Composition of Freeze-Dried Bovine Blood[a]

Item	Percentages				
	Ash	Fat	N	Protein, N x 6.25	Other
Whole blood	3.8	0.22	14.9	93.3	2.7
Serum	9.9	0.11	13.1	82.1	7.9

[a]Results on a moisture-free basis.

free-flowing beef blood plasma named Isolated Beef Protein (IBP) that was 88-90% protein. The amino acid analysis indicated that isoleucine was low (2.9%), about 55% that of casein. Methionine was low, 1.1%, but IBP contained cystine. The tryptophan content was the same and the lysine content was higher than that of casein. The amino acid analyses indicate this protein would be useful in supplementing foods low in lysine but having adequate to high isoleucine and sulfur amino acids.

There is little data on the PER of blood fractions in the literature. Young and co-workers (1973) determined the PER of the spray-dried globin and plasma fractions of Tybor et al. (1973). The plasma fraction had a PER of about 2.2. Although globin did not support life (rats died during the sixth week of continued feeding on the globin diet), supplementing it with isoleucine in rat feeding studies produced an apparent PER of 2.2.

Bovine blood collected and prepared for food use offers possibilities as protein food supplements, food emulsifying and binding agents, and other uses.

In 1973 Tybor and co-workers reported on the emulsification capacity of spray-dried globin, plasma, and serum concentrates. Satterlee, Free, and Levin (1973) reported from their investigations of the use of several high protein tissue powders as binder/extenders in meat emulsions that whole beef blood had high emulsion capacity and stability. Crenwelge et al. (1974) reported on the effects of pH, protein solubility, and concentration on the

TABLE 6

Essential Amino Acid Composition of Bovine Blood Fractions[a]

Amino acid	Blood[b]	Globin[c]	Plasma[c]	Serum[d]	Fibrin[d]
Histidine	--	6.6	3.0	1.9	2.5
Isoleucine	0.4	0.3	3.1	3.4	5.8
Leucine	13.6	13.2	9.2	10.1	10.7
Lysine	9.4	9.8	8.9	7.9	8.7
Methionine	1.8	1.6	1.0	1.7	2.6
Cystine	--	0.1	2.2	3.6	2.0
Phenylalanine	8.0	7.6	5.1	5.0	4.5
Tyrosine	2.6	2.5	4.9	5.0	5.6
Threonine	4.7	4.1	6.0	6.3	7.3
Tryptophan	1.4	2.0	1.9	1.8	3.5
Valine	8.0	9.4	6.9	7.5	4.1
Total	49.9	57.2	52.3	54.2	57.3

[a]Analyses taken from the literature.

[b]Percentage of total protein (Olson, 1970).

[c]Grams per 100 grams protein. Rounded off to first decimal (Young et al., 1973).

[d]Grams of amino acid per 16.0 grams of nitrogen (Block and Weiss, 1956).

emulsification capacity of decolorized bovine hemoglobin (Tybor et al., 1973).

The technology for recovering beef blood proteins for food use is fairly well developed (Gordon, 1971; Halliday, 1973; Porter and Michaels, 1971; Garner et al., 1971; Tybor et al., 1973). However, we find that there is considerable need for studies concerned with obtaining optimum functionality, including uses strictly for nutritional purposes. We have such work in progress.

Soy Proteins

Recently we had the opportunity, in collaboration with USDA Food and Nutrition Service, to determine the amino acid composition of 4 commercial samples of textured vegetable protein and 3 samples of meat patties containing textured vegetable protein.

The PER value was determined for each product. Values ranged from 1.7 to 2.1 for the four samples of textured vegetable protein. Those for meat patties with textured vegetable protein ranged from 2.1 to 2.3 and do not meet USDA regulations. They were not much higher than the PERs of the textured vegetable protein samples. An amino acid analysis for each type of product is given in Table 7. These analyses indicate that the meat patties with textured vegetable protein contained higher amounts of glycine and proline than either textured vegetable protein or lean beef, and 2.6-3.2% hydroxyproline (textured vegetable protein had no hydroxyproline and lean beef contained only a slight trace of hydroxyproline, Table 9), indicating a higher collagen content than was found in lean beef. There are products on the market that contain some partially defatted beef fatty tissue with meat and soy and this may explain the composition of these products. The total sulfur amino acids were low, about 65% of those found in lean beef and lower than those in textured vegetable protein.

Recently investigators have been obtaining information on the use of soy proteins in meat and meat products. Korslund et al. (1973) and Kies and Fox (1973) studied the nutritive value of beef and soy proteins using human feeding tests. Rakosky (1974) reported on the nutritive value of soy products and of mixtures of soy and meat protein. Wilding (1974) reported on the nutritional quality of blends of textured soy and beef proteins and Wolford (1974) reported on consumer acceptance of beef/soy. The functionality and performance of soy proteins in meat blends in comminuted meat systems and in processed meat products were recently investigated by Judge et al. (1974), Schweiger (1974), and Roberts (1974).

Recently, we had PERs determined on mixtures containing 60,

70, or 80% lean beef proteins and 40, 30, or 20%, respectively, of the proteins of a soy concentrate, PER 2.2. The PER results are found in Table 8. There was no significant difference between the PER values of these three mixtures or between either one and the PER of casein at 2.5. However, mixtures containing higher concentrations of soy would be expected to have lower PERs than casein.

The essential amino acid composition of lean beef, the lean beef-soy mixtures, and the soy protein concentrate is shown in Table 9. The amino acid compositions for the beef-soy mixtures were calculated from the determined amino acid composition of lean beef and of the soy protein concentrate. All PER values were determined by rat feeding tests.

The essential amino acids which have the greatest variation throughout the five samples are histidine, lysine, methionine, and the total sulfur amino acids. Methionine sulfoxide, an oxidation product of methionine, was also found in these samples. Bennett (1939) reported that under the conditions of her experiments DL-methionine sulfoxide was able to replace DL-methionine in the diet of the albino rat. Kohler et al. (1974) touched on the nutritive value of methionine sulfoxide. Compared with lean beef, the soy protein concentrate contains about 26% methionine; 55% methionine plus methionine sulfoxide; and 71% total sulfur amino acids, methionine, methionine sulfoxide, and cystine. Methionine is the first limiting amino acid. Although the proteins of soy contain only 74% as much lysine as lean beef protein, soy proteins have about the same lysine as whole egg, a reference protein of high quality. Tryptophan varies little. There is a linear correlation between the PER values and each essential amino acid in the five samples. The correlation coefficient (r) equals ± 0.97 with one exception, r = 0.98 for isoleucine.

Combinations of Lean Beef Proteins with Four Protein Concentrates

PER values for combinations of lean beef proteins and proteins of whey, whole fish, soy, or cottonseed protein concentrates in

TABLE 7

Amino Acid Composition and PER Value of a Textured Vegetable Protein and a Sample of Meat Patties with Textured Vegetable Protein[a]

Amino acid	Textured vegetable protein	Meat patties with textured vegetable protein
Histidine	3.2	2.9
Isoleucine	5.3	4.5
Leucine	7.9	7.3
Lysine	6.8	6.3
Methionine	1.0	1.0
Methionine sulfoxide	0.9	0.6
1/2 cystine	1.2	1.0
Phenylalanine	5.9	4.9
Tyrosine	4.3	3.7
Threonine	4.2	3.7
Tryptophan	1.3	1.0
Valine	5.2	5.2
Alanine	4.2	5.7
Arginine	8.0	7.3
Aspartic acid	10.8	9.8
Glutamic acid	16.0	15.1
Glycine	3.8	6.4
Hydroxylysine	0.0	Trace
Hydroxyproline	0.0	3.2
Proline	5.0	6.3
Serine	4.9	4.1
Approximate % of total N accounted for	84.7	89.3
PER[b]	2.1	2.1

[a]Grams of amino acid residues per 100 grams of total amino acid residues.

[b]PER values corrected to that of casein at 2.5.

TABLE 8

PER Data on Protein Mixtures of Lean Beef and a Soy Protein Concentrate (PC)[a]

Lean beef, %	Soy PC, %	PER[b]
100	--	2.8
--	100	2.2
80	20	2.5[c]
70	30	2.6[c]
60	40	2.5[c]

[a]Proteins, singly or in mixture, fed as 10% of diet.

[b]PER values corrected to that of casein at 2.5.

[c]These PER values were not significantly different from each other or from the PER of casein.

mixtures of 70 and 30%, respectively, are in Table 10. All mixtures met the minimum PER requirement of 2.5, complying with USDA regulations for meat products for the School Lunch Program. The whey-lean beef mixture had the highest PER, although it was not significantly better than the lean beef-soy or lean beef-fish mixtures. The animal proteins tested had higher PER values and tended to produce mixtures with higher PERs than the plant proteins tested. This suggests the possible advantages of combining lean beef and soy proteins with a third protein of good quality, such as whey, fish, or perhaps blood plasma proteins to ensure nutritious meat products with a PER similar to that of lean beef, particularly if there is mutual supplementation of the amino acids. PER tests are in progress now of 70-20-10 and 60-20-20 combinations of lean beef, soy, and a third protein, either whey, fish, or cottonseed protein concentrate, respectively. We also plan to determine PERs of cooked mixtures of lean beef and soy proteins and cooked mixtures with a third protein.

TABLE 9

Amino Acid Composition and PER Data for Lean Beef and Soy Proteins and their Mixtures[a]

Amino acid	Lean beef	Lean beef-soy protein mixtures[b,c]			Soy protein[b]
		80-20	70-30	60-40	
Essential amino acids:					
Histidine	4.3	4.1	3.9	3.8	3.2
Isoleucine	5.2	5.2	5.2	5.1	5.0
Leucine	8.2	8.0	7.9	7.9	7.4
Lysine	9.0	8.6	8.3	8.1	6.7
Methionine	2.7	2.3	2.1	1.9	0.7
Methionine sulfoxide	0.4	0.5	0.6	0.6	1.0
1/2 cystine	0.92	0.96	0.98	1.0	1.15
Phenylalanine	4.9	5.1	5.1	5.2	5.6
Tyrosine	3.8	3.9	3.9	4.0	4.2
Threonine	4.7	4.6	4.5	4.5	4.2
Tryptophan	0.89	0.90	0.91	0.91	0.94
Valine	5.6	5.5	5.4	5.4	5.1
Total	50.21	49.16	48.19	47.81	44.19

Nonessential amino acids:					
Alanine	5.5	5.2	5.0	4.9	4.0
Arginine	6.9	7.2	7.3	7.5	8.3
Aspartic acid	9.4	9.8	10.0	10.3	11.6
Glutamic acid	14.5	15.0	15.3	15.5	17.1
Glycine	4.5	4.3	4.3	4.2	3.6
Hydroxyproline	very slight trace	--	--	--	0.0
Proline	4.5	4.6	4.7	4.8	5.3
Serine	4.0	4.2	4.3	4.4	4.9
Total	49.70	50.80	51.50	52.20	55.80
Approximate % of total N accounted for	84.13	--	--	--	88.86
PER[d]	2.8	2.54	2.57	2.46	2.2

[a]Grams of amino acid residues per 100 grams of total amino acid residues.

[b]The soy protein was soy protein concentrate.

[c]The amino acid compositions of the lean beef-soy protein mixtures were calculated from the determined amino acid composition of lean beef and soy protein.

[d]PER values corrected to that of casein at 2.5.

TABLE 10

PER Data on Protein Mixtures of Lean Beef and Several Protein Concentrates[a]

Lean beef %	Whey %	Whole fish %	Soy %	LCP[b] cottonseed %	PER[c]
70	30	--	--	--	2.7
70	--	30	--	--	2.6
70	--	--	30	--	2.6
70	--	--	--	30	2.5

[a]Proteins in mixture fed as 10% of the diet.

[b]Liquid cyclone process.

[c]PER values corrected to that of casein at 2.5.

Cattlehide Collagen

Collagen, a high-molecular-weight, insoluble, fibrous protein, is a promising food texturizing agent. Food components such as soy flours, whey, dry milk powder, gums, or gelatine may be used in admixture with meat or in meat analogues for economical and nutritional reasons. They produce products with textures that frequently are undesirable and there is evidence that collagen in small quantities can improve the texture of such products.

Our research is mainly concerned with utilizing the fibrous collagen present in mature cattlehides and especially the lower layer of lime-unhaired hide called the flesh split (Whitmore et al., 1970). The Engineering and Development Laboratory at the Eastern Regional Research Center has developed processes for comminuting the collagen in splits into small particles and produced 5 wet products, their differences being particle size (Komanowsky et al., 1974).

Fibrous collagen has unique physical and chemical properties. It is practically odorless and tasteless, has a bland flavor and a hydrothermal shrinkage temperature of about 60-65°C. It is amphoteric and may act as a buffer. It absorbs and binds a large

quantity of water. Whitmore et al. (1972) found that fibrous, insoluble, limed collagen will form a wide variety of aqueous dispersions producing characteristics from a fibrous paste to a liquid virtually free of fibers. The dispersions may be thixotropic. This technology has made it possible to prepare collagen foams, films, coatings, emulsions, gels, and pastes. Collagen offers the potential of varying the character, viscosity, consistency, mouth feel, tenderness, and juiciness (succulence) of extended meat and other food products to meet consumers' expectations.

Fibrous cattlehide collagen was about 90% digestible in rat feeding tests. It has an unusual and characteristic amino acid composition. About one-third of the amino acid residues is glycine. It contains hydroxyproline and hydroxylysine and is completely lacking in tryptophan and cystine. It is deficient in all the other essential amino acids as compared with casein or whole egg. A PER of zero was obtained when rats were fed a diet containing 10% collagen as the only source of protein. However, probing tests supplementing collagen with DL-tryptophan and DL-methionine and feeding it at 20% of the diet resulted in a positive PER value.

To establish parameters on combinations of collagen with other proteins, we have obtained the PER values listed in Table 11, on three combinations of collagen and lean beef proteins and on lean beef-collagen protein blends in combination with proteins of a whey or soy protein concentrate.

The PER of lean beef was 2.8. Adding 10% collagen to lean beef reduced the PER to about 2.5, the PER of the standard casein. A mixture of 50% collagen and lean beef proteins had a PER of 1.7.

All of the PER values of lean beef-collagen protein mixtures with whey protein were similar to the PER for casein. Those with soy protein were lower. Of the two products used, the whey protein supplemented the lean beef-collagen blend proteins to a greater degree. They have a higher methionine and total sulfur amino acid content and methionine is probably the second limiting amino acid in the lean beef-collagen blend.

TABLE 11

PER Data on Lean Beef, Whey and Soy Proteins, and Mixtures with Lean Beef and Collagen Proteins[a]

Lean beef, %	Collagen, %	Whey[b], %	Soy[b], %	PER[c]
100	--	--	--	2.8
90	10	--	--	2.5
50	50	--	--	1.7
10	90	--	--	0
--	--	100	--	2.7
90	5	5	--	2.5
50	25	25	--	2.4
25	25	50	--	2.6
--	--	--	100	2.2
50	25	--	25	2.2
25	25	--	50	2.1

[a]Proteins, singly or in mixture, fed as 10% of diet.

[b]Protein concentrate.

[c]PER values corrected to that of casein at 2.5.

These data indicate that collagen as an added component in meat products or meat analogues in limited quantities can result in products that have a satisfactory PER.

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Reference to brand or firm names does not constitute

endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

REFERENCES

American Meat Institute. 1950. By-products of the Meat Packing Industry, Institute of Meat Packing, Chicago, Illinois.

AOAC. 1970. Official Methods of Analysis (11th Ed.). Association of Official Agricultural Chemists. Washington, D.C.

Bennett, M.A. 1939. Metabolism of sulphur.X. The replaceability of DL-methionine in the diet of albino rats with its partially oxidized derivative, DL-methionine sulphoxide Biochem. J. 33-1794.

Bird, K.M. 1974. Plant proteins: progress and problems. Food Technol. 28:3:31.

Block, R.J. and K.W. Weiss. 1956. Amino Acid Handbook, Methods and Results of Protein Analysis. Charles C. Thomas, Springfield, Illinois. pp. 252-253.

Crenwelge, D.D., C.W. Dill, P.T. Tybor and W.A. Landmann. 1974. A comparison of the emulsification capacities of some protein concentrates. J. Food Sci. 39:175.

Derse, P.H. 1965. Evaluation of protein quality (biological method). J. Ass. Offic. Anal. Chem. 48:847.

Edwards, R.H., R.E. Miller, D. De Fremery, B.E. Knuckles, E.M. Bickoff and G.O. Kohler. 1973. Presented at the 166th Meeting of the American Chemical Society, August 27-30, Chicago, Illinois. (Abstract).

Garner, R.G., G.J. Mountney and S.E. Zobrisky. 1971. Agricultural processing wastes: a review. Proceedings of the 68th Annual Convention of the Association of Southern Agricultural Workers, Inc. (Abstract).

Gordon, A. 1971. Animal blood as a source of protein in food products. Food Trade Rev. 41:4:29.

Halliday, D.A. 1973. Blood - a source of proteins. Process Biochem. 8:12:15.

Happich, M.L., R.A. Whitmore, S. Feairheller, M.M. Taylor, C.E. Swift, J. Naghski, A.N. Booth and R.H. Alsmeyer. 1975. Composition and protein efficiency ratio of partially defatted chopped beef and of partially defatted beef fatty tissue and combinations with selected proteins. J. Food Sci. 40:35.

Judge, M.D., C.G. Haugh, G.L. Zachariah, C.E. Parmelee and R.L. Pyle. 1974. Soya additives in beef patties. J. Food Sci. 39:137.

Kies, C. and H.M. Fox. 1971. Comparison of the protein nutritional value of TVP, methionine-enriched TVP and beef at two levels of intake for human adults. J. Food Sci. 36:841.

Knox, R., G.O. Kohler, R. Palter and H.G. Walker. 1970. Determination of tryptophan in feeds. Anal. Biochem. 36:136.

Kohler, G.O. 1974. Private communication.

Kohler, G.O., H.G. Walker Jr., D.D. Kuzmicky and S.C. Witt. 1974. Problems in analysis for sulfur amino acids in feeds and foods. Presented at the 168th Meeting of the American Chemical Society, September 9-13, Atlantic City, New Jersey. (Abstract). See also this volume, Part 1.

Komanowsky, M., H.I. Sinnamon, S. Elias, W.K. Heiland and N.C. Aceto. 1974. Production of comminuted collagen for novel applications. J. Amer. Leather Chem. Ass. 69:410.

Korslund, M., C. Kies and H.M. Fox. 1973. Comparison of the protein nutritional value of TVP, methionine-enriched TVP and beef for adolescent boys. J. Food Sci. 38:637.

Liu, T.Y. and Y.H. Chang. 1971. Hydrolysis of proteins with *p*-toluenesulfonic acid. J. Biol. Chem. 246:2842.

Olson, F.C. 1970. Nutritional aspects of offal proteins. Proceedings of the Meat Industry Research Conference, University of Chicago, March 26-27. p. 23.

Pals, C.H. 1970. The practical aspects of blood component procurement. Proceedings of the Meat Industry Research Conference, University of Chicago, March 26-27. p. 17.

Piez, K.A. and L. Morris. 1960. A modified procedure for the automatic analysis of amino acids. Anal. Biochem. 1:187.

Porter, M.C. and A.S. Michaels. 1971. Membrane ultrafiltration. 3. Applications in the processing of meat by-products. Chem. Technol. July, p. 440.

Rakosky, Joseph Jr. 1974. Soy grits, flour, concentrates, and isolates in meat products. J. Amer. Oil Chem. Soc. 51:1:123A.

Rama Rao, P.B., H.W. Norton and B.C. Johnson. 1961. The amino acid composition and nutritive value of proteins. J. Nutr. 73:38.

Roberts, L.H. 1974. Utilization of high levels of soy protein in comminuted processed meat products. J. Amer. Oil Chem. Soc. 51:1:195A.

Rose, W.C. and R.L. Wixom. 1955. The amino acid requirements of man. XIII. The sparing effect of cystine on the methionine requirement. J. Biol. Chem. 216:763.

Rose, W.C. and R.L. Wixom. 1955. The amino acid requirements of man. XIV. The sparing effect of tyrosine on the phenylalanine requirement. J. Biol. Chem. 217:95.

Satterlee, L.D., B. Free and E. Levin. 1973. Utilization of high protein tissue powders as a binder/extender in meat emulsions. J. Food Sci. 38:306.

Schweiger, R.G. 1974. Soy protein concentrates and isolates in comminuted meat systems. J. Amer. Oil Chem. Soc. 51:1:192A.

Sidwell, V.D., B.R. Stillings and G.M. Knobl Jr. 1970. The fish protein concentrate story. 10. U.S. Bureau of Commercial Fisheries FPCs: nutritional quality and use in foods. Food Technol. 24:8:40.

Tybor, P.T., C.W. Dill and W.A. Landmann. 1973. Effect of decolorization and lactose incorporation on the emulsification capacity of spray-dried blood protein concentrates. J. Food Sci. 38:4.

Vix, H.L.E., P.H. Eaves, H.K. Gardner Jr. and M.G. Lambou. 1971. Degossypolized cottonseed flour--the liquid process. J. Amer. Oil Chem. Soc. 48:611.

Watt, B.K. and A.L. Merrill. 1963. Composition of Foods, Agric. Handbook No. 8. USDA, Washington, D.C. p. 15, no. 352.

Whitmore, R.A., H.W. Jones, W. Windus and J. Naghski. 1970. Preparation of hide collagen for food. J. Amer. Leather Chem. Ass. 65:383.

Whitmore, R., H. Jones, W. Windus and J. Naghski. 1972. Preparation and visco-elastic properties of fibrous collagen dispersions from limed cattlehide splits. J. Food Sci. 37:302.

Wilding, M.D. 1974. Textured proteins in meats and meat-like products. J. Amer. Oil Chem. Soc. 51:1:128A.

Wolford, K.M. 1974. Beef/soy: consumer acceptance. J. Amer. Oil Chem. Soc. 51:1:131A.

Young, C.R., R.W. Lewis, W.A. Landmann and C.W. Dill. 1973. Nutritive value of globin and plasma protein fractions from bovine blood. Nutr. Rep. Int. 8:4:211.