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RECENT TRENDS IN CARBOHYDRATE CONSUMPTION

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INTRODUCTION

The amount and type of carbohydrate consumed by a specified population group is related to degree of affluence. As may be seen from Figure 1, much of the world's population subsists on diets providing 75–80% of energy from carbohydrate. As per capita income increases, less carbohydrate is eaten and the ratio of complex carbohydrates to simple sugars also decreases. Composition of the various dietary carbohydrates is influenced by the sophistication of food technology and marketing.

In the national food supply carbohydrate currently contributes 45%, fat 43%, and protein 12% of the energy content (27), whereas in 1909 the comparable percentages were 56%, 32%, and 12%, respectively (14). As is discussed below, the Dietary Goals (59) published by a Senate committee in 1977 suggested a return to a diet containing greater amounts of complex carbohydrate and less refined sugar and fat. The Dietary Goals provided the basis for negotiations resulting in the joint issuance by the Departments of Agriculture and Health, Education and Welfare (now Health and Human Services) of the Dietary Guidelines for Americans (68). Much controversy

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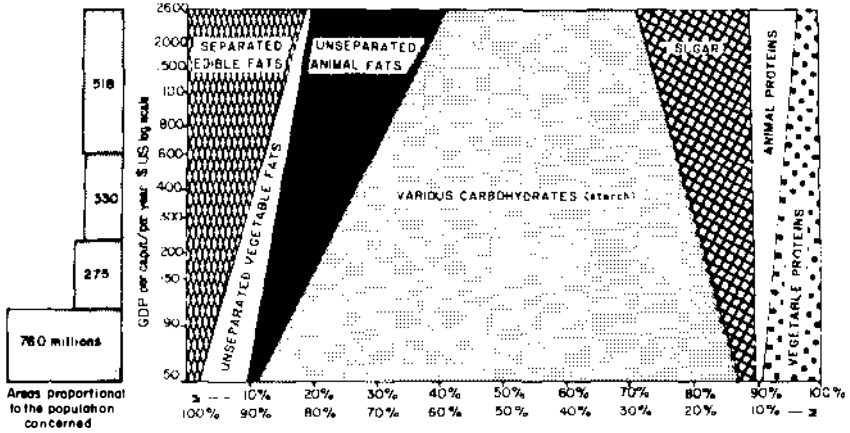

Figure 1 Calories derived from fats, carbohydrates, and proteins as percentage of total calories according to the income of the countries (1962) (correlation based on 85 countries) (38).

has surrounded the publication of both the Dietary Goals and the Dietary Guidelines. The seven recommendations included in the Dietary Guidelines concerned the need to eat a variety of foods; maintenance of ideal body weight; avoidance of excessive intakes of saturated fat, cholesterol, sugar, sodium, and alcohol; and encouragement of increased intakes of complex carbohydrates and fiber. Future trends in carbohydrate consumption would probably have been influenced by the continued promotion of these dietary guidelines; however, free distribution of the recommendations was sharply curtailed in the spring of 1981 because of budget cutbacks and a decision to reduce direct federal involvement in human nutrition. The impact of the dietary guidelines and the subsequent controversy upon intake of various carbohydrates by the American consumer is not known.

Because of the importance of nutrient interaction, one cannot discuss the health aspects of consuming a particular mix of carbohydrates without some consideration of the influence of other dietary components. The quantities of carbohydrate in a "typical American diet" may not be conducive to prevention of the nutrition-related degenerative diseases of greatest public health significance (59, 10, 63, 20), especially in view of the relatively high intake of saturated fat. However, a number of nutritionists doubt that changing the composition of the current US diet would significantly alter the prevalence of coronary heart disease, hypertension, or diabetes (3, 13, 19, 18).

The composition of dietary carbohydrate in the present-day US diet is influenced by a number of factors, some of which are not directly controlled by the consumer. This is true particularly of the technologic and economic

considerations that determine the type and amount of sweeteners added to processed foods.

LIMITATIONS IN ESTIMATING INTAKE OF SPECIFIC CARBOHYDRATES

Sources of Data

Obtaining accurate estimates of intake of various foods and determining specific nutrient content of foods selected from a complex and continually changing food supply are not easy tasks. Application of appropriate sampling statistics, interviewer techniques, and computerized data banks of food ingredient and nutrient content is required.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA) ECONOMIC RESEARCH SERVICE (ERS) The USDA-ERS compiles annual per capita consumption data for approximately 350 foods and for major food categories. These data are derived by dividing estimates of food "disappearance" into civilian wholesale distribution channels by the total civilian population (21). Such disappearance data include food consumed in homes, in eating places, and as snacks purchased from retail stores and vending machines, as well as foods wasted in these places, lost in distribution, used in feeding pets, or put to other uses. Estimates of consumption are likely to be exaggerated for all foods, but particularly for those most subject to these latter considerations.

Year-to-year comparison of these data provides useful information about average per capita consumption at one time and in establishing trends in consumption over a period of time. They do not tell us what people actually eat nor do they provide insight into age, sex, income, or geographic differences in average per capita consumption of various foods.

USDA-AGRICULTURAL RESEARCH SERVICE (ARS) The USDA-ARS has over the past 40 years conducted large-scale surveys of household food consumption in a representative sample of the US population and, in 1965 (65) and 1977 (66), has surveyed individual food consumption during a 24-hr period. (The current designation for the agency responsible for collection and analysis of these data is Human Nutrition Information Service, Consumer Nutrition Center.) Household food consumption data on quantities of foods used during a specified period are in general agreement with USDA-ERS estimates of per capita food consumption. Nutrient intake has been calculated from the data collected.

Surveys of food consumption by individuals permit inferences about average consumption by the total sample and also by users of a specific food.

From these data it is possible to evaluate various demographic and socioeconomic characteristics of food intake by individuals. Burk & Pao (5) have reviewed the methodology used in large scale surveys of household food procurement and individual diets.

SURVEY OF GENERALLY RECOGNIZED AS SAFE (GRAS) SUBSTANCES A subcommittee of the National Research Council, National Academy of Sciences, sent questionnaires to food manufacturers inquiring about the usual and maximum usage levels of GRAS substances added to processed foods (33). Possible human intake of these substances was estimated using Market Research Corporation of America records of frequency of consumption of various food items and USDA data on sizes of meal portions of these foods. Many assumptions were made that resulted often in overstating intakes. In 1972, the Food and Drug Administration (FDA) entered into a contract with the Federation of American Societies for Experimental Biology (FASEB) to conduct an evaluation of the health aspects associated with the use of GRAS food ingredients. This evaluation was conducted by the Select Committee on GRAS Substances (SCOGS). A summary of the problems surrounding consideration of the safety of GRAS substances used in foods has been prepared by SCOGS (56).

THE HEALTH AND NUTRITION EXAMINATION SURVEY (HANES) 1971–74 HANES includes findings on dietary intake of calories and selected nutrients based on a recall of food consumption over a 24-hr period (1). A probability sample of the US population 1–74 years of age provided dietary intake data by age, sex, race, and income level.

TEN-STATE NUTRITION SURVEY 1968–70 The dietary component of the Ten-State Nutrition Survey 1968–70 (7) provided data on 24-hr recall of food consumption for selected subsamples of the US population and for households in five states with relatively low per capita income and five states with higher per capita income. A series of standards were developed to evaluate dietary intake by various age groups.

PRESCHOOL NUTRITION SURVEY 1968–70 The Preschool Nutrition Survey 1968–70 (36) provided data on nutritional status of a probability sample of preschool children in the United States. A two-day record of food intake was collected in the home by trained interviewers. Information on food habits and methods of food preparation was also compiled.

FDA TOTAL DIET STUDY For the past 20 years estimates of pesticide, heavy metal, and radionuclide content of the total diet have been based on

the collection of 117 foods divided into twelve composites for analysis. In 1974, the 20 collections, representing adult food intake, were increased to 30 with the addition of 10 collections representative of infant and toddler food intake. Analysis of selected minerals was also initiated at that time. Recent changes in the program have reduced the number of collections to 4, but sampling will include separate analysis of 234 foods (37).

TRADE ASSOCIATIONS Per capita consumption and sales figures for specific foods and food ingredients are prepared by a wide variety of trade associations. These reports are sometimes published in trade journals and occasionally in the scientific literature, but many are unpublished.

Estimates of Intakes

Reasonably accurate per capita estimates of consumption of a specific unprocessed food (e.g. potatoes) or of a broad group of foods (e.g. grain products) can be obtained through the use of disappearance data. Trends in per capita consumption of these foods can also be evaluated with reasonable accuracy.

The 24-hr recall method of estimating intake of specific foods has proven useful in arriving at intake estimates for groups of people but has limited accuracy in providing information about usual intakes of individuals since the period over which the interview was conducted may have been atypical. Because individuals eat less than their usual intake one half of the time, dietary surveys consistently overestimate inadequate intakes of certain nutrients that may not be consumed each day.

Accurate estimates of intake of specific carbohydrates are further complicated by the high percentage of total food intake consumed away from the home and in the form of processed foods. The recollection that a piece of coffeecake was consumed at breakfast does not reveal much about specific carbohydrate content. The product is likely to contain lactose, starch, and one or more sweeteners but the amounts cannot usually be determined from information supplied by the manufacturer or food service. Some carbohydrate ingredients, such as sugar used in yeast doughs, are changed or lost during processing.

Analytical Data

In the traditional proximate analysis of a food (22) carbohydrate content is estimated by difference after water, ether extract, crude protein, ash, and crude fiber contents have been determined. It is now recognized that the crude fiber determination dissolves significant amounts of cellulose, hemicellulose, and lignin (72), thus underestimating fiber and overestimating carbohydrate content calculated by difference. Further inaccuracies can

arise if nitrogen-containing carbohydrates contribute to estimates of protein when nitrogen is determined and the factor N X 6.25 is utilized, or if carbohydrates present in glycolipids are calculated as part of ether extract.

Identification of specific carbohydrates contained in a food requires the application of sophisticated chemical, biochemical, or physical methods (41). Relatively few foods have been analyzed in this fashion, and most data banks do not contain accurate data on the carbohydrate content of foods.

The reducing properties of saccharides are often used to estimate sugar content of a food. Jenness (23) points out that analysis of milk lactose content usually represents the sum of the actual lactose and the lactose equivalent of the reducing power of the oligosaccharides. A human milk sample reported to contain 7 gm of lactose per 100 ml might actually contain 6.5 gm lactose and 1 gm of oligosaccharides with an average size of tetrasaccharides and reducing power equivalent to about 0.5 gm of lactose. Thus this chemical method is of limited usefulness in analyzing for specific sugars.

TRENDS IN CONSUMPTION OF SPECIFIC CLASSES OF CARBOHYDRATES

Carbohydrates are among the most important structural components of plants and are a major contributor to the energy stored in seeds and tubers. Although carbohydrates are present in lower concentrations in animal tissue, they are ubiquitous constituents of most mammalian milks and in various substituted forms are present in all cell membranes, ground substance, connective tissue, nucleic acids, and in many enzymes and hormones.

The food industry utilizes many purified and chemically modified carbohydrates that have been extracted from natural sources. Many of these are added to foods for their functional characteristics rather than their nutritional value.

In nature, carbohydrates exist in many stereo configurations and structural forms that may be significantly altered during food processing and storage or during isolation and purification processes. Therefore, trends in consumption of naturally occurring carbohydrates will be considered separately from those in consumption of refined, processed carbohydrates added to foods. Carbohydrates may be classified into three major groups—monosaccharides, oligosaccharides (carbohydrates that upon hydrolysis yield 2–15 monosaccharides), and polysaccharides. In the following discussion, naturally occurring substituted carbohydrates are treated as a separate class.

Naturally Occurring Carbohydrates

MONOSACCHARIDES Although at least 200 different monosaccharides are known to occur in nature, relatively few are of dietary significance. Those of greatest nutritional importance are aldoses (e.g. glucose, galactose, mannose, xylose) or ketoses (e.g. fructose) containing five or six carbon atoms. Glucose and fructose, the two most abundant naturally occurring monosaccharides, contributed an estimated 9.4% of total sugar content of the food supply in 1970 and 20.2% in 1980 (Table 1). The marked increase in consumption of these two sugars during the past ten years is the result of increased use of various forms of corn sweeteners. Fruits are generally thought to provide the greatest concentrations of naturally occurring glucose and fructose, but as indicated in Table 2, certain vegetables such as carrots, squash, and snap beans also provide substantial amounts.

Polyhydroxy alcohols may be formed by reduction of monosaccharides: xylitol from xylose, sorbitol from glucose or fructose, and mannitol from mannose or fructose. These sugar alcohols are widely distributed in fruits, berries, and mushrooms and are of interest because of their sweet taste, relatively low cariogenicity, and such functional characteristics as moisturizing, texturizing, and dispersing.

OLIGOSACCHARIDES Lactose and sucrose are the major dietary disaccharides, contributing approximately equally to the intake of naturally occurring sugars (26). Dairy products and fruits, respectively, are the principal sources of these carbohydrates in their naturally occurring form. Lactose is the most important dietary carbohydrate during early infancy for breast-fed infants and those fed milk-based formulas. In children 5–12 years of age Morgan & Zabik (32) reported that milk provides approximately 20% of total sugar intake.

Table 1 Sugars in the US food supply, selected years[a]

	Total sugars (gm/day)	Individual sugars (%)					
		Fructose	Glucose	Lactose	Maltose	Sucrose	Unclassified
1909–1913	157	4.0	3.5	13.5	1.1	64.8	13.1
1950	197	2.4	5.5	14.1	1.5	63.6	12.9
1960	192	2.5	5.4	14.4	1.7	62.8	13.2
1970	204	2.4	7.0	12.5	2.8	61.8	13.5
1980[b]	214	7.4	12.8	10.3	3.5	51.2	14.8

[a]Prepared by R. M. Marston, Home Economist, US Dept. Agriculture, Human Nutrition Information Service, Consumer Nutrition Center, Hyattsville, MD 20782. Personal communication. 1981.
[b]Preliminary.

Table 2 Free sugars in foods[a]

Foods	Total solids (%)	Sugar content of food (% of total solids)					
		Glucose	Fructose	Sucrose	Maltose	Raffinose	Stachyose
Fruits							
Apple	15.96	7.3	37.8	23.7			
Apricot	14.44	12.0	8.9	40.4			
Peach	12.79	7.1	9.2	54.1	0.9		
Pear	13.58	7.0	49.9	11.9	2.3		
Plum	17.97	19.4	8.5	27.5	0.8		
Vegetables							
Beet	11.19	1.6	1.4	54.6			
Carrot	12.00	7.1	7.1	35.3			
Sweet Corn	22.69	1.5	1.4	13.4			
Squash (winter)	13.08	7.3	8.9	12.3			
Sweet potato	22.53	1.5	1.3	15.0			
Legumes							
Lima bean	26.74	0.1	0.3	9.7		2.5	2.2
Snap bean	7.79	13.9	15.4	3.2		1.4	2.4
Pea (Alaska)	25.54		0.3	11.7		0.2	0.2

[a] Adapted from (60).

The marked decline in lactose in the US food supply over the past 20 years (Table 1) reflects reduced milk consumption. Per capita yearly consumption of yogurt has increased ten-fold over the past 20 years, from 0.26 lbs/capita in 1960 to 2.59 lbs/capita in 1979. Yearly per capita consumption of cheese has doubled over this same time interval (8.2 lbs to 17.5 lbs). However, increased intakes of reduced fat milks, yogurt, and cheese (29) have not compensated entirely for the decline in whole fluid milk intake.

The reduction in sucrose in the food supply over the past ten years is mostly due to its replacement by corn sweeteners (Table 1). The percentage of sucrose from natural sources has undoubtedly increased because of this shift in usage. The increased content of maltose in the food supply is also the result of increased use of corn sweeteners.

Approximately 85% of the total sugars in the food supply can be characterized as specific mono- and disaccharides. The remaining 15% remain unclassified because of inadequate information about the specific sugars present in foods known to contain simple carbohydrates.

The trisaccharide, raffinose, and the tetrasaccharide, stachyose, are components of legumes (Table 2); hence, dietary intake is dependent upon intake of legumes. Metabolism of tri- and tetrasaccharides by colonic bacteria contributes to the flatulence often associated with consumption of legumes (11).

The remarkable resurgence of interest in breast feeding in the United States (28) has resulted in a change in oligosaccharide intake by nursing infants. Human milk oligosaccharides have not been precisely quantitated;

however, the concentration of larger oligosaccharides (penta- to tetradecasaccharides) may range from 40–200 mg/100 ml (15, 31) and that of tri- and tetrasaccharides is as high as 1 g/100 ml in mature milk and 2.5 g/100 ml in colostrum (31). The concentration of oligosaccharides in cow milk is only about 100 mg/100 ml (30) and hence the intake of formula-fed infants is much lower than that of breast-fed infants.

POLYSACCHARIDES Cellulose is the most ubiquitous polysaccharide in nature, but its dietary significance, and that of other components of dietary fiber (hemicellulose, gums, mucilages, pectins) in man is largely limited to its effects on gastrointestinal motility, absorption of nutrients, and gut microflora. Amylose and amylopectin are the two forms of starch that occur widely as the reserve carbohydrate of tubers, seeds, grains, and many fruits. Since the beginning of record keeping by the USDA in 1909, the amount of these polysaccharides in the food supply has decreased approximately 30%, largely due to decreased intake of potatoes and grain products (14).

Most animal cells contain glycogen—i.e. glucose polymers in chains that are more highly branched than those of amylopectin. Although approximately 70% of the protein in the food supply is obtained from animal sources (14), glycogen does not provide a significant contribution to dietary polysaccharide intake, partly because most animals are killed in the fasted state, resulting in relatively low glycogen content of muscle; and liver, the organ with the highest glycogen content, is not a widely consumed food item.

SUBSTITUTED CARBOHYDRATES A wide variety of carbohydrates are found as components of glycoproteins, glycolipids, mucopolysaccharides, DNA, and RNA. These sugars may be aminated, N-acetylated, carboxylated, methoxylated, or substituted by other groups such as sulfate or phosphate. A nine-carbon straight-chain sugar, neuraminic acid and its N-acetylated derivative, sialic acid, are also important cell constituents. Cell-membrane carbohydrates in the form of glycoproteins and glycolipids are thought to be involved in cellular adhesion and recognition (40). Excellent reviews of the biochemistry of glycoproteins (61) and of glycolipids (12) are available.

The monosaccharide ribose and its deoxy derivative make up approximately one third of the RNA and DNA molecules. Thus carbohydrate is centrally involved in the genetic expression and protein metabolism of every cell.

Little is known about the intestinal absorption and subsequent metabolism of substituted carbohydrates. Pectin, a methoxylated polygalacturonic acid, is not thought to be absorbed by man, although it can influence the

absorption of various nutrients (e.g. cholesterol, iron). Glucosamine is estimated to represent approximately 9% of the nonprotein nitrogen in human milk, but its metabolic fate is unknown (17). Nitrogen-containing oligosaccharides in human milk are believed to be part of the bifidus factor (16) responsible for the fact that the gut microflora of breast-fed infants are predominantly lactobacilli, whereas *E. coli* is the dominant bacterial species in the gut of formula-fed infants.

Substituted carbohydrates do not make up a significant percentage of total carbohydrate intake, but their presence in the diet is important because of their influence on various physiologic processes.

Refined Carbohydrates Added to Foods

When carbohydrates are added to foods they are commonly purified, partially digested, or modified in some manner to influence appearance, taste, or functional properties. Sucrose, corn starch hydrolysates, and substituted and nonsubstituted carbohydrates in semipurified form are referred to as refined carbohydrates.

SUCROSE Extraction and purification of sucrose from sugar cane or sugar beet involve complex chemical processes resulting in a crystalline product of high purity. From data presented in Table 3 it is apparent that sucrose

Table 3 Sweetener composition (67)

Sweetener	Yearly per capita consumption of caloric and noncaloric sweeteners (lbs.)			
	1960	1970	1980	1990[a, b]
Sucrose	98	102	86	74
Corn sweeteners				
dextrose	4	5	4	4
corn syrup	8	13	18	21
high-fructose corn syrup		1	19	37
Total	12	19	41	62
Minor caloric[c]	2	1	1	
Total	112	122	128	136
Noncaloric sweeteners[d]	2	6	7	

[a] S. Kolodny, Vice President, Economic Research, American Sugar Division, Amstar Corporation, 1251 Avenue of the Americas, New York, NY 10020. Personal communication to L. J. Filer, Jr., University of Iowa, 1980.
[b] Estimate.
[c] Includes honey and other syrups.
[d] Sugar sweetness equivalent—assumes saccharin is 300 times as sweet as sugar and cyclamate is 30 times as sweet as sugar. Cyclamate food use was banned by FDA effective in 1970.

currently provides approximately two thirds of the total refined caloric sweetener intake. Its contribution has declined over the past 20 years and is expected to decline further during the next 10 years because of the greater market share of various forms of corn sweeteners.

Substantial controversy exists regarding effects of the intake of so-called "empty calories" in the form of sucrose on the dietary habits and nutritional status of children. Sucrose is no longer added to strained fruits and fruit juices produced by the manufacturers of baby food in the United States, and other food processors have reduced use of sugar in their products largely in response to greater consumer interest in lower calorie foods.

LACTOSE Purified forms of lactose are used in a wide variety of food products. Commercially prepared milk-based infant formulas provide more than one half of the carbohydrate in the form of added lactose. The addition of fat-free milk solids to low fat milks serves as a source of added lactose for other age groups.

CORN SWEETENERS Acid and/or enzymatic hydrolysis of corn starch yields a broad range of compounds with varying degrees of sweetness. Sweetness of corn starch hydrolysates increases with the completeness of hydrolysis. Changes in the mono- and oligosaccharide content of a corn syrup that occur as hydrolysis of the starch becomes more complete are shown in Figure 2. Because fructose is sweeter than sucrose, the production of high-fructose corn syrups, through the action of glucose isomerase on corn starch hydrolysates, has increased markedly during the past ten years (Table 3). It is projected that by 1990 corn sweeteners will provide approximately 45% of total refined caloric sweetener intake.

MODIFIED FOOD STARCHES Starches that have been oxidized, acid hydrolyzed, gelatinized, or chemically cross-linked and/or stabilized are known as modified food starches. Many such starches exhibit properties desirable in food processing. Most of these starches are derived from corn but some are from wheat, milo, or tapioca. Waxy corn and milo are genetic variants composed almost entirely of amylopectin, whereas the starch from normal cereal grains is composed of 15–30% amylose with the remainder amylopectin. In 1971, modified food starches accounted for approximately one half of the total starch used by food processors (58).

A number of questions have been raised about the safety of adding modified starches to foods. Certain of the reagents that were at one time used in the process of modifying starches were demonstrated to be mutagenic in tests with microorganisms or carcinogenic in tests with rodents (70). Modified starches prepared with these reagents, although not demonstrated to be mutagenic or carcinogenic for any organism, are no longer

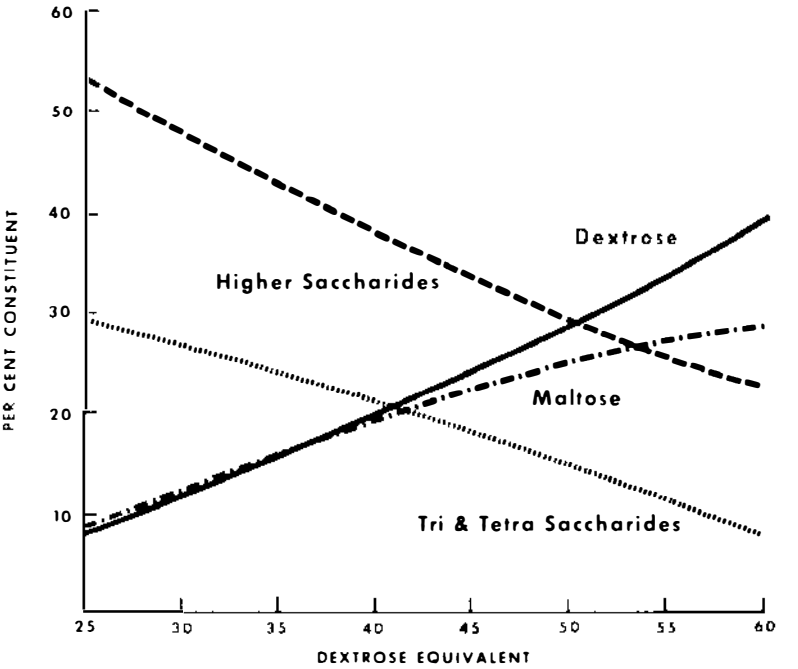

Figure 2 Percentage of higher saccharides, tri- and tetrasaccharides, maltose, and glucose in acid-hydrolyzed corn syrup with dextrose equivalency from 25 to 60 (35).

used in foods. In 1978, the Committee on Nutrition of the American Academy of Pediatrics (8) concluded that use of modified food starch then used in infant foods was justified, that their use was not associated with clinical problems, and that they did not appear to interfere with the bioavailability of trace elements. However, the subsequent opinion of SCOGS was more cautious, concluding that additional data on safety of a number of these modified starches would be desirable (58).

MISCELLANEOUS CARBOHYDRATES A wide variety of other purified and semipurified carbohydrates are added to foods, usually for organoleptic purposes unrelated to the nutritional value of the product. Estimated intake of several carbohydrates listed as GRAS substances is shown in Table 4. Although total intake of these compounds is not great when expressed as a percentage of total carbohydrate intake, the statistic of interest is the increase in estimated usage of several of these carbohydrates during the past ten years.

Increased usage of sorbitol and mannitol is associated with their relatively low cariogenicity and their desirable functional characteristics in food processing. Various forms of cellulose are added to low-calorie foods, ice

Table 4 Estimated yearly per capita intake of selected GRAS food substances

	SCOGS estimated yearly intake (g)	Increase in food use 1970:1960	Reference
Gums	87	3	42, 43, 46, 47, 48, 49, 54
Agar agar	1	2	51
Carageenan	11	2	50
Alginates	5	—	52
Pectin	18	—	57
Sorbitol	29	7	44
Mannitol	7	10	45
Dextrins	66	—	55
Cellulose	18	7	53
Modified food starches	254	—	58

cream, and to those foods with artificially increased amounts of dietary fiber.

EFFECT OF FOOD PROCESSING ON CARBOHYDRATE

Carbohydrates present in fresh, unprocessed foods may be significantly altered in chemical structure and digestibility by processing and/or storage. Changes due to storage may be demonstrated by the reduction of sweetness of sweet corn as the simple sugars present at the time of picking are enzymatically converted to starch. The ripening process of fruits results in accumulation of simple sugars and of the esters that provide the distinctive aroma and flavor of the mature fruit.

The "shelf life" of processed foods is influenced by many factors. Staling of baked goods results from complex changes in degree of hydration of carbohydrates as well as from their interaction with other ingredients. Rate of staling can be inhibited through the use of a wide variety of food additives (56). Carbohydrates in acidic processed foods may be changed after prolonged storage into dehydration, condensation, or fragmentation compounds that differ markedly from the starting ingredients (60).

Maillard Reaction

The nonenzymatic browning (Maillard) reaction (39) is important in the production of desirable colors and flavors in baked goods. This reaction

occurs through the complexing of reducing sugars with free amino groups present in amino acids and proteins. The brown color of bread crust, breakfast cereals, and other baked products is associated with a decrease in the bioavailability of the amino acids (usually lysine) involved in the reaction. One might anticipate that this reaction would occur more readily in processed foods containing corn sweeteners as a replacement for sucrose.

Lactulose

The synthetic disaccharide, lactulose, consisting of one galactose and one fructose moiety, is formed in commercial processing of cow milk by the alkaline enolization of the glucose moiety of lactose to fructose. Human subjects have no disaccharidase that will split lactulose, and its effect on the gastrointestinal tract of a normal individual is therefore similar to that of lactose consumed by a lactase-deficient individual.

Lactulose is known to exert a laxative effect if given in sufficient quantity (6). Presumably the laxative action is mediated through the osmotic properties of the molecule when it reaches the colon and through the products of bacterial degradation of the molecule. Lactulose has been utilized as a therapeutic agent in reducing the extent of hyperammonemia in portal-systemic encephalopathy (9). Adachi & Patton (2) have reported that the lactulose content of evaporated milk may be as high as 940 mg/100 ml.

CARBOHYDRATE INTAKE—DIETARY SIGNIFICANCE

The trend has been toward decreased intakes of total carbohydrate, starch, and naturally occurring sugars (particularly lactose) and increased intakes of refined sugars (particularly in the form of corn sweeteners). The public health significance of these changes in carbohydrate usage has been hotly debated among nutritionists, dietitians, food technologists, and consumer groups. At one extreme are those who maintain that no national food supply has ever provided more variety, greater safety, or better nutrition than ours, and who cite statistical evidence of improved general health and increased longevity. According to this group, health is achieved by selecting a wide variety of foods to assure a nutritionally adequate diet and by avoiding excess energy intake (13).

This optimistic appraisal of the current food supply and the ability of the average American to make wise food choices is not accepted by many nutritionists and consumer groups. Concern is expressed that the food industry is producing foods containing empty calories and additives of questionable safety, formulated with little attention to nutritional value.

A report has been issued by a Task Force evaluating the evidence relating six dietary factors to the nation's health (71). One of the Consensus Statements dealt with the relationships between carbohydrate intake and disease

(4), noting no evidence that (*a*) the body can somehow distinguish a glucose molecule obtained from the digestion of starch from that obtained from digestion of simple sugars, (*b*) the body can distinguish a sucrose molecule obtained from fruit from that obtained from table sugar, (*c*) complex carbohydrates and "naturally occurring" sugars contain components that are missing from refined sugars and that either prevent deficiency disorders or are otherwise beneficial to health, and (*d*) refined sugars may contain harmful substances or lead to harmful effects when consumed in relatively large quantities. The Consensus Statement also found little proof that sugar consumption is associated with any health hazard except dental caries.

Although dental caries is not a nutritional disease per se, it is a major public health problem and should not be viewed with the laissez-faire attitude so common among nutritionists. The Preschool Nutrition Survey (36) found an average of 5.8 defective tooth surfaces in white children and 8.5 such tooth surfaces in black children between five and six years of age. Among persons 45–64 years old the combined effects of dental caries and periodontal disease have produced an adult population 37% of whom are edentulous in one or both dental arches (69).

The high incidence of dental caries among the US population almost suggests that this major public health problem is accepted as an inevitable consequence of eating. Insufficient effort has been devoted toward increasing awareness that occurrence of dental caries is increased by the frequent consumption throughout the day of sweet food retained in the mouth long enough to reduce pH below the point where enamel demineralization occurs.

Trends in consumption of various carbohydrates have been accompanied by many other changes in composition of the food supply and in eating habits. Since the period 1909–1913 the percentage of calories in the US diet provided from fat has increased while the contribution of carbohydrate to total caloric intake has decreased (14). Traditional family meals have been replaced, in part, by between-meal snacks and by meals eaten away from the home.

As shown in Table 5, total sucrose intake obtained through household use in 1980 was only 25% compared to 68% in 1909–1913. The decrease in sugar used in the household would be even greater if the contribution of corn sweeteners were included (i.e. expressed as a percentage of total refined sugars) in Table 5. The net result of decreased household use of sugar is that more than 75% of sugar usage can be controlled only by the decision not to purchase a food item to which sugar has been added.

The increasing consumption of sugar-containing beverages (Table 6) has led to an increased intake of sucrose from this source (Table 5) and increased intakes of various corn sweeteners. These figures represent disappearance intake, and since some individuals consume no soft drinks, others

Table 5 Refined sucrose usage (% of total)[a]

	Household use	Processed foods	Beverages	Other[b]
1909–1913	68	21	5	6
1950	39	41	11	9
1960	34	43	14	9
1970	25	47	24	4
1980[c]	25	43	28	4

[a] Prepared by R. M. Marston, Home Economist, US Dept. Agriculture, Human Nutrition Information Service, Consumer Nutrition Center, Hyattsville, MD 20782. Personal communication. 1981.
[b] Includes use by eating and drinking places, institutions, and the military.
[c] Preliminary.

must consume large quantities. In one day in Spring 1977 (66) 40% of 1–2-year-old children surveyed consumed soft drinks with an average intake of 9 oz/day (272 12-oz containers per year). Average daily soft drink consumption for all children (users and non-users) in this age group was about 3.5 oz. Surveys by the USDA (64) indicate that in the highest consumption category, 10% of the people consume 1.5–3.5 times as much as the remaining 90%. Even if concern is limited to that 1% of the population with greatest intakes of a particular food, more than 2.25 million individuals are involved.

Increasingly sophisticated technology in food processing has resulted in use of semipurified ingredients to produce novel organoleptic qualities. As these foods have gained greater consumer acceptance, dietary fiber content of the food supply has been reduced by approximately one third since 1909–1913. (14).

The factors contributing to development of food habits have been little studied. It is generally assumed that food habits are formed early in life and once formed are difficult to change. If these assumptions are correct, guidance in use of sweetened foods must be provided during early life. Younger age groups have higher than average intakes of cariogenic foods (24).

Table 6 Estimated annual per capita consumption of soft drinks (34)

Year	Per capita (12-oz. containers)
1909	11
1950	105
1960	128
1970	242
1980	410

A comparatively recent influence in shaping food habits has been the advertising of foods on television. Manoff (25) has estimated that more than 50% of the money spent on television food advertising concerns foods that have known or potential adverse effects on health. Over 50% of the total advertising expenditure during one weekend on four Chicago television stations in 1975 was devoted to promotion of nonnutritive beverages (59).

Many social factors influence wise selection of nutritious foods from an abundant food supply composed of a high percentage of continually changing processed foods. New product development often emphasizes convenience and unique organoleptic properties. Product proliferation quickly occurs when a new food gains consumer acceptance. Food advertising often appears to be weighted toward those products providing perceived advantages other than nutritional value. With respect to consumer economics, almost 30% of the adult population are functionally illiterate (59). Clearly, intelligent use of the vast array of foods produced by the food industry requires a degree of knowledge that may not be currently possessed by a significant portion of the population.

Figure 3 illustrates the 70-year trend in consumption of various carbohydrates. The increase in percentage of total carbohydrate provided by sugars has been accompanied by an increase in refined, processed sugar intake and a decrease in sugar obtained from naturally occurring sources. Increased use of sugar has been associated with increased consumption of soft drinks and low-fiber snack foods.

A pattern of dietary carbohydrate consumption similar to that of the period 1909–1913 has been proposed as part of the controversial Dietary Goals (Figure 3). Such a pattern would require foods to be less highly processed and of higher fiber content, and soft drink consumption to de-

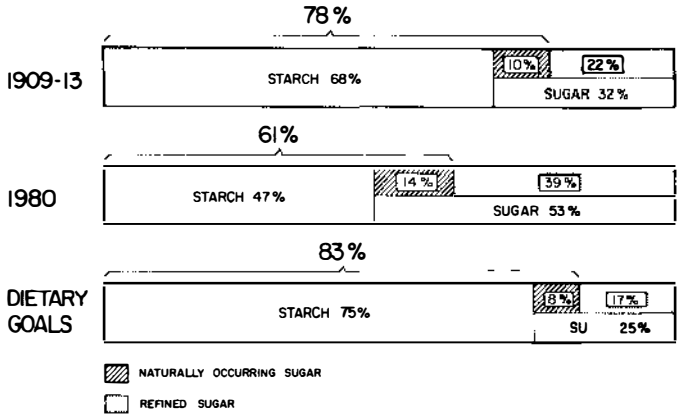

Figure 3 Per capita consumption of carbohydrate (percent of total). Data for 1909–1913 and 1980 adapted from (26). Percentage of naturally occurring sugars in Dietary Goals estimated from 1909–1913 ratio of naturally occurring sugar: total sugar (1:3).

cline. It has been estimated that the energy input into the US food supply approximates 10 kcal for each kcal of food consumed (62). Less energy input would result in lower food cost, and this fact alone may exert pressure toward change in the direction suggested.

A food supply composed of fewer processed foods and foods with higher starch and fiber content would be less cariogenic. Selection of foods more compatible with the carbohydrate composition suggested in the Dietary Goals would require the exercise of parental responsibility with possible ramifications beyond improvement of the dental health of the nation's children.

It would be difficult to take issue with recommendations and conclusions of the Food and Nutrition Board of the National Academy of Sciences in the booklet *Toward Healthful Diets* (13). Unfortunately, many Americans now do not select a nutritionally adequate diet of dairy products, meats or legumes, vegetables and fruits, and cereals and breads in the amounts necessary to maintain appropriate weight for height. To expect wider acceptance of this practice may be unrealistic. On the other hand, it is held by some that the Dietary Goals would encourage not only the proper use of the existing food supply but also broader concerns for traditional meanings of foods and the manner of their consumption, for energy conservation, and for the value of individual responsibility for health.

Literature Cited

1. Abraham, S., Carroll, M. D., Dresser, C. M., Johnson, C. L. 1979. *Dietary Intake Source Data, United States 1971–74.* Washington DC: Dept. HEW Publ. No. (PHS) 79–1221. pp. 2–421
2. Adachi, S., Patton, S. 1961. Presence and significance of lactulose in milk products: a review. *J. Dairy Sci.* 44: 1375
3. American Medical Association Council on Scientific Affairs. 1979. Concepts on nutrition and health. *J. Am. Med. Assoc.* 242:2335–38
4. Bierman, E. L. 1979. Carbohydrates, sucrose, and human disease. *Am. J. Clin. Nutr.* 12(Suppl.):2712–22
5. Burk, M. C., Pao, E. M. 1976. *Methodology for Large-Scale Surveys of Household and Individual Diets. Home Econ. Res. Rpt. No. 40.* Washington DC: USGPO. 88 pp.
6. Bush, R. T. 1970. Lactulose: an ideal laxative for children. *New Zeal. Med. J.* 71:364–65
7. Center for Disease Control. 1972. *Ten-State Nutrition Survey, 1968–70,* part V. Atlanta, GA: Dept. HEW Publ. No. (HSM) 72–8133. 340 pp.
8. Committee on Nutrition. 1978. *Review of Safety and Suitability of Modified Food Starches in Infant Foods.* Evanston, IL: Am. Acad. Pediatr.
9. Conn, H. O., Leevy, C. M., Vlahcevic, Z. R., Rodgers, J. B., Maddrey, W. C., Seeff, L., Levy, L. L. 1977. Comparison of lactulose and neomycin in the treatment of chronic portal-systemic encephalopathy. *Gastroenterology* 72: 573–83
10. Connor, W. E. 1979. Too little or too much: the case for preventive nutrition. *Am. J. Clin. Nutr.* 32:1975–78
11. Cristofaro, E., Mottu, F., Wuhrmann, J. J. 1974. Involvement of the raffinose family of oligosaccharides in flatulence. In *Sugars in Nutrition,* ed. H. L. Sipple, K. W. McNutt, 20:313–36. NY: Academic Press. 768 pp.
12. Fishman, P. H., Brady, R. O. 1976. Biosynthesis and function of gangliosides. *Science* 194:906–15
13. Food and Nutrition Board. 1980. *Toward Healthful Diets.* Washington DC: Nat. Acad. Sci./Nat. Res. Counc. 24 pp.

14. Gortner, W. A. 1975. Nutrition in the United States, 1900 to 1974. *Cancer Res.* 35:3246–53
15. Grimmonprez, L., Montreuil, J. 1975. Isolement et étude des propriétés physico-chimiques d'oligosaccharides du lait de femme. *Biochimie* 57:695–701
16. György, P. 1974. Effect of carbohydrates on intestinal flora. See Ref. 11, 14:215–26
17. Hambraeus, L. 1977. Propietary milk versus human breast milk in infant feeding. *Pediatr. Clin. North Am.* 24:17–36
18. Harper, A. E. 1978. Dietary goals—a skeptical view. *Am. J. Clin. Nutr.* 31: 310–21
19. Harper, A. E. 1980. "Healthy people": critique of the nutrition segments of the Surgeon General's report on health promotion and disease prevention. *Am. J. Clin. Nutr.* 33:1703–12
20. Hegsted, D. M. 1978. Dietary goals—a progressive view. *Am. J. Clin. Nutr.* 31:1504–9
21. Hiemstra, S. 1968. *Food Consumption, Prices, Expenditures. U.S. Dept. Agric., Econ, Res. Serv., Agric. Econ. Rpt. 138.* 193 pp.
22. Horwitz, W., Chichilo, P., Reynolds, H., eds. 1970. Animal feed. In *Official Methods of Analysis of the Association of Official Analytical Chemists,* 7:122–38. Washington DC: Assoc. Official Analyt. Chem. 1015 pp. 11th ed.
23. Jenness, R. 1979. The composition of human milk. *Semin. Perinatol.* 3: 255–39
24. Le Bovit, C. 1978. Who eats the sweets? *Natl. Food Rev.* 4:62–63
25. Manoff, R. K. 1972. *Intl. Cong. Nutr., 9th,* pp. 256–77
26. Marston, R. M., Peterkin, B. B. 1980. Nutrient content of the national food supply. *Natl. Food Rev.* 9:21–25
27. Marston, R. M., Welsh, S. O. 1981. Nutrient content of the national food supply. *Natl. Food Rev.* 13:19–22
28. Martinez, G. A., Nalezienski, J. P. 1979. The recent trend in breast-feeding. *Pediatrics* 64:686–92
29. Milk Industry Fnd. 1980. *1980 Milk Facts.* Washington DC: Milk Industry Fnd. 30 pp.
30. Montreuil, J., Antony, N., Descamps, J. 1963. The glycoproteins of human and cow's milk. *Ann. Biol. Anim. Biochim. Biophys.* 3:(Hors Sér 1) 129–33
31. Montreuil, J., Mullet, S. 1960. Étude des variations des constituants glucidiques du lait de femme au cours de la lactation. *Bull. Soc. Chim. Biol.* 42: 365–77
32. Morgan, K. J., Zabik, M. E. 1981. Amount and food sources of total sugar intake by children ages 5 to 12 years. *Am. J. Clin. Nutr.* 34:404–13
33. National Research Council, Committee on Food Protection. 1972. *A Comprehensive Survey of Industry on the Use of Food Chemicals Generally Recognized as Safe (GRAS).* Washington DC: Natl. Acad. Sci.
34. National Soft Drink Association. 1981. *Sales Survey of the Soft Drink Industry. NSDA 1980.* Washington DC: Natl. Soft Drink Assoc. 16 pp.
35. Newton, J. M. 1970. Corn Syrups. In *Symposium Proceedings.* Washington DC: Corn Refiners Assoc., Inc. 13 pp.
36. Owen, G. M., Kram, K. M., Garry, P. J., Lowe, J. E., Lubin, A. H. 1974. A study of nutritional status of preschool children in the United States, 1968–1970. *Pediatrics* 53:597–646
37. Pennington, J. 1980. Total diet study results and plans for selected minerals. *FDA Bylines* 10:179
38. Périssé, J., Sizaret, F., Francois, P. 1969. The effect of income on the structure of the diet. *FAO Nutr. Newsl.* 7:1–9
39. Reynolds, T. M. 1969. Nonenzymic browning sugar-amine interactions. In *Symposium on Foods: Carbohydrates and Their Roles,* ed. H. W. Schultz, R. F. Cain, R. W. Wrolstad, 12:219–52. Westport, CT: AVI Publ. Co., Inc. 458 pp.
40. Roseman, S. 1975. Sugars of the cell membrane. *Hosp. Pract.* 10:61–70
41. Schultz, H. W., Cain, R. F., Wrolstad, R. W., eds. 1969. Advances in analytical methodology. See Ref. 39, Sect. III:133–204
42. Select Committee on GRAS Substances. 1972. *Evaluation of the Health Aspects of Carob Bean Gum as a Food Ingredient. SCOGS-3.* Bethesda, MD: Life Sci. Res. Off., FASEB. 10 pp.
43. Select Committee on GRAS Substances. 1972. *Evaluation of the Health Aspects of Gum Tragacanth as a Food Ingredient. SCOGS-4.* Bethesda, MD: Life Sci. Res. Off., FASEB. 10 pp.
44. Select Committee on GRAS Substances. 1972. *Evaluation of the Health Aspects of Sorbitol as a Food Ingredient. SCOGS-9.* Bethesda, MD: Life Sci. Res. Off., FASEB. 10 pp.
45. Select Committee on GRAS Substances. 1972. *Evaluation of the Health Aspects of Mannitol as a Food Ingredient. SCOGS-10.* Bethesda, MD: Life Sci. Res. Off., FASEB. 8 pp.

46. Select Committee on GRAS Substances. 1973. *Evaluation of the Health Aspects of Gum Ghatti as a Food Ingredient. SCOGS-12.* Bethesda, MD: Life Sci. Res. Off., FASEB. 7 pp.
47. Select Committee on GRAS Substances. 1973. *Evaluation of the Health Aspects of Guar Gum as a Food Ingredient. SCOGS-13* Bethesda, MD: Life Sci. Res. Off., FASEB. 12 pp.
48. Select Committee on GRAS Substances. 1973. *Evaluation of the Health Aspects of Gum Arabic as a Food Ingredient. SCOGS-1.* Bethesda, MD: Life Sci. Res. Off., FASEB. 16 pp.
49. Select Committee on GRAS Substances. 1973. *Evaluation of the Health Aspects of Sterculia Gum as a Food Ingredient. SCOGS-5.* Bethesda, MD: Life Sci. Res. Off., FASEB. 13 pp.
50. Select Committee on GRAS Substances. 1973. *Evaluation of the Health Aspects of Carrageenan as a Food Ingredient. SCOGS-6.* Bethesda, MD: Life Sci. Res. Off., FASEB. 16 pp.
51. Select Committee on GRAS Substances. 1973. *Evaluation of the Health Aspects of Agar-Agar as a Food Ingredient. SCOGS-23.* Bethesda, MD: Life Sci. Res. Off., FASEB. 14 pp.
52. Select Committee on GRAS Substances. 1973. *Evaluation of the Health Aspects of Alginates as Food Ingredients. SCOGS-24.* Bethesda, MD: Life Sci. Res. Off., FASEB. 14 pp.
53. Select Committee on GRAS Substances. 1973. *Evaluation of the Health Aspects of Cellulose and Certain Cellulose Derivatives as Food Ingredients. SCOGS-25.* Bethesda, MD: Life Sci. Res. Off., FASEB. 26 pp.
54. Select Committee on GRAS Substances. 1975. *Evaluation of the Health Aspects of Gum Guaiac as a Food Ingredient. SCOGS-64.* Bethesda, MD: Life Sci. Res. Off., FASEB. 16 pp.
55. Select Committee on GRAS Substances. 1975. *Evaluation of the Health Aspects of Dextrin and Corn Dextrin as Food Ingredients. SCOGS-75.* Bethesda, MD: Life Sci. Res. Off., FASEB. 17 pp.
56. Select Committee on GRAS Substances. 1977. Evaluation of health aspects of GRAS food ingredients; lessons learned and questions unanswered. *Fed. Proc.* 36:2519–62
57. Select Committee on GRAS Substances. 1977. *Evaluation of the Health Aspects of Pectin and Pectinates as Food Ingredients. SCOGS-81.* Bethesda, MD: Life Sci. Res. Off., FASEB. 19 pp.
58. Select Committee on GRAS Substances. 1979. *Evaluation of the Health Aspects of Starch and Modified Starches as Food Ingredients. SCOGS-115.* Bethesda, MD: Life Sci. Res. Off., FASEB. 100 pp.
59. Senate Select Committee on Nutrition and Human Needs. 1977. *Dietary Goals for the United States.* Washington DC: US GPO. 83 pp. 2nd ed.
60. Shallenberger, R. S. 1974. Occurrence of various sugars in foods. See Ref. 11, 5:67–80
61. Sharon, N., Lis, H. 1981. Glycoproteins: research booming on long-ignored, ubiquitous compounds. *Chem. Eng. News* 59:21–44
62. Steinhart, J. S., Steinhart, C. E. 1974. Energy use in the U.S. food system. *Science* 184:307–16
63. The Surgeon General's Report on Health Promotion and Disease Prevention. 1979. *Healthy People.* Washington DC: Dept. HEW Publ. No. 79–55071
64. US Dept. Agriculture. 1960. *High Consumption of Foods.* Washington DC: USGPO
65. US Dept. Agriculture. 1972. *Food and Nutrient Intake of Individuals in the United States, Spring 1965. Household Food Consumption Survey 1965–66, Rpt. No. II.* Washington DC: USGPO 289 pp.
66. US Dept. Agriculture. 1980. *Food and Nutrient Intakes of Individuals in 1 day in the United States, Spring 1977. Nationwide Food Consumption Survey 1977–78, Preliminary Rpt No. 2.* Washington DC: USGPO. 121 pp.
67. US Dept. Agriculture. 1981. Sugar and sweetener—outlook and situation. *Sugar and Sweetener Rep.* 6:40
68. US Dept. Agriculture and Dept. Health, Education and Welfare. 1980. *Nutrition and Your Health—Dietary Guidelines for Americans.* Washington DC: USGPO. 20 pp.
69. US Dept. Health, Education, and Welfare. 1979. *Dental Manpower Fact Book.* Hyattsville, MD: Dept. HEW Publ. No. (HRA) 79–14. 106 pp.
70. van Duuren, B. L., Goldschmidt, B. M., Katz, C., Seidman, I., Paul, J. S. 1974. Carcinogenic activity of alkylating agents. *J. Natl. Cancer Inst.* 53:695–700
71. Van Itallie, T. B., ed. 1979. Report of the Task Force on the evidence relating six dietary factors to the nation's health. *Am. J. Clin. Nutr.* 12(Suppl.):2621–748
72. van Soest, P. J. 1978. Dietary fibers: their definition and nutritional properties. *Am. J. Clin. Nutr.* 31:S12–S20