Cholesterol, Phytosterol, and Tocopherol Content of Food Products and Animal Tissues

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[EDITOR'S NOTE: *This paper is essentially a tabulation of about 700 reported values from 100 sources, arranged under various headings. It is offered as a help to technologists, dietitians, nutritionists, and physicians who need information on the cholesterol and vitamin E content of foods, animal tissues, and other materials.*]

NUTRITIONISTS, physicians, and food technologists have become increasingly interested in the quantities of sterols, particularly cholesterol, and of tocopherols present in various natural materials. Nutritional and clinical interest in cholesterol stems from the belief that the cholesterol content of the diet has an influence on the health and well-being of man. The tocopherols are of interest because of their vitamin activities (vitamin E) and of their behavior as antioxidants for fats in foods. Since the pertinent information is widely scattered, an attempt has been made to select the more important data on sterol and tocopherol content of foods and related materials and to tabulate same for convenient consultation. The resulting tables are presented below, with a specific reference in support of each analytical value included and with brief discussion intended to aid in a general understanding of the data.

Sterols

Sterols seem to be present in most living tissues. According to origin, they may be grouped into zoö-, phyto-, and mycosterols. One sterol, namely cholesterol seems to be entirely an animal product (14a). Its only known synthesis in nature is by the animal organism, and it has not been found in plant tissues or in lipids derived from plants. It is interesting to note that vertebrate animals produce essentially only one sterol, namely cholesterol (23), while numerous phytosterols have become known, several of them being formed simultaneously in one plant. A glance at the literature shows that some authors have not made a distinction between sterols in general and cholesterol in particular but simply designated any substance obtained even from vegetable material as cholesterol when it gave the reactions common to the whole sterol group. From Schoenheimer's work it has commonly been concluded that plant sterols (phytosterols) in the diet are not a source for formation of cholesterol in the animal organism and they are not even absorbed from the intestines but are excreted in the feces. Phytosterols experimentally deposited in the subcutaneous tissue of a dog are not esterified or modified by the organism and are treated like an inert, foreign material while cholesterol is readily esterified. Rabbits absorb cholesterol fed with the diet and deposit it in their organs while phytosterols are practically completely recovered from the feces and no deposition in the organs is observed. Experiments show that the phytosterols isolated from the feces are identical with those fed to the animal and have not been subjected to any modification during their passage through the intestinal tract (81). The selectivity of the intestinal walls in the absorption of steroids is remarkable; slight changes in the structure of cholesterol completely prevent absorption (82). After simultaneous feeding of cholesterol and phytosterols, only cholesterol can be isolated from the lymph duct and no trace of phytosterols is found. Since absorbed cholesterol together with the bulk of the absorbed fat is transferred from the intestine into the organism mainly through the lymph and can be readily recovered from it, the experiment has been considered as proof that the phytosterols are treated by the intestine as an inert substance and are not absorbed (8). This rejection of phytosterols by the animal organism is the main reason why nutritional and medical interest centers around cholesterol (64b).

In sterol analyses, color tests and precipitation reactions are not specific for any individual sterol. The total quantity of sterols present in a sample may readily be established and also the question answered whether the material is cholesterol or phytosterol while the separation and determination of individual phyto- or mycosterols from their natural mixtures requires a considerable amount of work. Sterols, after saponification to liberate any sterol originally present as ester, may be determined colorimetrically by a modification of the Liebermann-Burchard reaction (56), by the Schoenheimer-Sperry method (84), by precipitation as the digitonide (64a, 97b), or some of them may be precipitated as insoluble dibromides (37). According to Bömer (14b), a distinction between cholesterol and phytosterols is possible by microscopic studies of the crystal forms of the sterols or melting point determinations of their acetates; the methods are also applicable to cholesterol in the presence of a small admixture of phytosterols. Plant sterols to which some cholesterol has been added may be studied using a method described by Windaus (97a), which is based on the sparing solubility of cholesterol dibromide in a mixture of ether and glacial acetic acid; however the bromide of stigmasterol, a phytosterol, precipitates under the same conditions (98). Due to the difficulty of separating phytosterols into their components, literature data on the composition of phytosterols are limited. However the fact that phytosterols have a potential value as starting materials for the preparation of vitamin D-active compounds and sex hormones will certainly lead to comprehensive analytical studies.

In Tables I to V the total cholesterol content of animal materials is given in mg./100 g. of moist material unless otherwise stated. Although physiologically of less interest, the sterol (phytosterol) content of vegetable materials is also given for comparative purposes in Table VI to VIII.

Tocopherols

The four naturally occurring tocopherols (α, β, γ, and δ) are similar in chemical and physical properties and in nature occur in mixtures of varying proportions. While the colorimetric determination of total tocopherol content often may be carried out without too much difficulty, the quantitative estimation of each individual component is tedious (7), and

A. Cholesterol Content in Animal Matter

TABLE I

Cholesterol in Mammals

	Moist material	Reference
	mg./100 g.	
Beef, muscle meat (medium fat)	125	64b
Beef, muscle meat (lean)	95	64b
Beef, skeletal muscle	60, 60	47*
Beef, veal, shank	140	64b
Beef, veal, breast	100	64b
Beef, veal, skeletal muscle	65	47*
Beef, liver	320	64b
Beef, liver	260, 190	47*
Beef, calf's liver	360	64b
Beef, tripe	150	64b
Beef, sweetbread	280	64b
Beef, sweetbread	220, 250	47*
Beef, brain	2360, 2110	47*
Beef, heart	140, 150	47*
Beef, kidney	400, 410	47*
Beef, lung	350, 390	47*
Beef, retina	650	15
Beef, tallow	75	51
Beef, tallow	140	9
Beef, bone marrow fat	300	48
Beef, calf, total blood	131.5	43
Cat, heart muscle, dry	440	13b
Cat, skeletal muscle, dry	190	13b
Cat, lipids in hairs	10300	24b
Dog, heart muscle, dry	610	13b
Dog, skeletal muscle, dry	320	13b
Dog, smooth muscle, dry	350	13b
Dog, lipids in hairs	30900	24b
Dog, blood	146.6	43
Dog, bile	36.8	70
Guinea pig, liver, normal diet	540	66
Guinea pig, liver, cholesterol-high diet	5400	66
Guinea pig, lung, normal diet	410	66
Guinea pig, lung, cholesterol-high diet	1320	66
Guinea pig, heart, normal diet	200	66
Guinea pig, heart, cholesterol-high diet	280	66
Guinea pig, spleen, normal diet	380	66
Guinea pig, spleen, cholesterol-high diet	1100	66
Guinea pig, blood, normal diet	156	66
Guinea pig, blood, cholesterol-high diet	304	66
Guinea pig, adrenal, normal diet	6900	66
Guinea pig, adrenal, cholesterol-high diet	7100	66
Guinea pig, adrenal	3250	13c
Horse, fat	80	9
Horse, blood	97.8	43
Horse, erythrocytes	116	43
Horse, leucocytes	521	43
Mouse, liver	520-670	83
Pig, spareribs	105	64b
Pig, liver	420	64b
Pig, skeletal muscle	60	47*
Pig, lard	108	99
Pig, lard	120	48
Pig, lard	114	54
Pig, fat	74.5-122	51
Pig, fat	50	9
Pig, retina	270	15
Rabbit (whole)	117	23
Rabbit, heart muscle	200	13b*
Rabbit, liver (stock), dried	530	18
Rabbit, liver (old), dried	310	18
Rabbit (lab. specimen), skeletal muscle	50	13b*
Rabbit (wild specimen), skeletal muscle	80	13b*
Rabbit, total blood	92.8	43
Rabbit, blood	114-243	24b
Rabbit, lipids in hairs	33900-41200	24b
Rat, diet with 15% fat, liver	310	64b
Rat, diet with 15% fat, lung	370	64b
Rat, diet with 15% fat, spleen	460	64b
Rat, diet with 15% fat, kidney	430	64b
Rat, diet with 15% fat, heart	220	65
Rat, diet with 15% fat, brain	1420	65
Rat, diet with 15% fat, skin (no hair)	610	65
Rat, diet with 15% fat, hashed carcass	130	64b
Rat, diet with 15% fat, fat (adipose tissue)	140	65
Rat, diet with 15% fat, placentae	280	64b
Rat, diet with 15% fat, fetuses	170	64b
Rat, diet with 15% fat, liver (pregnant animals)	460	64b
Rat, diet with 15% fat, liver (12-16 days old)	320	64b
Rat, diet with 15% fat, milk	60	64b
Rat, lipids in hairs	13300	24b
Rat, female, livers, pregnant rats, normal diets	460	65
Rat, female, livers, pregnant rats, cholesterol high diet	5000	65
Rat, female, non-pregnant rats, normal diet	340	65
Rat, female, non-pregnant rats, cholesterol high diet	6700	65
Rat, diet, placenta, normal diet	280	65
Rat, diet, placenta, cholesterol high diet	380	65
Rat, fetuses, normal diet	168	65
Rat, fetuses, cholesterol-high diet	198	65
Rat, livers of young rats (12-16 days old), cholesterol-low mothers	320	65
Rat, livers of young rats (12-16 days old), cholesterol-fed mothers	760	65
Seal, oil	60	89
Sheep, wool fat (degras)	about 15000	100
Sheep, lipids in wool	6300-12500	24b
Sheep, mutton tallow	28	51
Sheep, mutton tallow	100	48
Sheep, suprarenal gland, dry	3000	29
Sheep, lamb, liver	610	64b
Sheep, lamb, skeletal muscle	70	47*
Sheep, lamb, lipids in wool	4600-8600	24b
Whale, oil	85	9
Whale, oil	200	48

* The data were taken from a publication by R. Okey (64b) who converted the originally published figures from dry to normal moisture basis.

only recently have reliable analytical methods for this purpose been developed. Much of the progress in this field has been reported from the laboratories of Distillation Products inc.

From the extensive literature on physico-chemical tocopherol analysis, a few publications indicating steps in the development of present-day methods are mentioned here. The Emmerie-Engel method (26a), generally used for the determination of the total tocopherol content and also in the estimation of individual tocopherols, is based upon the quantitative reduction of ferric ions by the tocopherols and the color reaction of the ferrous ions formed with

TABLE II

Cholesterol in Fowl

	Moist material	Reference
	mg./100 g.	
Chicken, total animal	527	23
Chicken, heart muscle	160	13b*
Chicken, skeletal muscle, light	90	47*
Chicken, skeletal muscle, dark	60	47*
Chicken, skeletal muscle	70	13b*
Duck, wild, heart muscle	160	13b*
Duck, wild, skeletal muscle	70	13b*
Duck, lipids in feathers	9400	24b
Goose, fat	41	51
Goose, fat	760	48
Goose, lipids in feathers	13600	24b
Pigeon, heart muscle	160	13b*
Pigeon, skeletal muscle	110	13b*
Turkey, lipids in feathers	14100-25800	24b

* The data were taken from a publication by R. Okey (64b) who converted the originally published figures from dry to normal moisture basis.

TABLE III

Cholesterol in Dairy Products and Eggs

	Moist material	Reference
	mg./100 g.	
Milk	13	99
Milk, powder	88	99
Butter	185	99
Butter	280	64b
Butter	71	51
Butter, fat	240	9
Casein, raw	65	64b
Cheese, American	160	64b
Cheese, American, processed	155	64b
Cheese, Swiss, processed	145	64b
Cheese, Monterey Jack	190	64b
Cheese, Velveeta	160	64b
Cheese, Limburger, processed	135	64b
Cheese, Pimento Cream, processed	140	64b
Egg, yolk	1342	99
Egg, yolk, vacuum-dried	1750	29
Egg, frozen, whole	600	37
Egg, frozen, yolk	1365	37
Egg, Chinese dried yolk	2810	37
Egg, commercial frozen, whole	562	37
Egg, commercial frozen, yolk	1272	37
Egg, commercial dried eggs	2770	37
Egg, yolk, dried	3900	64b
Egg, yolk, fresh	2000	64b
Egg, fresh, whole	468	47*

* The data were taken from a publication by R. Okey (64b) who converted the originally published figures from dry to normal moisture basis.

α,α′-dipyridyl. A number of modifications have been developed, most of them involving the preliminary treatment of the sample and the removal of interfering substances, necessitated not only by the nonspecificity of the ferric reduction, but also by the different rates of reaction of the tocopherols.

On the other hand, use has been made of these differences in reaction rates for the determination of individual tocopherols in mixtures. Mild hydrogenation of tocopherol-containing lipids on a semi-micro scale, to eliminate interference from vitamin A, carotenoids, and other components in the Emmerie-Engel test, was introduced by Quaife, Harris, and Biehler (74, 76a). Later, as Dam *et al.* had done before (20, 33), Quaife and Harris (76b) used molecular distillation to concentrate the tocopherols in lipids of low tocopherol content and to separate interfering minor constituents. The fact that γ-tocopherol couples with a diazo compound to form a red dye while α- and β-tocopherols do not was used by Quaife (73a) as the basis for a new colorimetric test for the determination of γ-tocopherol specifically. Weisler *et al.* used a similar diazo reaction for the specific estimation of γ- and δ-tocopherols in a tocopherol mixture by varying the alkalinity of the coupling reagent and observing the difference in color intensities produced; α-tocopherol could be estimated by difference (95).

TABLE IV

Cholesterol in Other Vertebrates

	Moist material	Reference
	mg./100 g.	
Alligator (caiman), liver oil	900-1000	63
Codfish, skeletal muscle	50	47*
Codfish, liver oil	516	51
Codfish, liver oil	420	9
Codfish, liver oil	488	99
Codfish, liver oil	540	39a
Frog, skeletal muscle	40	47*
Grass snake, (whole)	80	23
Halibut, liver oil	7600	48
Mackerel (whole)	22	23
Salmon, skeletal muscle	60	47*
Salmon, Rhine, sperm cells	2200	62
Turtle, heart muscle	160	13b*
Turtle, skeletal muscle	60, 70	13b*

* The data were taken from a publication by R. Okey (64b) who converted the originally published figures from dry to normal moisture basis.

TABLE V

Cholesterol in Human Tissues

Tissue	Moist weight	Reference
	mg./100 g.	
Brain, woman, total	2690	30
Brain, man, cerebrum	1150	30
Brain, man, white substance	2470	30
Brain, man, cerebellum	1310	30
Brain, man, pons varolii and medulla oblongata	4030	30
Nervus ischiadicus (dry)	5610	16
Nerve tissue	1100	28
Nerves, femoral	1450	77
Nerves, sciatic	1470	77
Nerves, posterior	1300	77
Nerves from arteriosclerotic subject, sciatic	710	77
Nerves from arteriosclerotic subject, posterior tibial	600	77
Spinal cord	3350-4260	31
Blood	167-255	21
Blood, woman	210-240	13a
Blood, man	190-250	13a
Plasma, young women	78.0-226.6, mean 152.8	32
Plasma, young men	100.5-222.8, mean 169.4	32
Serum	138.1-286.4	84
Serum, normal average	202.7	69
Serum, normal adults	159-260	50
Serum, persons with xanthoma	>300	1
Serum, persons with xanthoma and coronary artery disease	>300	1
Kidney	250-370	13c
Liver	180-380	13c
Muscle	350-370	13c
Suprarenal	2600-6700	13c
Chyle	94.3	92
Bile	229	70
Gallstones, solitary	98000-99000	70
Gallstones, mixed or combination	94000	70
Fat	175	51
Fat	240	48
Fat, average	127	43
Fatty tissue, subcut. from abdomen	240	24a
Dry skin	580-1500	25
Lipids in cutaneous epithelium	13000-24000	25
Lipids in hair	3000	48
Lipids in hair, adults	1200-5400	24b
Lipids in hair, children	8700-11800	24b

The fat technologist is interested in the antioxidant properties of tocopherols while the nutritionist is mainly interested in their vitamin E activities. Olcott and Emerson (67) found an increase in antioxidant activity of α-, β-, and γ-tocopherols at 75°C. in the order named, while Hove and Hove (42b) reported that the relative activity depends upon temperature and that these three tocopherols have about the same activity at low temperatures. Stern *et al.* (88) observed that the resistance of the tocopherols to atmospheric oxidation in oil solution parallels their activity as antioxidants, δ- being the most resistant and α-tocopherol the least resistant to oxidation. Thus, in general, α tends to show the lowest antioxidant potency (34), which is just the reverse of the vitamin activity of these substances. The greatest vitamin

B. Phytosterol Content in Vegetable Matter

TABLE VI

Phytosterol in Vegetable Oils

Source of oil	Fat	Reference
	mg./100 g.	
Castor bean	500	48
Cocoa butter	170	9
Cocoa butter	200	48
Coconut, hydrog	79.8	51
Coconut, hydrog	60	89
Coconut, hydrog	80	9
Coffee bean	730-770	6
Common bean, *Phaseolus vulgaris*	2750-3600	68
Corn	580	89
Corn	1000	3
Corn germ	800-1000	91c
Cottonseed	311.2	51
Cottonseed	260	9
Cottonseed	260	89
Crisco, a dehydrogenated vegetable shortening	232	71
Grapeseed	600	48
Linseed	416	51
Linseed	410	9
Linseed	370	89
Margarine Base Stock L (P&G)	206	71
Mowrah fat	40	9
Olive	133.7	51
Olive	210	9
Palm, crude	30	89
Palm Kernel	120	9
Palm Kernel	60	89
Peanut	247.9	51
Peanut	200	89
Peanut	190	9
Poppyseed	247.9	51
Primex, a hydrogenated vegetable shortening	150	64b
Pumpkin seed	500	48
Rapeseed	345	51
Rapeseed	440	9
Rice bran	750	48
Rye germ	1200-3650	91a
Sesame	549.4	51
Sesame	520	9
Sesame	430	89
Shea fat	90	9
Soybean	380	60
Soybean	195	53
Soybean	230	89
Soybean	150	86
Sweetex, a hydrogenated vegetable shortening	242	71
Tobacco seed	150	80
Wheat germ	3600-6700	48
Wheat germ, pressed	1300-2000	91b
Wheat germ, extracted	1300-1700	91b

E activity in the rat-antisterility test is shown by α-tocopherol (44) and δ is the least active (88), so that there has been some tendency to identify the α form with vitamin E. However it is now recognized that each tocopherol may play an essential role in the living organism as a component of vitamin E (7). Quaife and Dju (75) have shown recently that α-tocopherol is the predominant form of tocopherol found in human tissues, but some γ- or δ-tocopherols also occurred in a male subject and they were present in most of the tissues of a female subject to the extent of 20 to 40% of the total tocopherols present.

It is commonly recognized that the animal organism is not able to synthesize the tocopherols. They are formed in plants, and these vegetable materials are the primary source of vitamin E found in animal tissues (39b).

Tables IX to XIII show the tocopherol content of various vegetable and animal materials in mg./100 g., with such additional information as can be included without need of extensive explanations. The references should be consulted for further details.

It is interesting to note that the principal edible oils of the temperate zones, cottonseed, soybean, and

TABLE VII

Phytosterol in Leaf and Root Meals

Source of meal	Dehydrated meal	Reference
	mg./100 g.	
Alfalfa leaf	80	93b
Beet, top	95	93b
Beet, root	25	93b
Broccoli	329	93b
Cabbage	125	93b
Carrot, top	116	93b
Carrot, root	65	93b
Celery, top	144	93b
Corn leaf	125	93b
Iris leaf	90	93b
Kale leaf	464	93b
Lily leaf, Canadian	75	93b
Hemerocallis leaf	85	93b
Lima bean leaf	144	93b
Pea leaf	272	93b
Spinach leaf	184	93b
Turnip, top	160	93b
Turnip, root	63	93b

TABLE VIII

Phytosterol in Miscellaneous Vegetable Products

Material	Material	Reference
	mg./100 g.	
Almond, sweet, dry, skin	30	59
Almond sweet, dry, meat	17.5	59
Barley, dry, hull	60	59
Barley, dry, meat	34	59
Broad bean, dry, hull	47.5	59
Broad bean, dry, meat	42	59
Buckwheat, dry, hull	55	59
Buckwheat, dry, meat	34	59
Chestnut, dry, hull	57.5	59
Chestnut, dry, meat	19.5	59
Chickpea, dry, hull	70	59
Chickpea, dry, meat	35	59
Common bean (*Phaseolus vulgaris*), dry	90	68
Common bean, before germination	64.8-86.3	10
Common bean, grown 3 weeks in the dark	121	10
Corn gluten	940	2
Durum flour, solids	24	37
Semolina, solids	23	37
Flour, solids	28	37
Garlic, dry, skin	30	59
Garlic, dry, interior	22.5	59
Hempseed, dry, hull	455	59
Hempseed, dry, meat	17.5	59
Jerusalem artichoke, dry, skin	60	59
Jerusalem artichoke, dry, interior	22.5	59
Lentil, dry, hull	20	59
Lentil, dry, meat	18	59
Millet grass, dry, hull	62	59
Millet grass, dry, meat	54	59
Oats, dry, hull	62.5	59
Oats, dry, meat	54	59
Pea, dry, hull	54	59
Pea, dry, meat	52.5	59
Pea, before germination	63.0-68.7	10
Pea, grown 3 weeks in the dark	131.0-137.5	10
Pea, grown 3 weeks in light	107.5	10
Soybean, dry, hull	67.5	59
Soybean, dry, meat	52.5	59
Soybean, dry	97	58
Vetch, dry, hull	51	59
Vetch, dry, meat	52.5	59

C. Tocopherol Content in Vegetable Matter

TABLE IX

Tocopherol in Vegetable Oils

Source of oil	Mg./100 g. oil					
	Total tocopherol	α	β	γ	δ	Reference
Babassu, crude	3					5
Beechnut	100					26c
Carrot	162					76b
Carrot	500			0	0	38
Castor bean	50					5
Cocoa fat	12.5					26c
Cocoa fat	2.8					71
Coconut, refined	3					5
Coconut, hydrogenated	3					72
Coconut	5					71
Coconut	8.3	3.6		$\gamma+\delta$	4.7	35a
Corn, Mazola	119					72
Corn, crude	110					85
Corn, refined	104	6				42a
Corn, European brand	250					26c
Corn, refined	90	9		81		27
Corn, refined	95					5
Corn, crude	97					76c
Corn, Mazola	102	12.6		89.4		73c
Corn, Mazola	....	7.0				76d
Corn, refined	87	7		$\gamma+\delta$	80	35a
Cottonseed, Wesson	110					72
Cottonseed, refined	83	51				42a
Cottonseed, refined	92					85
Cottonseed, crude	110	76		34		27
Cottonseed, crude	110					5
Cottonseed, refined	90					5
Cottonseed, refined	90.1			34.5		76b
Cottonseed, refined	90	56		$\gamma+\delta$	34	35a
Cottonseed, refined	86	41		36	9	95
Cottonseed, Wesson	87.0	49.3		37.7		73c
Cottonseed, Wesson	....	56.0				76d
Cottonseed, crude	110-120					71
Hazelnut, crude	45					52a
Hazelnut	52					71
Linseed	113					71
Morroseed (*Crescentia alata* HBK)	65					71
Oat germ	60	10				11
Okraseed	112					71
Okraseed, crude	74	31		43		27
Olive	8					45
Olive	25					72
Olive	5-30					52a
Olive	3					26c
Olive	14					71
Olive	20					5
Olive	6.9					76b
Palm	2.7					45
Palm	44	mainly α (52)				52a
Palm	50					5
Palm	<11					71
Palm	56	30		$\gamma+\delta$	26	35a
Peanut, refined	51					4
Peanut	26					26c
Peanut, crude	40					52a
Peanut, crude	52	30		22		27
Peanut, crude	52					5
Peanut, refined	48					5
Peanut	59					71
Peanut, refined	36	23				42a
Peanut	34	13		14	7	95
Peanut, refined	22	11		$\gamma+\delta$	11	35a
Pecan, refined	42	20		22		27
Pecan, refined	45					5
Poppyseed, crude	44					52a
Rapeseed, crude	55					52a
Rice bran, refined	91	58		33		27
Rice bran, crude	100					5
Rice bran, refined	90					5
Safflower, crude	80					5
Sesame,** refined	18					52a
Sesame, refined	50					5
Sesame	65					71
Sesame	60					87

TABLE IX *(Concluded)*

Tocopherol in Vegetable Oils

Source of oil	Mg./100 g. oil					
	Total tocopherol	α	β	γ	δ	Reference
Soybean, crude	152, 212					72
Soybean, refined	125, 175					72
Soybean, refined	92	9				42a
Soybean	120					26c
Soybean, refined	99	21		78		27
Soybean, refined	110					5
Soybean, alkali refined	190				57 (approx.)	88
Soybean	150-220					71
Soybean	168	20		98	50	95
Soybean, water refined	190					87
Soybean, salad oil	74.0	9.6		41.8	22.6	73c
Soybean, extracted	169-280					78
Soybean, refined	140	10		γ+δ	130	35a
Sunflower seed, crude	70					52a
Wheat germ	520					45
Wheat germ	240					26b
Wheat germ	310, 380					72
Wheat germ	178					12
Wheat germ	140-250					20
Wheat germ, pet. ether extr	450					20
Wheat germ, pressed	250	70 approx.				11
Wheat germ, pressed	230					20
Wheat germ, solvent extr	274	192				42a
Wheat germ, crude	420					85
Wheat germ, medicinal	320					85
Wheat germ	150-250					26c
Wheat germ, medicinal, cold pressed	300					71
Wheat germ, crude	400					5
Wheat germ, solvent extr	550					5
Wheat germ	....				5% of total	88
Wheat germ, Merit	268	161	107			73c
Influence of Processing on Tocopherol Content						
Cottonseed Oil						
Crude	102.8					71
Water-washed	102.0					71
Alkali-refined, bleached, filtered	100.7					71
Refined, bleached, filtered, deodorized	95.9					71
Refined, bleached, filtered, hydrogenated	98.3					71
Refined, bleached, filtered, hydrogenated, deodorized	97.6					71
Finished Commercial Products (From Oil Mixtures)						
Crisco, a hydrogenated vegetable shortening	104.2					71
Margarine Base Stock L (P&G)	100.5					71
Primex, a hydrogenated vegetable shortening	98.4					71
Sweetex, a hydrogenated vegetable shortening	101.0					71

** Since sesamol, present in sesame oil, gives the Emmerie-Engel test, the reliability of the data quoted here is uncertain (see paper presented by P. Budowski *et al.* at the 23rd Fall Meeting of the Am. Oil Chem. Soc., Chicago, 1949).

corn oils, approach in tocopherol content the range of wheat germ oil, the principal natural vitamin E-rich source. On the other hand, the typical tropical oils, such as coconut oil, appear to be lower in tocopherol. Animal tissues and fats generally are very low in the vitamin. However it is remarkable that human tissues appear to be higher in tocopherol than the reported figures for animal tissues. In fact, lipids isolated from certain tissues or organs of the human body may be as rich in tocopherol as vegetable oils from moderate climates.

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TABLE X

Tocopherols in Fruits and Vegetables
Survey of Tocopherol Distribution (73d)

Vegetable type	Principal forms of tocopherol	Total tocopherol in mg./100 g.
Root and stem	alpha	0.5-10.0
Wheat	beta, alpha	1.0- 2.0
Legumes; peas and beans	gamma	0.5- 4.0
Soybeans	delta, gamma	6.0-11.0
Leafy	alpha, gamma	0.1- 3.0
Seeds and cereals	alpha, gamma	1.0- 3.0

Material	Mg./100 g. material (normal moisture)		
	Total tocopherol	α	Reference
Alfalfa leaf meal	26		93a
Apples	....	0.74	76d
Apples	0.74	0.72	35a
Bananas	0.40	0.37	35a
Beans, white	4		26c
Beans, dried navy	3.60	0.10	35a
Beets, leaf meal	71		93a
Beets	<0.01		20
Beets	0.2		26c
Broccoli, leaf meal	42		93a
Cabbage, red	0.2		26c
Cabbage, white	0.7		26c
Cabbage	....	0.06	76d
Cabbage	0.11	0.06	35a
Carrot	1.5		26c
Carrot, root fresh (moisture-free)	13		93a
Carrot, top fresh (moisture-free)	56		93a
Carrot	0.45	0.45	76c,d
Celery	2.6		26c
Celery	0.48		76c
Celery	0.48	0.46	35a
Cocoa powder	3.1		26c
Grapefruit	0.26	0.25	35a
Kale	8		26c
Kale, leaf meal	39		93a
Lettuce	0.6		26c
Lettuce	0.16		57
Lettuce	0.43, 0.54	0.29, 0.29	35a
Lettuce, dry	9-35		52b
Lima beans, leaf meal	70		93a
Onion	0.2		26c
Onion	0.26	0.21	35a
Oranges	0.24	0.23	35a
Parsley	5.5		26c
Peanut	9.30	4.60	35a
Peas, fresh	0.030		57
Peas, canned, small	0.400		57
Peas, green	5.4-6.4		26c
Peas, gray	8.0		26c
Peas, green	2.10	0.10	35a
Potatoes, boiled	0.1		26c
Potatoes	....	0.06	76d
Potatoes, sweet	4.0	4.0	35a
Radish, black	0.04		26c
Rhubarb, leaf meal	120		93a
Rose hips, dry	20-50		20
Rose hips, petr. ether ext.	2300		20
Spinach, dry	50		20
Spinach	1.7		26c
Spinach, dry	4-24		52b
Spinach, fresh	0.510		57
Spinach, frozen (moisture-free)	43		93a
Spinach, leaf meal	40		93a
Sprouts, Brussels	1.7		26c
Tomatoes	0.36	0.27	35a
Tomatoes, purée	0.825		57
Turnip	0.02		26c
Turnip, leaf meal	30		93a
Turnip, greens	2.30	2.24	35a

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TABLE XI

Tocopherol in Cereals and Cereal Products ***

Material	Mg./100 g.		
	Total tocopherol	α	Reference
Barley	3.2-5.2		26c
Biscuit	2.4		26c
Bread, whole wheat	1.30		35a
Bread, brown	2.1		26c
Bread, white	1.4		26c
Bread, white	0.23		35a
Corn	10.0		26c
Corn, whole	3.0	0.3	11
Corn, meal, yellow	1.70	0.84	35a
Doughnuts	2.0		40
Doughnuts	2.52	0.78	35a
Groats	1.2		26c
Oats	2.1		26c
Oats, dry	0.8		11
Oats, flour	0.650		57
Oats, flakes	0.250		57
Oats, meal	2.10	1.94	35a
Rice	0.4		26c
Rice, brown	2.40	1.20	35a
Rice, polished	0.57	0.35	35a
Rye	2.2-3.5		26c
Soda Crackers	3.7		76c
Wheat, whole hard (mill product)	0.91		12
Wheat, patent flour	0.03		12
Wheat, 1st clear flour	1.46		12
Wheat, 2nd clear flour	2.87		12
Wheat, red dog	5.77		12
Wheat, shorts	3.18		12
Wheat, bran	0.30		12
Wheat, germ	15.84		12
Wheat, whole Durum (mill product)	1.08		12
Wheat, Semolina	0.26		12
Wheat, 1st clear flour	0.52		12
Wheat, 2nd clear flour	1.00		12
Wheat, red dog	1.73		12
Wheat, shorts	2.33		12
Wheat, bran	1.32		12
Wheat, germ	15-38		20
Wheat	2.6-3.4		26c
Wheat, white flour (80% extraction)	1.20		35a
Wheat, whole wheat flour	2.20		35a
Wheat, spaghetti	1.20		35a

*** For tocopherol content of miscellaneous foods see (35a).

D. Tocopherol Content in Animal Matter

TABLE XII

Tocopherol in Animal Fats and Oils, Meats, and Related Materials

Material	Mg./100 g. Total tocopherol	Mg./100 g. α	Reference
Beef, liver	0.95		46
Beef, liver	1.40	1.40	35a
Beef, muscle	0.59		46
Beef, muscle	0.33		52b
Beef, hypophysis, front lobe	2.6-3.0		52b
Beef, hypophysis, anterior lobe	0.9-1.1		52b
Beef, brain, white substance	2.3		52b
Beef, brain, gray substance	1.2		52b
Beef, serum	0.2-1.5		52a
Beef, blood plasma	0.582, 0.685		96
Beef, fat	1.0		52a
Beef, steak	0.63	0.47	35a
Beef, cow blood	0.45		36
Chicken	0.25	0.21	35a
Dog, plasma	0.56		85
Dog, serum	0.3		52a
Fish, liver	1.81		57
Guinea-pig, serum	0.15-0.25		52a
Haddock	0.39	0.35	35a
Herring, Baltic Sea	1.05		57
Hog, fat	0.22		46
Hog, ruffle fat	0.78, 2.87		17
Hog, leaf fat	0.67, 2.13		17
Hog, ham facing	0.53		17
Hog, back fat	0.64		17
Hog, lard	1.2		52a
Hog, lard	2.7	2.3 (<0.4 mg.γ)	35a
Hog, pork chops	0.71	0.63	35a
Hog, bacon	0.53	0.44	35a
Horse, muscle	0.53		46
Horse, heart	0.49		46
Horse, liver	1.32		46
Horse, kidney	0.63		46
Horse, serum	0.2		52a
Lamb, chops	0.77	0.62	35a
Rabbit, serum	0.45		52a
Rabbit, liver	0.92		41
Rabbit, muscle	0.80		41
Rabbit, muscle, leg	0.13-0.33		52b
Rabbit, brain	0.5-1.8		52b
Rabbit, lungs	1.0, 1.9		52b
Rabbit, heart	0.7-1.3		52b
Rabbit, spleen	1.0		52b
Rabbit, liver	0.9-1.4		52b
Rabbit, kidney	0.5, 0.7		52b
Rabbit, intestine	0.4-0.7		52b
Rabbit, stomach	0.6, 1.2		52b
Rabbit, skin	0.26		52b
Rabbit, fat	0.6		52b
Rat, muscle	1.18		22
Rat, muscle of old severely deficient males	0.75		22
Rat, muscle, male	0.75		17
Rat, liver	2.21		17
Rat, serum	0.20-0.25		52a
Rat, feces, stock diet	0		17
Rat, feces, tocopherol-supplemented diet	....		34a
Dairy Products and Eggs			
Butter	2.1-3.3		26c
Butter	2.1-2.5		57
Butter	2.40		35a
Butter, summer cow's butter fat	4.2		36
Butter, winter cow's butter fat	1.7-3.0		73b
Butter	....	2.4	76d
Cheese, 20% fat	0.6		26c
Cheese, American	1.00		35a
Milk, 2.5% fat	0.02		26c
Milk, powder	0.5		26c
Milk	0.056		57
Milk, summer cow	0.17		36
Milk, winter cow	0.08-0.15		73b
Milk, winter cow, fat	2.3		36
Milk, fat	2.99, 3.19		96
Milk, whole fluid	0.12		35a
Milk, evaporated	0.30		35a
Egg, boiled	3.0		26c
Egg, lipid	13.0	(4.4 mg.γ)	76b
Egg, whole	2.00	1.16	35a
Fish Liver Oils			
Cod	26		72
Mangona Shark	10	about 10	79

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TABLE XIII

Tocopherol in Human Tissues
Tissues of Two Healthy Human Subjects,
Killed in Accidents (75)

Subject	Tissue	Tocopherol content: Total, Tissue	Total, Fat	γ+δ, Tissue
		mg./100 g.	mg./100 g.	mg./100 g.
Male, 30 years old	Muscle, pect. major	1.32	20.9	<0.27
	Muscle, abdom. wall	0.62	15.9	<0.05
	Liver	2.49	40.7	<0.05
	Fat, abdom., subcut.	24.7	29.7	2.63
	Fat, abdom., subcut.	29.2	35.9	3.33
	Heart	1.11	33.1	<0.09
	Testis	2.83	121	<0.08
	Kidney	0.80	12.2	<0.19
	Pancreas	5.49	53.3	<0.13
	Lung	1.16	30.5	0.34(?)
	Spleen	1.88	75.7	0.56(?)
Female, 43 years old	Muscle, rect. abdom.	1.56	25.7	<0.11
	Muscle, psoas	3.80	87.7	1.02
	Liver	2.19	39.6	<0.14
	Fat, abdom., subcut.	49.5	60.5	18.6
	Fat, perirenal	39.2	62.6	11.5
	Heart	1.28	38.7	<0.14
	Uterus	1.47	116	0.31
	Kidney	3.32	72.7	0.85
	Pancreas	10.6	60.9	3.75
	Spleen	4.70	51.0	1.92

Estimated Content of Total Tocopherols in Human Subjects (75)

Tissue	Woman	Man
	mg.	mg.
Fat	6180	1885
Muscle	269	285
Blood	45	64
Liver	33	45
Pancreas	10	7
Spleen	7	4
Heart	4	3
Kidney	10	2
Uterus	2	
Lung	....	12
Testis		2
Total tissues investigated	6560	2309
Total on basis of 50 kilos body weight	8120	
Total on basis of 70 kilos body weight		3440

Total tocopherol content in human subjects, in mg./100 g. material

	Mg.	Reference
Serum	0.6-1.4	61
Serum	0.4-1.4	52a
Normal plasma	0.9-1.6 avg. 1.2	76a
Serum, from 12 healthy young individuals	0.59-1.62 avg. 0.96	94a
Blood serum from adults with amyolateral sclerosis	0.67	94b
Placenta	0.5	52b
Milk, 1st week after parturition	0.13-3.6	73b
Milk, fat, 1st week after parturition	7.6-180	73b
Milk, composite samples from 1st to 8th month of lactation	0.11-0.15	73b
Milk, fat, composite samples from 1st to 8th month of lactation	3.7-5.8	73b
Blood serum, in newborn	0.3	49
Blood serum, 2-13 months old	0.44	49
Blood serum, 1-3 years	0.8	49
Blood serum, 3-8 years	0.83	49
Blood serum, 8-16 years	0.94	49
Blood serum, over 20 years	0.87	49
Blood serum	0.54-1.90 avg. 1.07	73e
Plasma, from men and non-pregnant women	1.04, 1.05	35
Plasma, in 1st 24 weeks of pregnancy	1.17	90
Plasma, in 25th to 36th week of pregnancy	1.62	90
Plasma, in mothers at delivery	1.70	90
Cord blood at infant's birth	0.34	90
Plasma of newborn, female	0.355	90
Plasma of newborn, male	0.318	90

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A Laboratory Deodorizer for Fats and Oils[1]

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THE apparatus shown in Figure 1 has been found convenient and effective for steam deodorization of fats and oils under vacuum. The source of water vapor for deodorization is the 100 ml. glass bulb shown at (A). The amount of water evaporating from this bulb is controlled by the temperature of the water bath in which it is immersed (30°C. is usually adequate). The neck of the water reservoir bulb is joined to the flask inlet tube (B) by a 12/30 standard ground glass joint. The inlet tube carries a 1 mm. stopcock for further regulation of incoming water vapor and leads to the bottom of the deodorizer flask containing the heated fat or oil. Although the water vapor entering the flask provides violent agitation as it is superheated by contact with the hot fat, no difficulty with bumping is encountered if the flask and the fat are dry when deodorization is begun.

The flask is a 12 l. round bottom three-necked container with 24/40 joints on the side necks and a 29/42 center joint. It is heated in a 12 l. hemispherical Glas-Col mantle, and the upper hemisphere of the heating mantle may also be used to minimize reflux. A safety glass shield is placed in front of the flask when the apparatus is in operation.

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