Enrichment of Special Dietary Food Products

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Special dietary foods are unique in their use. By definition they are designed to meet specific physiologic states, and in many situations, they may constitute a sole source of nutrient supply. Most special dietary foods are fed to relatively sensitive biological systems as illustrated by the rapidly growing human infant, the pregnant or lactating woman, persons with problems in weight control, or the diabetic. Enrichment of special dietary foods provides many challenging opportunities to the food technologist, nutritionist, and physician. Those associated with this segment of the food industry have been granted a major responsibility and an unusual opportunity to observe critically the outcome of technical advances in this field. Federal regulations should not restrict, through efforts at standardization, research and development in the area of providing nutritionally sound special dietary foods for persons of all ages and physiologic states.

Foods for special dietary use are intended to meet specific physiologic needs. These needs may exist due to pregnancy, lactation, allergic hypersensitivity to food, conditions of overweight or underweight, diabetes mellitus, or the need to control the intake of sodium. In the case of the human infant, these needs exist because formula serves primarily as a sole source of nutrition during the early months of life.

Currently effective federal regulations include foods represented for special dietary use by reason of specific vitamin or mineral content. At the present time, Food and Drug regulations are being revised so that foods designed for use as a complete meal are included within the category of special dietary foods. The new regulations are more specific in terms of labeling requirement, restricting enrichment to specific vitamins and minerals. Levels of nutrient addition are further regulated by age and physiologic states such as pregnancy or lactation.

To qualify a food for calorie-restricted diets, the new regulations require that such foods furnish no more than 50% of the calories supplied by the normal food counterpart. The term "low calorie" is to be restricted to foods containing no more than 15 calories per serving or supplying no more than 30 calories in an average daily consumption. Since most of these foods will contain an artificial sweetener the manufacturer must compare the caloric content of his product with a similar food of equivalent sweetness as provided by added sugar. For purposes of such comparison, 1 gram of cyclamic acid is considered equivalent to the sweetness of 30 grams of sugar and 1 gram of saccharin equivalent to the sweetness of 300 grams of sugar.

Currently effective regulations do not pertain to foods for diabetics. Under the new regulations such foods must be identified, and the label must state the quantity in grams of protein, fat, and carbohydrate, and available calories supplied by 100 grams of such food. The label must further define the sugar equivalent of added artificial sweeteners and the amount of any nonnutritive constituent. Regulations regarding hypoallergenic foods and foods for control of salt intake remain essentially unchanged from existing regulations.

The most disquieting aspect of the new regulations is found in that section of the law, Section 125.2, which deals with general label statements. In the context of the federal regulation, labeling includes information on the food package and promotional or advertising material relating to the product. Under the new regulation a food for special dietary use by reason of its vitamin or mineral property cannot be marketed with the implication that the food is adequate or effective for the treatment, prevention, or mitigation of any disease, condition, or symptom by reason of the presence of vitamins and/or minerals added to such food. Such a food cannot be marketed with the implication that significant segments of the population of the United States suffer or are in danger of suffering from a dietary deficiency of any of these vitamins or minerals.

Furthermore, the new regulation prohibits reference to the potential for a dietary deficiency or threatened dietary deficiency of vitamins and/or minerals owing to possible loss of nutrients by reason of the soil on which the food is grown or the storage, transportation, processing, and cooking of the food.

It seems reasonable to examine infant formula products, foods designed to control sodium intake, and hypoallergenic foods as they may be influenced by and possibly influence the new federal regulations regarding special dietary food products. Current enrichment practices and need for consideration of additional areas for nutrient addition are discussed.

INFANT FORMULA PRODUCTS

Trends. Since 1951 there has been a marked increase in acceptance and use of commercially prepared infant formula products. In 1966, 65% of infants discharged from the hospital were fed prepared formulas. Approximately 20% of infants were breast fed and the remaining 15% received formulas prepared by the mother from evaporated or fluid milk (Figure 1).

Prepared formulas feed the majority of infants through the first 3 months of life (Figure 2). By 4 months of age, 40% of infants are receiving prepared formulas and 40% of

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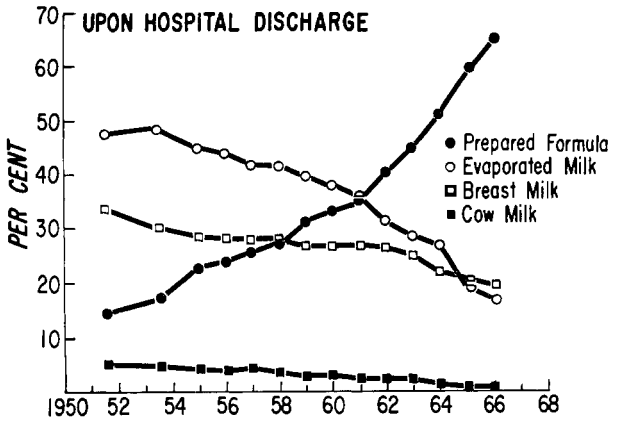

Figure 1. Change since 1951 in method of infant feeding at time of discharge from the hospital

infants are fed fluid milk (Fomon, 1967). At this age, approximately 80% of total daily caloric intake is provided by formula or fluid milk; thus, these foods essentially constitute a sole source of nutrition.

Under such circumstances, it is not difficult to understand why formula-fed infants are potentially vulnerable to nutrient lack or imbalance if the prepared formula or cow milk is deficient in one or more nutrients.

Ascorbic Acid. Prior to 1948, scurvy and megaloblastic anemia were not uncommon among artificially fed infants. This period predated the addition of ascorbic acid to prepared formulas at a level of 50 mg. per quart of formula as fed. With enrichment of prepared formulas with vitamin C and their increased use in infant feeding, scurvy and megaloblastic anemia, the latter secondary to the failure of conversion of folic acid to folinic acid, essentially disappeared as nutritional diseases of infancy. This situation however did not pertain to certain geographic areas of Canada, where prepared formulas containing ascorbic acid were not extensively used. To alleviate scurvy from segments of the Canadian population, it was necessary for the Canadian Food and Drug Directorate to modify the standards of identity as they apply to evaporated milk so that ascorbic acid could be added to this commodity. Since 1965, ascorbic acid may be added to evaporated milk produced in Canada. With this dietary modification, the incidence of scurvy reported in Canada has declined.

In 1939, Levine *et al.* demonstrated incomplete metabolism of aromatic amino acids by premature infants fed

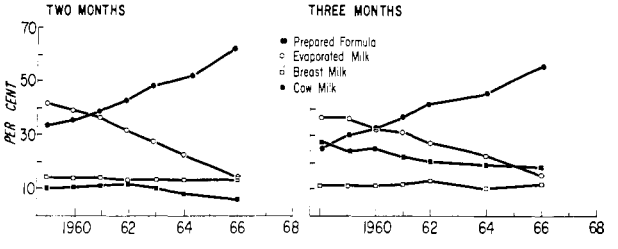

Figure 2. Change since 1959 in method of infant feeding at 2 and 3 months of age

diets high in protein or low in ascorbic acid. Thus the requirement for ascorbic acid during early infancy is dictated in part by dietary level of protein. In 1967, Avery and coworkers described a syndrome, transient hypertyrosinemia of the newborn, which in all instances responds to a reduction in dietary protein and, in some cases, to the administration of increased amounts of ascorbic acid.

Mild tyrosinemia probably occurs in 10% of full term infants during the first week of life with a severe form occurring in 30% of low-birth-weight infants. The lethargy associated with hypertyrosinemia is alleviated whenever ascorbic acid is supplied (Avery *et al.*, 1967).

Tyrosinemia, tyrosyluria, megaloblastic anemia, and scurvy respond to the addition of ascorbic acid to prepared formulas. A minimal level of fortification is probably 50 mg. of ascorbic acid per quart of prepared formula.

Vitamin B_6. In 1953, the processing loss of vitamin B_6 in infant formula products associated with changes in commercial sterilizing practice was linked to a group of infants with convulsive seizures. This nutrient deficit, once recognized, was readily corrected by the addition of pyridoxine hydrochloride to commercial formulas since it is more heat-stable than the natural forms—pyridoxal or pyridoxamine. The Committee on Nutrition of the American Academy of Pediatrics (1966) has recommended that infant formulas provide 20 μg. of vitamin B_6 per gram of dietary protein.

It is difficult to integrate this problem in infant nutrition with the new federal regulations regarding labeling. If in the course of time another essential nutrient is inadvertently lost during processing of a special dietary food and such loss is not uniform throughout all such marketed products, it seems only reasonable that those manufacturers whose products are not adversely effected should have the opportunity and sanction to make a labeling claim. Physicians directing infant feeding are entitled to know these facts. The way should be clear for manufacturers to inform physicians of the potential for nutritional deficiency and at the same time provide reassurance concerning uninvolved products.

Vitamin D. The Committee on Nutrition of the American Academy of Pediatrics (1963) has recommended that vitamin D fortification of fluid milk, evaporated milk, special milk products, and milk substitutes designed for consumption by infants be limited to no more than 400 International Units of vitamin D per quart of fluid milk or formula product when the latter is reconstituted to 20 calories per ounce. Because nonfat dry milk is gaining increasing use as a source of milk for children, this Committee (1967a) recently directed the attention of physicians to the fact that nonfat dry milk does not contain added vitamin D.

Since 1952 the syndrome, infantile hypercalcemia, has been associated with vitamin D intakes in excess of 400 International Units per day. In its mild form, infantile hypercalcemia is characterized by an increase in the calcium concentration of serum, failure to thrive, and mild azotemia. Such findings are reversible whenever intakes of calcium and vitamin D are restricted.

The severe form of infantile hypercalcemia may have its inception in utero. Infants born with severe infantile hypercalcemia have a low mean birth weight, a characteristic

elfin facies, impairment of renal function, mental retardation, hypoplasia of the arterial system, and supravalvular aortic stenosis. The mental retardation, renal and cardiovascular lesions are nonreversible. Association of vitamin D with the pathogenesis of infantile hypercalcemia is based upon epidemiologic evidence largely accumulated in Great Britain and the suggestion that the severe form, which probably arises in utero, represents an excessively sensitive maternal-fetal interaction of vitamin D.

According to Fraser *et al.* (1966), best estimates of the frequency of occurrence of all forms of infantile hypercalcemia is 1 case per 20,000 live births in Great Britain. They estimate that the severe form of the disease occurs approximately once for every 200,000 births in Britain and possibly once per 120,000 births in Canada.

In a recent review of the relation between infantile hypercalcemia and vitamin D, the Committee on Nutrition (1967b) concluded that circumstantial evidence impugned vitamin D in the pathogenesis of the syndrome; however, the results of studies to date are inconsistent enough to preclude a definitive cause and effect relationship.

Since 400 International Units of vitamin D per day amply provides the total vitamin D requirement for normal infants, children, and pregnant women, there is no reason for the normal individual to ingest more than this amount.

From a public health point of view, it should be stressed that the addition of vitamin D to milk products has essentially eliminated rickets in the United States and Great Britain. On the other hand, rickets continues to be seen among infants admitted to hospitals in Canada. In an effort to eliminate infantile rickets, the Canadian Food and Drug Directorate has recently sanctioned the addition of vitamin D to fluid whole milk.

Vitamin D is a potentially toxic substance. In approaching the enrichment of special dietary foods, whether they are infant formula products or complete meals, there is no reason to supply more than the recommended daily dose which is safe and effective (Committee on Nutrition, 1965).

Dale and Lowenberg (1967) have determined the daily consumption of vitamin D for 150 infants and children residing in the Seattle and Everett, Wash., area (Table I). Intakes between 1500 and 2000 units per day were noted in only two subjects, 9 to 14 years of age. Milk was the most uniform and dependable source of vitamin D for all age groups.

Table I. Average Daily Intake and Contributing Sources of Vitamin D in Washington State Values Given in International Units

Age of Subject, Years	Total	Source		
		Vitamins	Milk	Foods[a]
0–1	462	201	257	4
2–5	660	283	309	68
6–8	532	146	280	106
9–11	578	151	276	151
12–14	579	92	308	179
15–17	477	0	367	110
All	547	145	300	102

[a] Other than milk.

Good manufacturing practice with control of "overage" and physician awareness of the total daily intake of vitamin D by his patients will militate against both rickets and infantile hypercalcemia (Forbes, 1967).

Calcium, Phosphorus, and Magnesium. The new federal regulation regarding infant formula products has defined minimum amounts for 17 nutrients that must be provided by the formula. Failure to meet any of these minima will require a label statement directing the physician or consumer to obtain additional quantities of the vitamin or mineral in question from other sources. Under existing regulations, label statements are required only for ascorbic acid, vitamin D, and iron.

It is of interest to examine the new regulation with respect to minima set for daily intakes of calcium, phosphorus, and magnesium and compare these with the intakes of these nutrients as obtained by infants in the United States.

Table II shows that the breast-fed infant does not receive the minimal intakes specified for calcium, phosphorus, and magnesium. Indeed the infant fed fluid milk does not obtain the minimum amount of magnesium per 100 kcal. as required by the new regulation.

Human milk may not provide sufficient phosphorus to meet the growth needs of infants weighing less than 2000 grams (von Sydow, 1946). While Widdowson and McCance (1965) have concluded that the ion limiting skeletal mineralization in the human infant is phosphate, there is sufficient phosphorus in human milk to meet the growth requirement of the term infant.

It seems reasonable to regard the minima set for calcium, phosphorus, and magnesium by the new regulation as disconsonant with infant feeding practice. The minimal level specified for magnesium in the new regulation is obviously overstated. Unless modified this will require a label statement on all formula products derived from cow milk. Fluid milk would also fail to provide the recommended minimal level for magnesium.

Breast-fed term infants are not undermineralized; thus, minimal levels for calcium and phosphorus should relate closely to those levels found in human milk.

Iron. Nutritional iron deficiency is a major public health problem in the United States. While it is primarily regarded as a deficiency state more prevalent among nonwhite infants and infants from a low socioeconomic background, its occurrence is not restricted to major metropolitan areas (Table III).

If the daily requirement for iron during the first year of life ranges from 1.0 to 1.5 mg. per kg. per day a large seg-

Table II. Comparison of Usual Intakes of Calcium, Phosphorus, and Magnesium with FDA Recommended Minimal Values

Nutrient	Feeding, Mg./100 Kcal.			Recommended Minimal Intake, Mg./100 Kcal.
	Human milk	Cow milk	Formula	
Calcium	46	181	99	88
Phosphorus	21	139	77	44
Magnesium	5	17	8	19

Table III. Per Cent Incidence of Anemia among Hospitalized Infants 6 to 24 Months of Age[a]

Hospital	All (Infants)	Race		Classification	
		White	Non-White	Private	Indigent
Children's Hospital, Columbus, Ohio (Shaw and Robertson, 1964)	24.7	21.5	44.1	16.8	40.4
University Hospital, Iowa City, Iowa	21.0	19.5	50.0	14.3	26.1

[a] Hemoglobin 9.9 g./100 ml. or less.

ment of our infant population fails to attain this level of intake. Single-day diet histories from 8000 U.S. mothers of 6-month-old infants indicate that 25% of these infants receive about 50% of their daily iron requirement, Table IV (Filer and Martinez, 1963, 1964).

Unless an infant formula is enriched with iron, the primary source of dietary iron available to the infant is found in iron-fortified infant cereal products. Meat products provide the next best source of iron. At 6 months of age, 70% of calories come from milk or formula products. The infant of this age who is not fed or does not accept iron-enriched cereal products will not obtain dietary iron in any appreciable amount from other solid foods.

Adequate absorption and utilization of iron added to infant formula products has been demonstrated by use of the labeled-tracer technique and clinical studies in infants who have shown a satisfactory hematopoietic response.

Garby and Sjölin (1959), using the labeled-tracer technique, showed that iron is absorbed by infants under 3 months of age at a faster rate than at any other age. Absorption and utilization of labeled iron for hemoglobin synthesis has been demonstrated in low-birth-weight infants by Gorten *et al.* (1963) (Figures 3 and 4) and in low-birth-weight and term infants by Oettinger and co-workers (1954).

Schorr and Radel (1962), Gorten and Cross (1964), and Andelman and Sered (1966) have reported clinical results indicative of the utilization of dietary iron by low-birth-weight and term infants. The incidence of iron deficiency

Table IV. Single-Day Iron Intake[a] of 6-Month-Old Infants, Mg./Day

Sample	Percentile Distribution		
	25	50	75
Total U.S.	4.2	7.2	11.8
Urban	4.7	7.9	12.4
Rural	3.4	6.1	10.7
Education of mothers			
Grade	2.4	4.6	8.6
High	4.3	7.1	11.8
Post-high	5.1	8.2	13.0
Annual income			
Less $4000	3.4	6.0	10.4
$4000–$7000	4.4	7.5	12.2
More $7000	5.2	8.3	12.9

[a] Daily requirement 8 to 12 mg. per day.

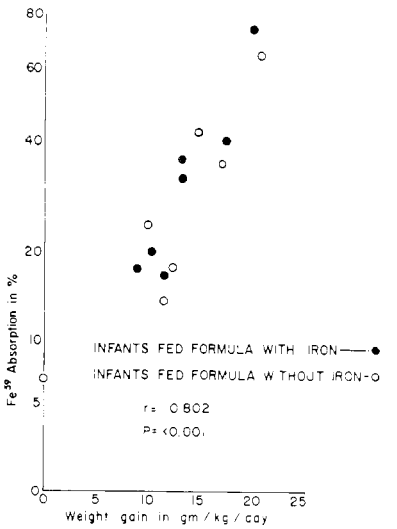

Figure 3. Per cent absorption of Fe^{59} related to incremental weight gain during period of observation

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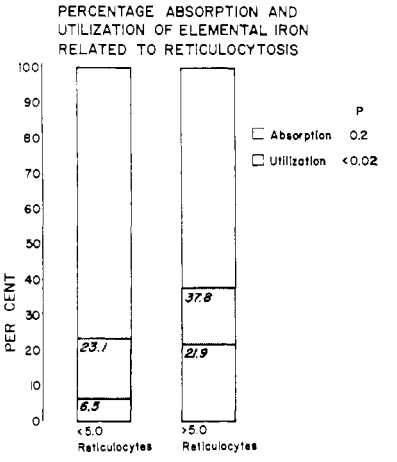

Figure 4. Percentage of iron absorbed and utilized for hemoglobin production by premature infants

Comparison is made between infants with less and those with more than 5% reticulocytosis
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anemia among low-birth-weight infants fed a formula not enriched with iron is 38%. In contrast, the incidence of iron deficiency anemia is 1.7% for a group of low-birth-weight infants fed an iron-containing formula (Table V).

Term infants from Child Welfare Stations in Chicago showed marked differences in serum iron and hemoglobin levels whenever infants fed an iron-containing formula were compared with infants fed a formula to which no iron had been added (Andelman and Sered, 1966). By 1 year of age, 299 or 67% of the latter group of infants developed hemoglobin levels less than 10 grams per 100 ml. Only 4% of the infants fed the iron-containing formula for the first 6 to 9 months of life had low hemoglobin concentrations by 12 months of age. At 18 months of age, the incidence of anemia in these two groups was 76 and 9%, respectively.

Within this context it seems reasonable for the manufacturer of an iron-containing infant formula to inform the physician of the clinical studies and results that support the efficacy of adding iron to formula products. For too many years, physicians have considered milk a poor commodity to enrich with iron and many physicians will not use an iron-containing formula on the basis that iron so supplied is unavailable. Labeling can serve an educational role to physicians and consumers.

Iron added to an infant formula in sufficient concentration can prevent nutritional iron deficiency. When such products are fed to low-birth-weight infants or infants from low socioeconomic groups, nutritional iron deficiency is prevented. The public health aspects of the incidence of this nutritional disease are well recognized, and federal regulations that restrict information of value to those charged with the responsibility of infant care should be challenged. While advertising of special dietary foods can be misleading, efforts to control misrepresentation of fact should not be subject to curtailment by legislative act at the expense of opportunities for the exchange of scientific information.

Table V. Incidence of Nutritional Iron Deficiency Anemia in Low-Birth-Weight Infants

Investigator	Formula	Infants, No.	Birth Weight, Kg.	Infants Developing Anemia, No.
Schorr and Radel, 1962	No Fe	19	1.32	15
	Fe	21	1.35	2
	No Fe	33	2.02	8
	Fe	25	2.05	0
Gorten and Cross, 1964	No Fe	76	1.89	25
	Fe	69	1.84	0
Total	No Fe	128		48 (38%)
	Fe	115		2 (1.7%)

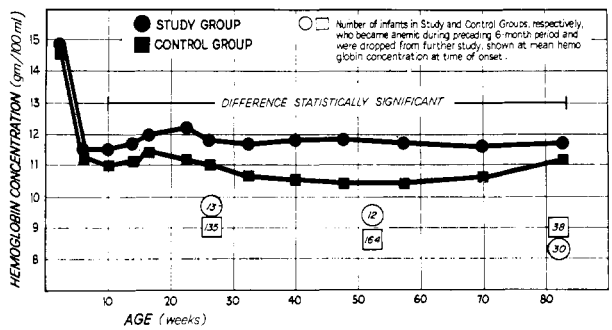

Figure 5. Mean hemoglobin concentration during the first 18 months of life for study group (fed iron-containing formula) and control group (receiving usual diet)

Reprinted by permission of Andelman and Sered (1966)

Zinc. Knowledge of the role of zinc in human nutrition has recently been subject to review by Prasad (1966). Its importance in infant nutrition however has not been adequately defined. Cavell and Widdowson (1964) have reported that breast-fed infants are in negative zinc balance during the first 10 days of life. These investigators have reported no data on the age or conditions under which positive balance is attained. Strain *et al.* (1966) have reported decreasing levels of zinc and iron in human infant hair during the first year of life. This may signify that the infant is prone to develop zinc deficiency in the same manner as he develops iron deficiency. The clinical symptoms of this potential deficiency remain to be determined.

Experimental animals fed diets containing soy protein isolates have an increased requirement for zinc. These observations are of interest in terms of the recent marketing of three hypoallergenic infant formulas prepared from soy protein isolates. Manufacturers of these hypoallergenic infant formulas add zinc at a level of 3 mg. per liter of 20 calories per ounce formula. This concentration of zinc exceeds that found in fluid milk and prepared formulas based on cow milk. Whether this level of addition to a formula prepared from soy protein isolates is sufficient to prevent zinc deficiency is as yet unproved.

FOOD FOR USE IN REGULATING SODIUM INTAKE

The sodium level of many foods can be kept low by avoiding the addition of sodium chloride during processing. However, fluid milk which contains 25 meq. of sodium per liter must be processed to reduce its sodium content. Low sodium milks have gained acceptance and use in regulating the daily sodium intake of many cardiac patients.

Some infants and children with congenital heart disease in congestive heart failure must be restricted in sodium intake. Lonalac, a low sodium, high protein food, contains 1 meq. of sodium and 27 meq. of potassium per quart of formula. It is prepared from casein, which has been precipitated, washed, and solubilized with calcium hydroxide. Since the daily requirement for sodium during the first year of life is estimated at somewhat greater than 2.5 meq., prolonged use of unsupplemented Lonalac may result in sodium deficiency and growth failure (Fomon, 1967).

Fluid milk has been subject to treatment with a cation exchange bed to effect the removal of sodium. Bales *et al.* (1965–66) have described methods for the removal of the radionuclides strontium-90, strontium-85, and iodine-131 from fluid milk on a commercial basis. Chemical analysis and short-term feeding studies of these ion-exchanged milks in rats and miniature pigs have demonstrated no

Table VI. Cesium-137 Content of Infant Formulas

Infant Formula	Protein Source	Cesium-137 pCi/Gram of Potassium
Similac	Cow milk	18
SMA S-26	Electrodialyzed whey	15
SMA S-26	Electrodialyzed whey	10
Similac PM 60/40	Ion-exchanged whey	3
Similac PM 60/40	Ion-exchanged whey	0
Lonalac	Casein-washed	3
Nutramigen	Casein hydrolyzate	6
Mull Soy	Soy	18
Sobee	Soy	13
Soyalac	Soy	10
ProSobee	Soy isolate	4
Isomil	Soy isolate	2
Meat base	Beef	88
Lambase	Lamb	114

nutritional deficiencies (Isaaks *et al.*, 1967, a and b).

By subjecting whey to electrodialysis or ion exchange on a mixed cation-anion bed, it has been possible to remove sufficient cations and anions to yield a demineralized whey that can be utilized for infant formula production upon replacement of specific electrolytes and trace elements. These formulas (SMA S-26 and Similac PM 60/40) provide electrolytes at the level found in human milk. Because these formulas are initially demineralized, radionuclides are effectively removed. This is shown by the data in Table VI where cesium-137 values reflect the efficiency of radionuclide removal. In the production of SMA S-26, some skim milk which has not been demineralized is used. This results in slightly higher levels of radionuclides relative to those products prepared by ion exchange, from casein hydrolyzates or isolates of soy protein.

If one extends the concept of regulating sodium intake to the broader view of regulating radionuclide intake, the processing of milk products to remove multiple cations and anions creates enrichment problems in essential nutrients that require more investigational effort.

HYPOALLERGENIC FOODS

Infant formula products designed for use as hypoallergenic foods based upon soy protein isolates are lower in content of radionuclides than hypoallergenic formulas prepared from soy flour (Table VI). Use of soy isolates in infant feeding provides the same challenge of determining those trace elements needed for enrichment that is provided by milk processed for the removal of cations and anions.

Within this context, serious consideration must be given to federal regulations as they relate to the addition of fluoride to foods. If fluoride is considered to be an essential nutrient preventing osteoporosis and dental caries, the need for fluoride enrichment of highly processed foods that may be consumed by infants independent of communal waters containing added fluoride must be explored.

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End of Symposium