Measuring Food Proteins

Using the Egg as the Standard

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Americans' desire to have quality and quantity protein sources is paramount in their food selections. However, we seem to have gone overboard in our enthusiasm for protein in that we are consuming far more animal protein than what is healthful. More than 250 scientific studies published in recent years show our propensity toward: (1) a high percentage of animal fats in our diets;[1–4] (2) a high proportion of total calories consumed from saturated animal fats—more than 40 percent[5]—and; (3) excess amounts of protein from animal sources. These factors are all contributing to a heightened risk of heart disease, cancer, and other degenerative conditions.[6,7] On the other hand, numerous studies[8,9] confirm that a properly balanced vegetarian program provides more than adequate amounts of protein, and such a regimen's lower fat content reduces the risk of various diseases.[10–12] The findings of these studies have not been widely implemented, though, partly because of some outdated assumptions that are, unfortunately, still extant.

The Old Thinking on Protein

For a long time, the prevailing assumption about protein, put forth in virtually all major health and nutrition texts, was that only proteins from animal sources were complete, i.e., contained all of the essential amino acids. Nonanimal foods were hardly considered to be protein sources at all. They were called incomplete and were to be used only adjunctively. Grains, legumes, nuts and seeds, vegetables, tubers, and fruits were acknowledged as important bearers of vitamins, minerals, and fiber, and their significant protein contributions were downplayed or ignored.

The New Thinking on Protein

The morbidity and mortality statistics of other cultures reveal that the old protein assumptions are at least partially incorrect. For instance, people in Japan and China today, and for some time, have lived longer and healthier lives than the average American, even without the benefit of Western medical advances and technology. A careful examination of these cultures' diets indicates that they consume a reverse ratio of animal–plant-source protein than the average American: 80 percent of American protein intake comes from animal sources; only 20 percent of the Chinese protein is from animals. This is true for many other cultures of the world in which vegetarian diets are providing people with adequate protein. What is more, these people are not suffering from the abundance of degenerative diseases—diseases in part attributable to diet—that are prevalent among Americans.

The good news is that today, many Americans are finally coming around to acknowledge the true protein picture. For instance, the newest thinking on protein is exemplified in a position statement on vegetarian diets of the American Dietetic Association (ADA). This group's journal, in its November 1993 issue, reported that "vegetarian diets are healthful and nutritionally adequate when appropriately planned."[8] More important, the report goes on to explain some of the health-promoting aspects of vegetarianism and of lowered protein consumption. It states that "plant sources of protein alone can provide adequate amounts of the essential and nonessential amino acids, assuming that dietary protein sources from plants are reasonably varied and that caloric intake is sufficient to meet energy needs."

Furthermore, the ADA now holds that conscious combining of foods within a given meal—the old complementary protein dictum—is unnecessary. "Additionally," says the ADA, "soy protein has been shown to be nutritionally equivalent in protein value to proteins of animal origin" and, thus, can serve as the sole source of protein intake if desired."

Vegetarianism's Virtues

With the ADA getting on the vegetarian bandwagon, it appears that a real paradigm shift toward an acceptance of vegetarianism is at hand in the United States.

Health Benefits. The ADA report summarizes health benefits as follows: "A

Research has shown that in cultures eating a high-fiber diet rich in fruits, vegetables, grains, and legumes, and low in animal products, colon and prostate cancer are rare.

considerable body of scientific data suggests positive relationships between vegetarian diets and risk reduction for several chronic degenerative diseases and conditions, including obesity, coronary artery disease, hypertension, diabetes mellitus, and some types of cancer." Indeed, meat is one of the major contributing factors in colon and prostate cancer. Research has shown that in cultures eating a high-fiber diet rich in fruits, vegetables, grains, and legumes, and low in animal products, colon and prostate cancer are rare. In countries such as ours, though, where a lot of fatty, fiberless foods, often of animal origin, are eaten, these cancers are common.

Equally important is the prevalence of heart disease. Because the main source of cholesterol in the American diet is the saturated fats contained in meat and other animal products, change to a diet that is mainly vegetarian may be an important step in preventing coronary and artery disease.

Antibiotic Ingestion. Another negative aspect of animal protein consumption involves the contaminants found in these foods. Antibiotics, hormones, pesticides, and fungicides are administered to livestock or included in their food, and all of these are consumed by meat and dairy eaters. Even though the antibiotics are present in subtherapeutic dosages, they can still present serious health risks for the consumer. Bacteria can adapt to a specific antibiotic and develop into "super germs" that are resistant to it. Additionally, an individual may be allergic to a particular antibiotic and not know it, or not know that he or she is receiving a continued dosage of it through food intake. Finally, antibiotics kill off not only harmful bacteria but "friendly" bacteria as well, thus destroying the natural bacterial balance of power within our digestive systems.

Low Cost Advantage. Economically, vegetarianism is a wise dietary choice because, ounce for ounce, plant foods cost less than meat. On the global economic scale, vegetarianism makes sense because it conserves natural resources. The breeding and slaughter of animals, as well as the subsequent processing of meat, use an inordinate amount of land, water, energy, and raw materials. Consider, for instance, that cows consume approximately 16 pounds of grain to yield just one pound of meat. This grain could go to feed people.

Taste considerations may seem like a potential problem in going vegetarian. But, for many, the taste for meat is an acquired one; it is not due to a natural craving for protein, and it disappears when meat is replaced with a variety of plant-derived foods. This is especially true when the easy art of creative vegetarian cooking with herbs is learned.

Creation of the Egg Protein Index

Using these facts and considerations, we created the Egg Protein Index (EPI), a protein analysis of the major foods, both animal and plant, as compared with the amount of protein usually found in an egg. We analyzed the exact amino acid structure, percentages, and quality of each, and came up with some interesting results. In fact, we believe that our findings should offer new insight, and hence direction, for dietitians, nutritionists, physicians, and public health educators.

We learned that all nonanimal foods, particularly grains and legumes, contain all eight essential amino acids. We found that vegetables, sea vegetables, and fruits also contain the essential amino acids, but in varying qualities and percentages. As a result of these findings, we have been able to show how, by combining a variety of plant foods in normal serving sizes, people can obtain all of the amino acid—and hence protein—that they need, without the use of any animal sources whatsoever.

Function of the EPI

Once we determined that all 8 essential amino acids are present in nonanimal food, it became necessary to employ an *unbiased* rating system that would allow us to compare *all* foods. An unbiased rating system ensures that the criteria for deciding what foods were best was not based on subjective factors, such as taste or flavor. Instead, the obvious criterion on which the EPI was founded was the essential amino acid composition of the food in question.

Although this new rating system assigns a unique number to each food or

Table 1. Master Listing

	Essential Amino Acids											
FOOD	**TRP**	**THR**	**ISL**	**LEU**	**LYS**	**MET**	**PHA**	**VAL**	**Total Protein**	**Essential Protein**	**Protein /Gm N2**	**% Essential**
Egg protein	103	311	415	550	400	196	361	464	31.3	2.8	6.25	44.80
Alfalfa seeds	0	134	143	267	214	145	0	0	1.30	0.90	6.25	14.44
Almonds, shelled	49	170	243	405	162	72	319	313	3.3	1.73	5.18	33.45
Amaranth	181	594	610	905	852	303	622	740	13.80	4.80	5.30	90.69
Asparagus, cooked	61	174	230	271	286	60	148	241	1.88	1.48	6.25	23.69
Barley, flour	177	410	512	942	410	223	655	604	9.60	3.93	5.80	67.81
Barley, pearled lt	73	197	248	405	197	84	301	293	6.15	1.79	5.83	30.84
Basmati (lng prbl)	26	74	93	169	77	46	102	130	7.70	0.72	5.90	12.15
Bean, aduki	60	270	313	566	553	115	420	350	7.50	2.64	6.25	42.35
Bean, broad dry	63	232	280	482	408	48	254	306	21.36	2.07	6.25	33.16
Bean, navy	58	271	355	537	464	63	345	379	6.64	2.47	6.25	39.55
Bean, red kidney	65	262	277	449	356	65	315	321	6.64	2.11	6.25	33.76
Bean, pinto	58	271	355	537	464	63	345	379	16.31	2.47	6.25	39.55
Bean, black	64	212	368	546	400	88	329	384	16.71	2.39	6.25	38.25
Bean, fava	60	786	936	659	151	172	101	999	7.10	3.86	6.20	62.32
Bean, lima	82	265	402	491	413	62	308	390	4.8	2.41	6.25	38.60
Bean, mung	85	178	301	399	376	77	266	297	3.26	1.97	6.25	31.66
Bean, snap	66	272	228	385	301	77	229	309	1.61	1.86	6.25	29.87
Beet, cooked	73	184	186	264	223	71	178	218	0.94	1.39	6.25	22.35
Beet, greens	98	186	130	279	183	50	166	184	1.44	1.27	6.25	20.41
Brazil nut	71	160	225	428	168	357	234	312	4.06	1.95	5.46	35.80
Broccoli, cooked	65	203	243	292	315	75	189	286	2.64	1.66	6.25	26.68
Brussels sprout	69	223	245	281	285	60	182	287	3.58	1.63	6.25	26.11
Buckwheat flour	88	246	235	365	367	110	236	324	4.31	1.97	5.83	33.80
Bulgur	66	177	203	399	161	99	253	244	11.20	1.60	5.70	28.10
Cabbage, raw	64	215	316	323	295	63	200	267	1.11	1.74	6.25	27.88
Carrot	66	228	248	260	243	42	195	264	0.94	1.54	6.25	24.73
Cashew nut	135	211	350	436	227	101	271	456	4.88	2.18	5.30	41.26
Cauliflower	82	227	238	365	335	88	223	314	1.95	1.87	6.25	29.95
Chard, swiss	60	287	512	450	343	65	381	381	2.04	2.47	6.25	39.66
Chickpea/garbanzo	51	222	359	462	431	83	304	308	15.38	2.22	6.25	35.52
Coconut	52	201	281	419	237	110	271	331	0.35	1.90	5.30	35.88
Coconut milk	56	150	163	338	288	81	238	250	6.10	1.56	5.30	29.50
Collards, cooked	81	220	254	387	297	85	222	305	3.06	1.85	6.25	29.61
Corn, kernel	144	251	251	675	266	130	291	359	2.72	2.26	6.25	36.27
Corn, flour	38	249	289	810	180	116	287	319	3.41	2.28	6.25	36.60
Couscous	127	340	390	766	309	190	486	468	12.50	3.07	5.70	53.96
Cowpeas, blackeye	72	233	335	446	411	89	343	362	5.03	2.29	6.25	36.65
Cucumber	50	169	194	264	260	51	169	202	0.77	1.35	6.25	21.74
Date	158	165	150	279	190	69	179	209	1.63	1.39	6.25	22.38
Eggplant, cooked	57	225	272	394	292	69	263	324	0.84	1.89	6.25	30.33
Filbert	88	173	356	392	174	58	224	390	3.39	1.85	5.30	35.00
Gluten, flour	61	151	262	427	109	99	310	270	21.75	1.68	6.25	27.02
Grits, hominy	60	227	251	582	257	71	239	286	7.41	1.97	6.25	31.56
Kale, cooked	76	279	374	437	374	60	320	342	3.83	2.26	6.25	36.19
Lentil	54	229	227	438	496	73	308	278	5.85	2.10	6.25	33.64
Lettuce, crisphead	45	286	404	380	406	76	263	335	0.77	2.19	6.25	35.12
Miso, red	88	329	426	634	264	93	264	370	13.50	2.46	6.25	39.48
Mushroom, agaicus	146	293	258	396	656	124	253	297	0.71	2.42	6.25	38.76
Mustard greens	69	166	228	192	285	59	166	243	1.88	1.40	6.25	22.52
Oatmeal	75	193	301	437	214	86	311	347	1.80	1.96	5.83	33.68

Table 1. Master Listing (continued)

FOOD	Essential Amino Acids TRP	THR	ISL	LEU	LYS	MET	PHA	VAL	Total Protein	Essential Protein	Protein /Gm N2	% Essential
Okra, cooked	52	203	216	328	252	66	203	284	1.71	1.60	6.25	25.66
Onion, raw	90	151	221	219	299	52	160	144	1.28	1.33	6.25	21.37
Papaya, raw	77	110	83	165	258	21	92	101	0.51	0.91	6.25	14.51
Parsley, chopped	125	0	0	0	400	30	0	0	0.83	0.56	6.25	8.88
Peanut	69	168	257	380	223	55	316	311	4.98	1.77	5.46	32.58
Pea, podded	61	220	360	510	450	25	200	610	5.36	2.43	6.25	38.97
Pea, green	43	234	225	373	366	95	231	271	4.59	1.83	6.25	29.40
Pea, sprouts	66	213	196	419	441	79	288	253	6.86	1.95	6.25	31.28
Peanut butter	69	168	257	380	223	55	316	311	1.14	1.77	5.46	32.58
Pecan, shelled	78	219	312	436	245	86	318	296	1.24	1.99	5.30	37.54
Pepper	80	230	202	327	278	75	193	264	1.01	1.64	6.25	26.38
Pine nuts	146	397	428	753	482	223	419	583	7.90	3.43	5.30	64.73
Pineapple	82	198	206	308	405	170	191	257	0.34	1.81	6.25	29.07
Plantain	71	164	175	282	290	82	212	219	0.94	1.49	6.25	23.92
Potato	97	227	254	367	380	99	278	352	1.61	2.05	6.25	32.86
Pumpkin, pulp	76	180	195	288	34	68	199	218	0.84	1.56	6.25	25.02
Pumpkin, squash	96	160	298	418	242	99	300	288	5.08	1.90	5.30	35.86
Rice, brown	64	233	279	513	235	107	299	416	5.63	2.14	5.95	36.06
Rye, flour	66	216	248	392	238	92	275	304	7.84	1.83	5.83	31.40
Seaweed, chlorella	92	251	202	496	329	88	289	92	60.30	1.83	6.25	29.42
Seaweed, dulse	80	290	245	425	225	136	285	550	29.00	2.23	6.25	35.77
Seaweed, hijiki	47	200	390	450	180	200	360	630	5.60	2.45	6.29	39.06
Seaweed, wakame	73	340	180	530	230	130	230	430	8.90	2.14	6.27	34.17
Sesame seed	91	194	261	461	160	175	400	244	3.41	1.98	5.30	37.47
Sesame seed, hulled	107	165	155	314	139	91	220	206	8.80	1.39	5.30	26.35
Soybean, immature	76	249	275	447	374	76	283	278	7.43	2.05	5.71	36.04
Soybean, sprouts	143	362	312	525	437	70	250	350	2.48	2.44	5.71	42.88
Soymilk	48	128	171	278	195	50	175	165	7.70	1.21	5.70	21.22
Spaghetti	67	222	286	378	184	86	298	324	10.63	1.84	5.70	32.36
Spinach, raw	84	267	319	486	382	115	282	352	2.72	2.28	6.25	36.59
Spirulina	35	124	136	209	112	54	109	155	62.00	0.93	6.25	14.94
Squash, summer	56	151	225	367	348	90	220	283	0.77	1.74	6.25	27.84
Sunflower, hulled	79	210	294	400	200	102	281	312	4.35	1.87	5.30	35.43
Sunflower, flour	85	201	253	386	211	126	276	315	16.00	1.85	5.30	34.96
Sunflower, butter	90	268	314	559	281	154	496	374	6.50	2.53	5.30	47.84
Sweet potato	77	311	313	459	308	154	375	409	1.39	2.40	6.25	38.49
Tempeh	84	267	340	538	404	71	305	349	19.50	2.35	5.71	41.29
Tofu	96	296	329	473	457	80	385	345	7.80	2.46	6.25	39.37
Tomato, raw	46	158	150	229	230	54	162	160	0.84	1.18	6.25	19.02
Triticale flour	138	377	533	896	428	223	419	583	14.70	3.59	5.80	62.01
Turnip, greens	108	343	323	527	407	141	384	425	1.88	2.65	6.25	42.52
Walnut, persian	62	208	271	434	156	108	271	344	1.85	1.85	5.30	34.98
Watercress	82	362	254	451	363	55	311	373	1.05	2.25	6.25	36.01
Watermelon seed	73	208	251	402	166	156	381	291	9.40	1.92	5.30	36.37
Wheat, flour	72	168	253	391	160	89	288	270	6.00	1.69	5.83	29.00
Wheat, bran	103	180	255	377	258	76	228	290	1.35	1.76	6.31	28.00
Wheat, flakes	64	188	262	470	190	67	252	302	1.16	1.79	6.31	28.44
Wheat, germ	61	309	271	393	353	939	209	314	13.50	2.84	6.31	45.15
Wheat, gluten	61	151	262	427	109	99	310	270	41.40	1.68	5.70	29.63
Yeast (brewers)	96	318	324	436	446	113	257	368	33.00	2.35	6.25	37.72

The Egg Protein Index itself is a comparison of a food's essential protein to that of the egg's essential protein.

Assumptions in Defining the EPI

As with any rating system there are certain inherent rules or assumptions. These assumptions define what data are used and how they are used. The mathematical model that represents these assumptions and the mechanism whereby we implement the EPI assumptions are explained below.

The EPI itself is a comparison of a food's essential protein to that of the egg's essential protein. To compare real-life data to that of a hypothesis or model, we performed a "regression analysis." This technique employs the average mean squared error[1,2] or least squares method:

$$\sigma^2 = \sum_{i=1}^{n} w_i^*(x_i - \bar{x})^2 \qquad (1)$$

In this method we evaluated, point by point, how close the actual data are to the model or predicted values. For our application we evaluated (by differences/residuals) the protein content for each of the eight essential amino acids. Our equation was as follows:

$$\mathrm{EPI} = \sum_{i=1}^{8} w_i^*(FOOD_i - EGG_i)^2 \quad (2)$$

where $FOOD_i$ is the protein content of the i^{th} amino acid of the food in question or being evaluated and EGG_i is the protein content of the i^{th} amino acid of the egg.

Assumptions

A. Compare "like" amounts (units of measure) of food.

The amount of essential amino acid that we used in our analysis for each food is listed in Table 1. For the "Essential Amino Acids" portion the values are listed in mg per gm of N2. The "Total Protein" is per unit of measure (the unit of measure varies by food type, viz. 3 oz, 1 cup, etc.). This assumption, i.e., *(a)* above, precisely defines $FOOD_i$ and EGG_i used in equation 1 above. Note that the % Essential column shows what portion of the (unit of measure) protein was used for comparison, the essential protein. Hence for the egg, of the 31.3 grams of protein in a one-cup serving, only 48.8 percent or 14 grams are essential protein. One extreme food in this category is amaranth, in which 90.7 percent of the protein is essential or for all practical purposes we could say all its protein is essential. At the other extreme, papaya and spirulina contain only 14 percent essential protein, just 1/7 of the total protein, available in these two foods.

B. Each essential amino acid is of equal importance.

To implement this assumption we dropped (set each w_i equal to 1) the weighting factors:

$$\mathrm{EPI} = \sum_{i=1}^{8} (FOOD_i - EGG_i)^2 \quad (3)$$

To refine the formula further, we made two subtle transformations. Instead of calculating differences based on actual amounts of amino acids, we used percentage values. This allowed us to retain the importance of a preferred proportion (that of the egg protein) and allowed us to take the logs of these percentages to minimize extreme variances.[3] Our transformed formula was as follows:

$$\mathrm{EPI} = \sum_{i=1}^{8} (\ln P_i - \ln E_i)^2 \quad (4)$$

where P_i = the percentage content of the i^{th} amino acid of the food or foods to be rated, and E_i = the percentage content of the i^{th} egg amino acid. The final equation was

$$\mathrm{EPI} = \sum_{i=1}^{8} (\ln P_i - \ln E_i)^2 * 1000 \quad (5)$$

that allowed us to complete the final value multiplying by 1000 for convenience of comparisons.

The Egg Protein Index is not a rating system to tell how much essential protein is present; it is a system to match, in proportion to each of 8 essential amino acids, one food or group of foods to an ideal food.

Results

In comparing rated foods by EPIs, comparisons should be made with like or same combinations. Compare pine nuts and cowpeas with beets and sweet potatoes, i.e., two foods are compared with a combination of two other foods. Similarly, a three-food combination would be compared with another three-food combination, not a two-food combination. To compare just broccoli with, say, rice, beans, and onions would be difficult to interpret, since in general, the more foods used in combination, the lower the EPI becomes.

The EPI is not a rating system to tell how much essential protein is present. It is a system to match, in proportion to each of 8 essential amino acids, one food or group of foods to an ideal food. An example of this important distinction was revealed in the original analysis. Two-food groupings received equivalent EPI rating values, as illustrated in Table 2 (listed with total protein and essential protein). One of the food groupings had almost twice as much essential protein as the other combination. The reason that they matched as equal was because of the way in which each of the combined 8 amino acids compared, in proportion, to that of our ideal food.

Applying the EPI to Rice

Rice computes with an EPI of 31.14. This places it in the grouping of animal proteins such as veal cuts, beef cuts, or chicken. Milk, on the other hand, is far better, having an EPI of 16.81. Because the proportion of essential amino acids is a key criterion, a "balancing" portion of selected amino acids can be added to make rice identical to the egg. Specifically, 448 milligrams of 7 of the 8 essential amino acids would be needed per 100 grams of rice. This precision is not necessary, however, to obtain desirable results. Only 180 milligrams of 4 of the essential amino acids could improve rice's EPI from 31.14 to 4.52.

Thoughtful attention must be given to the following. When we improve the quality of rice, as stated above, we are improving the essential protein portion. We are not producing more protein in the 100 grams of rice, nor are we making all of the rice's protein complete. Nevertheless, the rice now has a higher nutritional value.

White Rice Formula

(to be added to every 100 grams of rice)

Tryptophan	32 mg
Threonine	57 mg
Isoleucine	109 mg
Leucine	none
Lysine	139 mg
Methionine	76 mg
Phenylalanine	38 mg
Valine	17 mg

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Table 2. Excerpt from 2-Food Combination Results

RANK	Combination 1	Combination 2	EPI	
65	Pine nuts (7.9/3.4)	Pea, green (4.59/1.8)	8.068	(12.49/5.2)
66	Spirulina (62/0.93)	Amaranth (13.8/4.8)	8.102	(75.8/5.7)
67	Sunflower flour (16/1.8)	Bean, navy (6.64/2.4)	8.125	(22.64/43)
68	Basmati (7.7/0.71)	Asparagus (13.8/4.8)	8.167	(9.58/2.1)
69	Pine nuts (7.9/3.4)	Bean, snap (1.61/1.8)	8.197	(9.51/5.2)
70	Pine nuts (7.9/3.4)	Cauliflower (1.95/1.8)	8.208	(9.85/5.3)
71	Walnut (1.85/1.8)	Mushroom (0.71/2.4)	8.259	(2.56/4.2)

The standard that we decided to use was the egg, hence the *Egg* Protein Index. If the essential protein structure of a food were to match exactly that of the egg, then its EPI would be zero.

food group reflecting its quality, the real function of the EPI is to use these assigned numbers for comparative purposes. For example, carrots were assigned a 6 rating and black beans were assigned a 5 rating, and because the lower number signified quality (see below), we concluded that black beans were better than carrots.

Here is how a single number, using the EPI, can portray the essential amino acid composition of a food adequately. The EPI allows us to compare foods because the EPI itself reflects a comparison. The number assigned by this rating system tells how the food itself compares to a standard. The standard that we decided to use was the egg, hence the *Egg* Protein Index. If the essential protein structure of a food were to match exactly that of the egg, then its EPI would be zero. The poorer the match was, the higher the number would be. Thus, i n our example, since black beans compare closer or more favorably (EPI = 5) to the egg than carrots (EPI = 6), we conclude that blacks beans are better than carrots. □

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