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THE *IN VITRO* DIGESTIBILITY AND NUTRITIONAL QUALITY OF DEHYDRATED BEEF, FISH AND BEANS [a]

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Interest in the dehydration of foods has increased steadily in recent years. Dehydration is not only an effective means of preserving foods but also provides significant savings in shipping space, weight and refrigeration. Suitable methods have now been developed for the commercial dehydration of meat, fish *(3, 4, 5)*, and bean *(2, 10)*. Recently, Sheffner, Adachi, and Spector *(13)* published an *in vitro* method (PDR index) which accurately measures the net utilization value (biological value × digestibility) of food proteins. The new procedure not only considers changes in total amino acid content but also the enzymatic availability of the component amino acids and has been successfully applied to the nutritional evaluation of heat processed and irradiated proteins *(12, 13)*. The purpose of the present investigation was to determine by means of the PDR index the nature and extent of the nutritive changes in the proteins of beef, fish and beans which result from dehydration.

EXPERIMENTAL

The beef [c] selected for this study was U. S. Good grade sirloin butt steak. Steaks were sliced one-half inch thick and were about 4 ounces in weight. The steaks were frozen and freeze-dehydrated at a plate temperature of 110° F. for 24 or 48 hours depending upon the desired moisture content of the final product. The steaks were vacuum packed in cans or flexible packages with and without an in-package desiccant (calcium oxide). Dehydrated steaks were rehydrated by soaking for 30 minutes at room temperature. The steaks were pan-fried without added fat at 375° F. for a total time of 2½ minutes, the steaks being turned every one-half minute.

Haddock [c] caught in the mid-Atlantic Ocean during the late summer months was used in this investigation. The fresh haddock was on ice 6 days before it was filleted. Fillets were laid in 10-pound blocks, frozen and sawed into sticks. Frozen fish sticks were freeze-dehydrated at a plate temperature of 100.4° F. and a pressure of 200-250 μ for 28-29 hours. The dehydrated sticks were hermetically sealed under vacuum in cans. The fish sticks were rehydrated by soaking in water one minute at room temperature. Cooked fish was obtained by frying the fish for one minute in deep fat heated to 375° F.

Navy (Michigan pea variety), red kidney, and baby lima (Birdseye brand) beans [d] were selected for this experiment. The navy beans were washed and soaked overnight. The soaked beans were then screened to remove those that had not swelled. Pre-cooking

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[c] Beef and haddock samples were prepared by James Blair, Animal Products Branch, Quartermaster Food and Container Institute for the Armed Forces.

[d] Beans were selected and prepared by technologists of Plant Products Branch, Quartermaster Food and Container Institute for the Armed Forces.

was done in a pressure retort at 245° F. for 20 minutes. The beans were frozen and dehydrated for one and one-quarter hours in a Proctor and Schwartz through-air-flow tray dehydrator at 170° F. utilizing low humidity. Red kidney beans were washed and soaked overnight, precooked at 245° F. in a steam-pressure cooker for 15 minutes, frozen, and dehydrated for six and one-half hours at 130° F. Fresh frozen lima beans were precooked by simmering at 212° F. for 18 minutes. The beans were then treated with 0.05% sulfite solution for one minute, drained, frozen, and dehydrated at 160° F. for 3 hours. Procedures for preparation of enzyme digests, amino acid analyses, and calculation of the PDR index were previously reported *(14)*.

RESULTS AND DISCUSSION

Table 1 presents the pepsin digest-residue (PDR) indexes of beef samples subjected to one or several of the following treatments: dehydration, rehydration, cooking, and storage. The results indicated that dehydration, rehydration, and cooking (fresh or rehydrated) did not change the nutritional

TABLE 1

The pepsin digest-residue (PDR) amino acid index values of fresh, dehydrated, cooked ,and stored beef

Treatment	PDR Index
None (frozen fresh)	76
Fresh cooked	77
Dehydrated (2% moisture)	77
Rehydrated	78
Rehydrated cooked	76
Frozen fresh, stored 12 mo., −20° F.	68
Dehydrated (2% moisture), stored 12 mo., −20° F., flexible package	81
Dehydrated (8% moisture), stored 12 mo., 70° F., flexible package	76
Dehydrated (2% moisture), stored 12 mo., 100° F., canned	80
Dehydrated (8% moisture), stored 12 mo., 100° F., canned	76

quality of the beef. Storage of raw beef at — 20° F. produced a 10% decrease in nutritional quality, due primarily to destruction of small amounts of cystine, isoleucine, leucine, lysine, tryptophan, tyrosine, and valine; the release of amino acids by pepsin digestion was not impaired. Beef steaks dehydrated to 2% moisture had slightly higher PDR index values after storage for 12 months either at — 20° F. in flexible containers or at 100° F. in cans. If the beef steaks were dehydrated initially to only 8% moisture and then stored at 70° F. in flexible packages or at 100° F. in cans they did not show the increased nutritional values; however, their values were equivalent to that of fresh beef.

The PDR index values of fresh, processed, and stored haddock are presented in Table 2. It is apparent that dehydration, rehydration, and storage did not affect the nutritional quality of haddock. For fresh and dehydrated haddock PDR index values of 78 were obtained. This checks closely with a net protein utilization value of 74 obtained for vacuum-dried haddock by the nitrogen balance method *(6)*. Under our conditions, cooking significantly increased the nutritive value of fresh and rehydrated haddock. Dehydrated haddock retains its nutritive value during storage even at 100° F. The essential amino acid composition of haddock was found to be in close agreement with that reported by Proctor and Lahiry *(11)* and Neilands *et al. (9)*.

TABLE 2

The PDR index values of fresh, dehydrated, cooked, and stored haddock

Treatment	PDR Index
None (frozen fresh)	78
Fresh cooked	86
Dehydrated	78
Rehydrated	76
Rehydrated cooked	83
Frozen fresh, stored 12 mo., −20° F.	78
Dehydrated, stored 12 mo., −20° F.	80
Dehydrated, stored 12 mo., 40° F.	77
Dehydrated, stored 12 mo., 100° F.	78

The effect of cooking upon the PDR indexes of kidney, lima, and navy beans is indicated in Table 3. The PDR index value of 75 for cooked lima beans is higher than the net utilization value of 58 reported by Metta and Johnson *(7)*. Although this difference can be accounted for by variations in conditions (freshness, maturity), methods of preparation, and variety of bean, the extremely low net utilization value of 34 which Metta and Johnson found for raw lima beans is probably due to the growth inhibitors present in many legumes. The PDR index has been shown to predict the net utilization value of this type of product only if the "toxic" factors are inactivated by mild heat treatment *(12)*. The results indicate, therefore, that the net utilization values of cooked kidney, lima, and navy bean proteins approximate the values of 69 to 72 obtained for soybean *(8, 12)* and are almost as good as those for beef protein. Everson and Heckert *(1)* also found that the biological value of heated lima beans compared closely with that of soybeans.

Dehydration of the cooked beans did not produce significant changes in the PDR index values (Table 3). In addition, chili con carne, a combination item containing precooked dehydrated kidney beans as well as similarly treated meat had a PDR value of 77 which is equivalent to that of good quality beef alone.

TABLE 3

Effect of cooking and dehydration upon the PDR index values of kidney, lima, and navy beans

Product	Treatment	PDR Index
Kidney bean	None	69
Kidney bean	Precooked	68
Kidney bean	Precooked, dehydrated	70
Lima bean	None	74
Lima bean	Precooked	75
Lima bean	Precooked, dehydrated	74
Navy bean	None	71
Navy bean	Precooked	70
Navy bean	Precooked, dehydrated	70
Chili con carne [1]	Precooked, dehydrated	77

[1] Composition: 58.4% precooked, dehydrated red kidney beans; 25.3% precooked, freeze-dried hamburger; 6.68% tomato solids; 3.9% beef soup and gravy base; 2.97% chili powder; 2.23% sodium chloride; and 0.03% garlic powder.

The effect of heating upon the enzymatic release of amino acids from lima beans is presented in Table 4. Data show that in general there is no change in the quantity of amino acids released by pepsin; however, following cooking of the beans there was a considerable increase in the amounts of amino acids released by the pepsin plus pancreatin treatment. Similar results were obtained with kidney beans. However, the quantity of amino acids released by pepsin plus pancreatin digestion of cooked lima beans was decreased by subsequent dehydration of the beans. Although it has been shown that the degree of digestibility with pancreatic enzymes *per se* is not correlated with the nutritional quality of a protein, the findings indicate that the

TABLE 4

Effect of cooking and dehydration upon the enzymatic release of amino acids from lima beans

Amino acid	Pepsin			Pepsin plus pancreatin		
	Unprocessed	Precooked	Precooked dehydrated	Unprocessed	Precooked	Precooked dehydrated
	% liberation			% liberation		
Histidine	8.1	6.5	6.7	16.2	39.0	34.2
Lysine	2.5	2.0	2.0	16.2	44.5	28.5
Methionine	19.0	17.6	15.8	35.4	47.6	36.5
Cystine	3.5	1.7	2.0	0.0	1.1	0.0
Phenylalanine	15.8	19.8	17.9	33.4	50.3	46.2
Tyrosine	8.6	8.8	8.8	27.5	52.5	46.9
Leucine	29.9	39.6	33.8	39.5	65.2	51.2
Isoleucine	31.1	37.2	35.8	37.0	56.2	53.4
Valine	15.0	12.2	12.4	24.6	35.8	30.6
Threonine	38.6	39.6	34.6	46.6	62.2	53.2
Tryptophan	15.2	16.3	13.1	21.5	35.1	26.3

dehydration process is causing structural changes in the bean proteins. Although these changes do not reflect a decrease in the protein quality of the present product, they suggest that any further increase in severity of the dehydration process with regard to time or temperature will affect the availability of the amino acids during digestion.

The total essential amino acid compositions of kidney, lima, and navy beans were found to be similar (Table 5). Examination of the essential amino acid pattern furthermore revealed that the bean proteins were deficient only in the sulfur amino acids, methionine and cystine. In this respect, lima beans contained more of cystine which in some measure accounts for the higher PDR values of lima beans. In addition, the average essential amino acid content of lima bean protein is slightly greater than that of the other two types of beans.

A comparison of the essential amino acid patterns of kidney and navy beans indicates that the pattern in kidney protein more nearly approaches that of the standard reference protein, whole egg. However, the protein in the kidney beans used in this study was considerably less susceptible to pepsin digestion than was the protein of the navy beans; consequently, the two factors balanced out and the PDR values for the two types of beans were very similar.

TABLE 5

Total [1] essential amino acid composition of unprocessed, precooked, and dehydrated kidney, lima, and navy beans

Amino acid	Unprocessed			Precooked			Precooked dehydrated		
	Kidney	Lima	Navy	Kidney	Lima	Navy	Kidney	Lima	Navy
Histidine	30.9	33.0	30.4	29.5	32.8	29.5	29.8	33.4	29.7
Lysine	73.4	70.0	71.5	70.0	71.6	70.3	74.1	71.9	73.1
Methionine	10.0	9.6	8.8	9.7	10.2	9.0	8.8	10.3	9.6
Cystine	8.8	13.6	9.0	8.2	13.1	8.6	7.8	11.1	8.0
Phenylalanine	56.6	53.7	52.0	57.0	56.5	53.8	56.0	55.8	52.2
Tyrosine	32.1	33.5	32.9	34.1	33.0	33.8	34.0	32.6	34.1
Leucine	86.4	90.3	81.2	86.8	85.9	81.1	87.0	92.7	80.2
Isoleucine	47.9	53.4	46.5	47.0	49.7	45.0	48.7	48.2	43.6
Valine	55.1	57.6	54.4	53.5	57.8	53.2	55.0	58.5	53.4
Threonine	44.8	47.0	52.2	44.2	52.5	52.4	42.4	54.8	52.7
Tryptophan	14.1	18.5	16.5	13.9	18.5	17.0	13.3	18.3	14.5

[1] Expressed as mg./g. of protein (N x 6.25). Acid and alkaline hydrolysates were prepared as previously described *(13)*.

With respect to the destruction of amino acids, cooking, and dehydration were not found to have an appreciable effect upon the total essential amino acid content of any of the beans studied.

SUMMARY

Nutritional values are reported for dehydrated fish and meat, and precooked, dehydrated beans as measured by the PDR index. The results indicate that dehydration and cooking of haddock and beef, and precooking and dehydration of lima, kidney, and navy beans do not decrease the nutritional value of the proteins in these products. Dehydrated beef and haddock retained their nutritional quality on storage at 100° F. as well as or better than the frozen fresh products. The nutritional quality of kidney, lima, and navy bean proteins approximated that of soybean protein and was nearly as high as that of beef and fish.

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