TABLE E.4

THERMAL DATA FOR PROTEINS

Protein	C	H	O	N	S	Heat of Combustion Calculated[1] (kcal/g)	Reported[2] (kcal/g)	Calculated Metabolic Heat[3] (kcal/g)
Gluten	4288	6909	1564	1255	26	5.60	—	4.43
Gliadin	4366	6988	1600	1235	24	5.61	5.74	4.47
Glutenin	4201	6672	1565	1204	22	5.55	5.70	4.40
Soy Proteins	4125	6524	1448	1202	28	5.64	5.67	4.47

NOTE: The numbers in the C, H, O, N, and S columns are the numbers of atoms of these elements present in one molecule of the protein, as calculated from amino acid analysis data.

[1] Calculated from Equation 1.
[2] Benedict and Osborne (1907); for some metabolic results for proteins, see Schulz (1975).
[3] Calculated from Equation 2.

from the RQ method, previously described in this article.

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ENRICHMENT, RESTORATION, FORTIFICATION AND NUTRIFICATION

In practice these terms are used indiscriminately (Bender 1973), yet each term has a different technical as well as legal denotation (Lachance 1972).

RESTORATION

The least ambiguous term is restoration, which is the process of adding nutrients to processed foods in amounts sufficient to replenish those nutrients lost during processing. In restoration, nutrient addition is pegged at a level similar to that found in the raw commodity or principal ingredient. The addition of ascorbic acid to instant potatoes is an obvious example. Harkins (1972) points out that there is no attempt to set the restoration level to ameliorate a deficiency syndrome. To some degree the enrichment of flour, white bread and maize meal is a restoration to make good milling losses, but historically the rationale for these nutrient additions was based on a need to prevent malnutrition and therefore other nutrients were also added or some nutrients were added in excess of restoration levels. The food then became a carrier for nutrients not ordinarily expected in such a product. The practice was justified in terms of the public health. Sebrell (1972) explains the view that the quantity of nutrient added was based on that necessary to meet health needs and did not necessarily need to have any relation to the composition of the original food. This public health rationale was first applied with the addition of a fish oil concentrate to margarine as a source of Vitamin A, and the addition of iodine to salt to prevent goiter.

ENRICHMENT

Thus the term "enrichment" is a contraction of the rationale "public health enrichment" and it is the process of adding nutrients to selected and usually manufactured (formulated or fabricated) foods as a public health measure. This is usually a practice mandated by official decree. Examples are the addition of vitamin D to milk (not a manufactured food but an intact food) or bread (formulated food); the addition of vitamins A and/or D to margarine (a fabricated food) (Table E.5); the addition of iodine to salt (a condiment) and chocolate; and the addition of calcium and additional riboflavin to bread (a formulated food). In the case of bread the practice of restoration plus the practice of public health enrichment is legally termed enrichment, and the philosophy varies from country to country (Table E.6). In the U.S. the practice is covered by a standard of identity. A very recent development is the full realization that the vitamin losses which occur with the milling of wheat are as applicable to pantothenic acid, biotin, folic acid, pyridoxine and tocopherol as they are to thiamin, riboflavin and niacin (Fig. E.5) (NAS/NRC 1974). In other words, the practice of restoration has in no way been a complete or balanced restoration. The NAS/NRC has proposed a more balanced restoration policy for all cereal-grain products (Table E.7). It is very likely that the adoption of this more complete restoration will be considered a form of enrichment.

Fortification is without a doubt the most misused term because it has clearly different technical and legal definitions. Legally in the United States, whenever a nutrient which has no standard of identity (a specific product regulation permitting certain nutrients to be added, e.g., "enriched" bread) is added to a food, the food is said to have undergone fortification. The public health enrichment of salt with iodine is by law a fortification. The addition of vitamin A to margarine is sometimes labelled an enrichment (Sebrell 1972), but it is legally and technically a fortification.

TABLE E.5

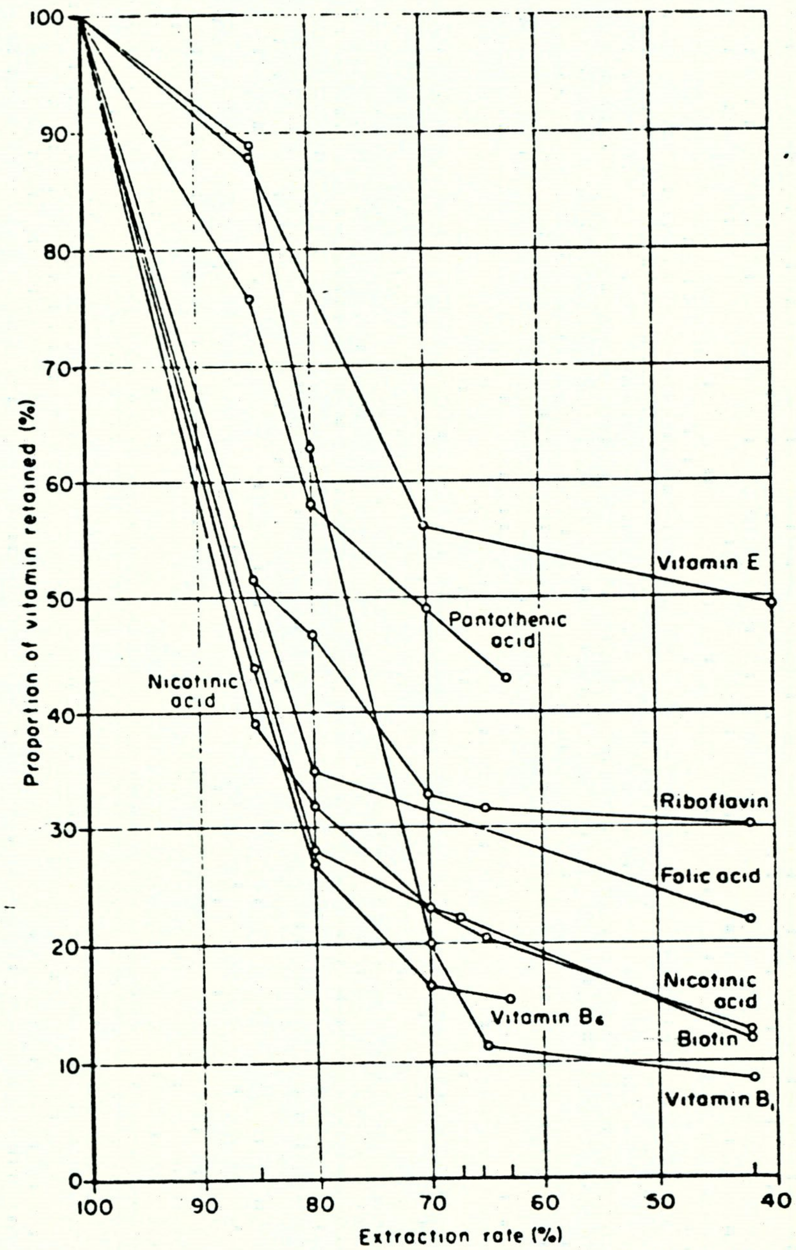
ENRICHMENT OF MARGARINE (PER KG)

	Vitamin A μg	Vitamin D μg
Australia	9000	100
Austria	6000	25
Belgium	6000	25
Brazil	4500-15000	12.5-50
Canada	10000	—
Chile	9000	25
Denmark	6000	15
Finland	6000	62-90
Germany	6000-9000	7-25
Greece	7500	37
India	7500	—
Israel	9000	75
Japan	6000-12000	—
Mexico	6000	50
Netherlands	6600	25
Norway	6000	62
Portugal	6000-10000	22-25
Sweden	9000	37
Switzerland	9000	75
South Africa	6000	25
Turkey	6000	25
United Kingdom	9000	70-90
United States	10000	110

SOURCE: Bender (1973).

FORTIFICATION

Fortification is the process of adding nutrient(s) to a level coinciding with the "image" or place of the food in the dietary. The "image" may be real (that is a natural product being emulated; e.g., butter is the standard for margarine which emulates butter) or the "image" may be theoretical (that is an unrelated external standard in terms of high nutritive value; e.g., egg protein or casein is the standard for the amino acid nutritive profile of proteins). Therefore, the addition of vitamin A to margarine is a fortification based on the image of butter. The addition of vitamin A to nonfat dry milk is a fortification based on the image of whole milk. But vitamin D is also added because it is a public health enrichment expected in whole milk. Vitamin C is added to fortify many beverages which supposedly are citrus fruit juice replacers. The citrus fruit juice is primarily considered a "vitamin C" food, although a thorough analysis would indicate that other key nutrients are often being overlooked, particularly in the case of orange juice which also contains folic acid, thiamin, potassium, and magnesium in significant quantities. Thus fortification based on a cursory image of the nutritive value of the intact commodity food is a practice with possible adverse public health implications if it is too frequently practiced.



From NAS/NRC (1974)

FIG. E.5. RELATION BETWEEN EXTRACTION RATE AND PROPORTION OF TOTAL VITAMINS OF THE GRAIN RETAINED IN FLOUR

Reproduced with permission from *Wheat in Human Nutrition*, Food and Agriculture Organization, Rome.

TABLE E.6

ENRICHMENT OF CEREAL PRODUCTS (PER KG)

	Thiamin mg	Riboflavin mg	Niacin mg	Iron mg	Calcium mg
Australia	1.6	2.4	16	14.7	1000
Brazil[1]	4.5	2.5	—	30	1000
Canada	4.4-5.5	2.7-3.3	35-44	29-36	1100-1400
Chile[1]	6.3	1.3	13	13.3	1700
(Rice)	4.4-8.8	2.6-5.3	35-70	29-57	1100-1650
Congo (Dem Rep)	4-6	2.5-3.5	32-45	26-35	1000-1500
Costa Rica	4.4-5.5	2.6-3.3	35-44	29-36	1100-1400
Denmark[1]	5	5	—	30	5000
(Rye flour)[1]	—	—	—	30	10000
Dominica	4.4-5.5	2.6-3.3	35-44	29-36	1100-1400
Germany	3-4	1.5-5.0	20	30	720-2000
Israel	—	2.5	—	—	—
Japan	5	3	—	—	1500
Nicaragua	1	1.4	15.7	13	500
Panama[1]	4.4	2.6	35	28.7	1100
Peru[1]	4.0	4.0	30	20	1000
Philippines[1]	4.4-5.5	2.6-3.3	35-44	29-36	1100-1400
Portugal	4.4-5.5	2.6-3.3	35-44	28-36	—
Puerto Rico[1]	4.2	2.4-2.5	30	26-36	1100
Sweden	2.6-4.0	1.2	23-40	30	—
Switzerland	2.8-4.2	1.7-2.5	29-44	18-26	—
United Kingdom[1]	2.4	—	16	16.5	1250
United States[2]					
White flour	4.4-5.5	2.6-3.3	35-44	29-36	1100-1400
Bread	2.4-4.0	1.6-3.5	22-33	18-28	660-1750
Corn meal	4.4-6.6	2.6-4.0	35-53	29-57	1100-1600
Rice	4.4-8.8	2.6-5.3	35-70	29-57	1100-2200
Pastas	8.8-11.0	3.7-4.8	60-75	29-36	1100-1400
USSR	2-4	4	10-30	—	—

SOURCE: Bender (1973).

[1] Legally enforced. (NOTE: Some of the information in this table is a compromise between conflicting reports.)

[2] Legal enforcement in 30 States (vitamin D also added 8-50 μg/kg).

TABLE E.7

NUTRIENTS AND LEVELS SUGGESTED FOR FORTIFICATION OF CEREAL-GRAIN PRODUCTS

Nutrient	Mg/Lb	Mg/100 G
Vitamin A[1]	2.2	0.48
Thiamin	2.9	0.64
Riboflavin	1.8	0.40
Niacin	24.0	5.29
Vitamin B-6	2.0	0.44
Folic acid	0.3	0.07
Iron	40.0	8.81
Calcium	900.0	198.20
Magnesium	200.0	44.10
Zinc	10.0	2.20

SOURCE: NAS/NRC (1974).

[1] Retinol equivalent.

The best example of the practice of fortification which enhances nutritive value by supplementing and enhancing an existing nutrient profile, the goal being a superior but unrelated external standard, is the practice of enhancing the utilizable protein of one commodity for human consumption by means of blends with other proteins of differing protein nutritive value profiles and/or fortification with amino acids (Bressani *et al.* 1971; Jansen 1974). The judicious use of protein fortification spares protein supplies and offers the means for a more equitable distribution of essential amino acids of proteins (Rosenfield 1973).

Experience in fortification technology has led to the concept of adding several nutrients to new foods (i.e., fabricated) resembling traditional foods in order to assure that the new foods are

TABLE E.8

NUTRITIONAL SPECIFICATIONS FOR TEXTURED MEAT ALTERNATES[1]

Nutrients (Unit)	Required Levels for All Products: Units Per Gram of Protein	Maximum
Moisture (% wt)		8
Ash, unflavored product (% wt)		6
Ash, flavored product (% wt)		8
Magnesium (mg)	1.14	
Iron (mg)	0.13	
Zinc (mg)	0.23	
Calcium (mg)	10.0	
Phosphorous (mg)	10.0	
Thiamin (mg)	0.014	
Riboflavin (mg)	0.010	
Niacin (mg)	0.30	
Vitamin B-6 (mg)	0.020	
Pantothenic acid (mg)	0.040	
Folic acid (μg)	0.40	
Vitamin B-12 (μg)	0.090	
Vitamin A (IU)	15.0	

SOURCE: Federal Register, *39*, No. 60, March 27, 1974.

[1] All specifications are expressed on a moisture-free basis except for moisture and ash which are expressed on "as-is" basis.

nutritionally equivalent to the traditional foods. An example of the application of this philosophy is the USDA regulation for meat extenders used in the National School Lunch Program. Specific nutrients (Table E.8) must be added to meat extender so that the final blend of extender and meat will not dilute the nutritive profile of meat alone. Similar proposals for several categories of food have been promulgated by the FDA in the United States (FDA 1974) and specific regulations recently have been issued by the Canadian Government (1974 and 1975). Historically, a number of guidelines for the rationale for nutrient additions have traditionally arisen from the medical and nutrition communities. The Council on Foods and Nutrition of the American Medical Association (1939) began the practice and subsequently several joint statements with the Food and Nutrition Board of the National Research Council were released. The most recent was published in 1973 (AMA 1973). A close examination of these guidelines reveals a concern more applicable to enrichment policy but otherwise concerned with avoiding imbalance and toxicity, and assuring stability and availability. The latter four principles of necessity apply to any nutrient addition.

For a concise discussion of the technology of fortification, the reader should consult Borenstein (1971). An increasing number of nutrients have been added to food products in order to meet specific marketing goals. The products range from those providing complete nutrition (infant formula, adult weight reduction/maintenance or weight gain formulas); meal equivalents products (instant breakfast, mini meal bars, "heat and serve" dinners) and partial meal replacers (e.g., a grain-fruit product which in combination with 8 oz of whole milk provides 25% of the U.S. RDA). These various foods are not readily classified as having undergone restoration, enrichment or fortification. In some instances a product may require the addition of a product (milk) which has already undergone enrichment (vitamin D), or be formulated with "enriched" flour which has undergone restoration, or may include a fortified ingredient in the legal sense, e.g., iodized salt, or a fortified ingredient in the technical sense, e.g., a complimentary protein or amino acid addition, or a fortified meat analog, etc.

NUTRIFICATION

Nutrification is the practice of adding a proportion of all necessary (minimally all U.S. RDA) vitamins and minerals to a formulated or fabricated food, or grouping of foods, marketed as a meal replacer (Lachance 1972). Infant formulas and instant breakfast are good examples. In contrast, ready-to-eat cereal products with added vitamins (even 100% U.S. RDA) are not nutrified but are fortified since the product is: (1) not a sole source of nourishment as packaged; (2) has no rationale for the fortification other than marketing; and (3) the addition of nutrients has no basis in terms of calories or utilizable protein content.

CALORIE VERSUS PROTEIN RATIONALE

Considerable controversy has existed over whether nutrient additions ought to be made in relation to calories or protein content. Nutrients added for public health enrichment have no direct relationship to caloric or protein value, e.g., iodine to salt or vitamin D to milk, but rather the rationale is based on known malnutrition and/or deficiencies in the food supply. Restoration philosophy has similarly evolved, but the restoration level is not set to ameliorate a deficiency syndrome. However, the most recent proposal of the NRC (1974) for cereal grains can be demonstrated to be closely related to protein content. Fortification additions of amino acids are based on protein, and fortification additions of vitamins and minerals for meat analogs, or weaning foods for international relief such as CSM (Corn-Soy-Milk) are based on protein; otherwise the fortification is based on the image of the food, rarely calories. In contrast nutrified food additions are titrated on utilizable protein content rather than calories, since products of varying caloric density are manufactured to meet differing age and physical activity requirements. Further, the role of vitamins and minerals in protein metabolism, as well as the economics and food technology limitations of protein, have been advanced as reasons for titrating on the basis of protein (Lachance 1972). The fact is that protein is also a caloric rationale albeit a more sophisticated one.

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Cross-references: *Food Additives Amendment; Nutritional Needs of Man; Protein-Calorie Malnutrition; L-Ascorbic Acid and Infectious Diseases.*

ENTROPY

The First Law of Thermodynamics has been stated as: "The total amount of energy in nature is constant." The Second Law: "The total amount of *entropy* in nature is increasing." The Third Law: "Every substance has a finite positive *entropy*, but at the absolute zero of temperature, the *entropy* may become zero and does so in the case of a perfect crystalline substance." The occurrence of the term "entropy" in two of the three Laws of thermodynamics may serve to emphasize the fundamental importance of this parameter. Not only has the concept of entropy proven useful in the sciences, it is also found in communication and management theories, theology, and other branches of study. But, little use has been made of entropy in the food science area.

This article will attempt to qualitatively define entropy. Detailed derivations of the laws of thermodynamics can be found in most texts on physical chemistry or thermodynamics. Several such texts are listed in the bibliography and the reader is urged to refer to them. Such reference will show that the property, entropy, is a rigorously derived function of the state of a system.

The entropy of a system is a measure of the disorder of the system. It can be calculated by the equation,

$$S = k \ln W, \qquad (1)$$

where W is the total number of configurations which are compatible with a given macroscopic state, and k is the Boltzman constant.

From Equation (1) it is seen that the entropy of a system can be only positive (never negative) and will be zero only if the system has only one configuration, as in the case of a perfect crystal at absolute zero. (If there is only one configuration, $W = 1$ and $\ln W = 0$.)

Whenever a substance is heated, its entropy will increase, and this is especially so if the heating