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VITAMIN E CONTENT OF FOODS [1]

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Information regarding the vitamin E content of a variety of American foods has not been available. Consequently, we are presenting results obtained in our laboratory in the past 4 years, during which time we have analyzed commonly used foods for total tocopherols and for α-tocopherol, utilizing chemical procedures recently described (Quaife and Harris, '48). Incidentally, using these new values for vitamin E in foods, we have made an estimate of the average per capita consumption of total tocopherols and of α-tocopherol in the United States.

METHOD

The foods in this survey were purchased on the open market in Rochester, New York. Except for bakery products, they were analyzed in their raw state, following such treatment as would be given them in the home prior to cooking, i.e., washing, peeling, and removal of inedible portions.

The chemical procedures used for determining total tocopherols and γ- plus δ-tocopherols in plant and animal tissues have been described in detail by Quaife and coworkers ('48, '49). The difference between total and γ- plus δ-tocopherol values was used as the measure of α-tocopherol content except in wheat products, where β-tocopherol is known to occur. Values reported are the means of quadruplicate analyses.

[1] Communication no. 164.

RESULTS

Fruits

It is interesting to note (table 1) that essentially all of the vitamin E in those fruits tested occurs as α-tocopherol. Practically no γ- or δ-tocopherol was found. However, the quantity

TABLE 1

Tocopherol content of fruits and vegetables

FOOD	TOCOPHEROL CONTENT					
	mg/100 gm fresh material			% of total tocopherols	mg/gm extracted lipid	
	Total	γ + δ	α	α	*Total*	α
Fruits:						
Apples	0.74	< 0.02	0.72	> 97	3.3	3.2
Bananas	0.40	< 0.03	0.37	> 93	2.3	2.1
Grapefruit	0.26	< 0.01	0.25	> 96	1.6	1.5
Oranges	0.24	< 0.01	0.23	> 96	1.5	1.4
Vegetables:						
Beans, dried navy	3.60	3.50	0.10	3	1.5	0.1
Cabbage	0.11	0.05	0.06	55	0.7	0.4
Carrots	0.45	0.00	0.45	100	2.1	2.1
Celery	0.48	< 0.02	0.46	> 96	5.4	5.2
Lettuce, head 1	0.43	0.14	0.29	67	2.6	1.7
Lettuce, head 2	0.54	0.25	0.29	54	..	..
Onions	0.26	0.05	0.21	81	3.6	2.9
Peas, green	2.10	2.00	0.10	5	2.6	0.1
Potatoes, white, peeled	0.06	...	...	..	1.2	..
Potatoes, sweet	4.0	0.0	4.0	100	5.7	5.7
Tomatoes	0.36	0.09	0.27	75	6.7	5.0
Turnip greens	2.30	< 0.06	2.24	> 97	4.2	4.1

of α-tocopherol in an average serving of these fruits is quite low, 0.23 to 0.72 mg, and this category of foods must be rated as a rather poor source of vitamin E.

Vegetables

In generalizing about the total tocopherol content of the vegetables shown in table 1, one would consider that they are better sources of vitamin E than fruits, since they range in

concentration up to 2.30 mg per 100 gm for turnip greens and 3.60 mg for dried navy beans. However, with regard to their α-tocopherol content, most vegetables fall in the range from 0.06 to 0.45 mg per 100 gm, and are thus similar to fruits as sources of vitamin E activity. An exception is turnip greens, which appear to be an excellent vegetable source of vitamin E, with 2.24 mg of α-tocopherol per 100 gm.

The tocopherols of certain vegetables — turnip greens, carrots, and celery — are almost 100% in the α-form. The tocopherols in legumes, navy beans and peas, contain practically no α-tocopherol, while in other vegetables α-tocopherol represents from 50 to 80% of the total tocopherols.

It is interesting to note that the α-tocopherol content of the present samples of celery, sweet potatoes, and tomatoes, when expressed on the basis of lipid content, is surprisingly high. Thus many vegetable oils may be considerably richer in vitamin E content than wheat germ oil.

Emmerie and Engel ('43) reported essentially the same range of values for vegetables in Holland as that shown in table 1. Their samples of carrots and celery, however, were three to 4 times richer in total tocopherols. In addition, they found kale with 8.0 mg and parsley with 5.5 mg of total tocopherol per 100 gm to be among the richest vegetable sources of tocopherol.

Potatoes, both in Holland and in this country, are low in vitamin E potency. Emmerie and Engel's value of 0.1 mg and the value in table 1 of 0.06 mg of total tocopherols per 100 gm establish this widely used vegetable as a poor source of vitamin E.

Cereals and bakery products

The foods in this classification are generally considered the richest sources of vitamin E in man's diet. And it is evident from table 2 that the α-tocopherol content of whole grain cereals is relatively high, ranging from 0.84 mg per 100 gm for corn to 1.94 mg for oats. East Indian unpolished rice (Engel

and deVries, '46) and Dutch oatmeal, barley and rye (Emmerie and Engel, '43) are probably also in this range, judging from their high total tocopherol values.

TABLE 2

Tocopherol content of cereal and bakery products

FOOD	TOCOPHEROL CONTENT					
	mg/100 gm fresh material			% of total tocopherols	mg/gm extracted lipid	
	Total	$\gamma + \delta$	α	α	*Total*	α
Cereals:						
Cornmeal, yellow	1.70	0.86	0.84	49	1.7	0.8
Farina (breakfast food)	1.60	...	...	..	1.9	..
Oatmeal	2.10	0.16	1.94	92	0.3	0.2
Rice, brown	2.40	1.20	1.20	50	1.1	0.6
Rice, polished	0.57	0.22	0.35	61	1.2	0.7
Rice, polished, converted	0.23	...	...	..	0.8	..
Wheat, white flour (80% extraction)	1.20	...	...	..	0.9	..
Wheat, whole wheat flour	2.20	...	...	..	1.4	..
Wheat, spaghetti	1.20	...	...	..	1.3	..
Bakery products:						
Bread, white	0.23	...	...	..	0.2	..
Bread, whole wheat	1.30	...	...	..	0.8	..
Cake, light, unfrosted 1	9.65	7.06	2.59	27	0.5	0.1
Cake, light, unfrosted 2	8.42	4.03	4.39	52	0.6	0.3
Cookies, sugar 1	6.86	4.87	1.99	29	0.7	0.2
Cookies, sugar 2	9.97	4.96	5.01	50	0.7	0.3
Cookies, chocolate marshmallow	4.82	3.40	1.42	29	0.3	0.1
Cookies, tea, mixed	8.74	4.92	3.82	44	0.5	0.2
Crackers, soda	3.70	...	...	..	0.3	..
Doughnuts	2.52	1.74	0.78	31	0.1	0.04
Pie, apple 1	0.20	< 0.04	0.16	> 80	0.02	0.02
Pie, apple 2	0.29	0.10	0.19	66	0.04	0.03
Pie, apple 3	2.20	1.40	0.80	36	0.3	0.1
Pie, lemon cream	7.64	4.90	2.74	36	0.6	0.2
Pie shell, baked	0.87	0.38	0.49	56	0.2	0.1

The tocopherols of oatmeal are almost all α-tocopherol, whereas in most other cereals only about half the tocopherols are in the α- form. However, it was practically impossible to analyze wheat and wheat products for non-α-tocopherol content because of an anomalous color reaction which they give with diazotization reagents. Consequently only total tocopherol values are reported for wheat products, although from bioassay data we estimate that about 50 to 60% of the tocopherols present are in the α- form.

The very great loss of vitamin E due to the processing of cereals is illustrated in table 2 by the tocopherol values of rice and wheat. The consumer of polished rice obtains only about one-quarter of the vitamin E that he would from brown, unpolished rice. Engel ('46) reports a similar value, one-sixth, as a measure of the vitamin E retained in rice after polishing. Whole wheat flour loses about half its total tocopherol content when milled to white flour such as was used (80% extraction) in wartime in this country. If comparison were made between white and whole wheat breads using the tocopherol values reported in table 2, it would be concluded that whole wheat bread supplies a much more significant portion of the total daily intake of vitamin E. Assuming a daily consumption of 200 gm (8 slices) of bread, the use of white bread would supply only 0.46 mg of tocopherols, whereas whole wheat bread would furnish 2.60 mg.

Similar conditions exist in Holland. Both wheat and rye flour (80% extraction) possess only one-half to one-third the vitamin E of the whole grain from which they were milled. Furthermore, the bleaching of flour with NCl_3[2] and benzoyl peroxide destroys as much as 70% of the remaining vitamin E in wheat, rye, and barley flour (Engel, '42).

The vitamin E content of bakery products varies both because of variable losses due to the cooking process used and because of the type of ingredients used in the recipe. All of the cakes, cookies and pies listed in table 2 were commercial bakery products obtained from grocery stores and bakeries,

[2] Agene.

and no information was available concerning their composition. It is evident from the tocopherol content of these products, expressed on a fat basis (0.02 to 0.74 mg tocopherols/gm of fat), that lard, vegetable shortenings, and mixtures of animal and vegetable fats could have been and probably were used as ingredients. The destruction of vitamin E by the baking process is probably relatively slight although the extent of destruction cannot be ascertained from these data.

However, deep-fat cooking can destroy considerable vitamin E, as is exemplified by our results obtained with doughnuts. Samples of both doughnuts and cooking fat were obtained from a small commercial doughnut bakery where baking operations were typical of this industry. The shortening used as an ingredient in the doughnut recipe and to refill the cooking vat was a good quality, partially hydrogenated vegetable oil containing 92.8 mg of tocopherols per 100 gm. At the start of the day's cooking operation, this shortening was added to the fat remaining in the cooking vat from the previous day's baking. A sample of this mixture contained 19.4 mg of tocopherols per 100 gm. The fat from doughnuts in the first batch cooked showed a tocopherol concentration of only 12.1 mg/100 gm. At the end of the day a sample of fat from the cooking vat had a tocopherol content of 10.7 mg/100 gm, and the fat from doughnuts baked in the last batch contained 6.8 mg/100 gm. The extent of the loss of tocopherol due to deep-fat cooking is not merely from 19.4 mg %, the potency of the fat in the cooking vat, to 6 to 12 mg %, the fat in the cooked doughnuts, but must be measured from a value somewhere between 19.4 mg % and 92.8 mg %, the concentration of tocopherol in the shortening used in the doughnut dough.

Meats, fish, poultry and dairy products

It is evident from an examination of table 3 that foods in this category are relatively poor sources of vitamin E, with

the exception of eggs. Two eggs will supply 2.4 mg of tocopherol, about 60% of which is α-tocopherol.

The low tocopherol content of animal tissues may reflect loss during and after processing, since many fresh animal tissues obtained from animals on diets containing a minimum of vitamin E have shown a tocopherol content as high as 10 times the values in table 3. Stored tissues oxidize quickly and lose vitamin E, even though stored at low temperatures (Chipault, Lundberg and Burr, '45; Quaife and Dju, '49). The

TABLE 3

Tocopherol content of meats, fish, poultry and dairy products

FOODS	TOCOPHEROL CONTENT					
	mg/100 gm fresh material			% of total tocopherols	mg/gm extracted lipid	
	Total	$\gamma + \delta$	α	α	*Total*	α
Meats:						
Bacon	0.53	< 0.09	0.44	> 83	0.01	0.01
Beef, steak	0.63	< 0.16	0.47	> 75	0.02	0.02
Beef, liver	1.40	0.00	1.40	100	0.3	0.3
Lamb, chops	0.77	< 0.15	0.62	> 81	0.03	0.02
Pork, chops	0.71	< 0.08	0.63	> 89	0.03	0.03
Fish:						
Haddock	0.39	< 0.04	0.35	> 90	0.7	0.6
Poultry:						
Chicken	0.25	< 0.04	0.21	> 84	0.05	0.04
Eggs, whole	2.00	0.84	1.16	58	0.2	0.1
Dairy products:						
Butter	2.40	...	...	..	0.03	..
Cheese, American	1.00	...	...	..	0.02	..
Ice cream, vanilla	0.30	...	...	..	0.05	..
Milk, whole fluid	0.12	...	...	..	0.03	..
Milk, evaporated	0.30	...	...	..	0.04	.

low tocopherol values in this category are probably also due to the low dietary intake of the animals, since the vitamin E content of eggs, and of the other animal products too, has been shown to be dependent upon the level of vitamin E in the feed of the chicken, turkey, pig, and rabbit (Chipault, Lundberg and Burr, '45; Major and Watts, '48). When the level of vitamin E feeding is low, seasonally or by locality,

the food products from the animals will be correspondingly low, and vice versa.

The relatively high value for the vitamin E content of fat from haddock, as shown in table 3 and in Jansen and Kringstad's report ('42) that sardines have 4.5 mg tocopherol/100 gm (0.45 mg/gm of fat), suggests that fish may be a rich source of this vitamin. However, except for sardines and cod roe, other fish are reported (Jansen and Kringstad, '42; Kringstad and Folkvord, '49) to be lower in tocopherol content and, in general, in the same range as mammalian meats and poultry; e.g., salmon and mackerel 1.6 to 1.8 mg %, and herring 0.5 mg %.

Abderhalden ('47) reported an average concentration of 0.06 mg % of tocopherols in cows' milk, with a range of from 0.02 to 0.10 mg %. Milk in the Netherlands has been reported to contain 0.02 mg of tocopherol per 100 gm (Emmerie and Engel, '43). The value in table 3 of 0.12 mg per 100 gm is higher than those reported abroad and is explained on the basis of probable differences in the tocopherol level in the feed of the cows, although differences in the analytical procedures used may provide a partial explanation. In general, however, it may be concluded that cows' milk is a relatively poor source of vitamin E. One quart of milk would furnish only about 0.5 mg of tocopherol.

The processing of milk to make cheese, butter, or evaporated milk apparently does not destroy vitamin E. The tocopherol content of these products is similar to that of milk when expressed on a comparable basis (table 3) — 0.02 to 0.04 mg of tocopherols per gram of fat.

Oils and fats

An examination of table 4 reveals a remarkable difference in the vitamin E content of fats and oils of vegetable origin compared with those of animal origin. The former with few exceptions are rather good sources of vitamin E, while animal fats are uniformly quite poor sources. Several oils —

TABLE 4

Tocopherol content of oils and fats

FOOD	TOCOPHEROL CONTENT						
	mg/100 gm of sample			% of total	Literature values		
	Total	*γ + δ*	*α*	*α*	*Total mg/100 gm*	*α, % of total*	*Reference*
Vegetable							
Coconut	8.3	4.7	3.6	43	..	..	
Coconut, hydrogenated	..	..	..	..	3	..	Quackenbush et al., '41
Corn, refined	87	80	7	8	250	..	Emmerie and Engel, '43
					90	10	Fisher, '45
					102	13	Quaife, '48
Cottonseed, refined	90	34	56	62	83	62	Hove and Hove, '44
					87	57	Quaife, '48
					91	71	Fisher, '45
Margarine,[1] clarified	54	26	28	52	8.9	..	Lundborg, '45
Olive	6.9	..	..	..	3	..	Emmerie and Engel, '43
Palm	56	26	30	54	44	..	Kofler, '43
					110	..	Emmerie and Engel, '43
Peanut, refined	22	11	11	50	26	..	Emmerie and Engel, '43
					36	63	Hove and Hove, '44
					11.2	..	Lundborg, '45
					48	50	Fisher, '45
					26.8	..	Tosić and Moore, '45
Rice bran	..	..	..	..	91	64	Fisher, '45
Soybean, refined	140	130	10	7	97	22	Fisher, '45
					23.4	..	Lundborg, '45
					125	..	Quackenbush et al., '41
					92	10	Hove and Hove, '44
					120	..	Emmerie and Engel, '43
					74	13	Quaife, '48
Wheat germ	..	..	..	..	150–250	..	Emmerie and Engel, '43
					274	70 [2]	Hove and Hove, '44
					268	60 [2]	Quaife, '48
					312	..	Tosić and Moore, '45
Animal							
Butter (80% fat)	2.4	..	..	..	2.5	..	Kofler, '43
					2.1–3.3	..	Emmerie and Engel, '43
Lard	2.7	< 0.4	2.3	> 85	1.0	..	Kofler, '43
					0.5	..	Chipault et al., '45
Shark liver	..	..	..	..	4–10	..	Robeson and Baxter, '43

[1] Margarines may be rich or poor sources of vitamin E, since they may have been manufactured from vegetable oils, animal fats, or mixtures of vegetable and animal fats.

[2] Remainder practically all β-tocopherol.

coconut, olive, and sesame — have relatively low concentrations of tocopherol, 3 to 18 mg per 100 gm, compared with other vegetable oils, but neverthless they are still superior to butter and lard with respect to vitamin E.

Soybean oil, as is characteristic of leguminous seed oils, and corn oil have only about 10% of their total tocopherols as α-tocopherol, whereas cottonseed, peanut, rice bran and

TABLE 5

Tocopherol content of miscellaneous foods

FOOD	TOCOPHEROL					
	mg/100 gm fresh material			% of total tocopherols	mg/gm of extracted fat	
	Total	γ + δ	α	α	*Total*	α
Chocolate, unsweetened	11.10	5.80	5.30	48	0.2	0.1
Cocoa (Emmerie and Engel, '43)	3.1	...	...	..	..	..
Peanuts	9.30	4.70	4.60	49	0.2	0.1
Potato chips	3.22	1.08	2.14	67	0.1	0.1
Pudding,[1] chocolate	0.69	0.0	0.69	100	0.3	0.3
Pudding,[1] vanilla	0.31	0.0	0.31	100	2.1	2.1
Yeast, dried brewers'[2]	0.0	0.0	0.0	...	..	..

[1] As purchased in dry powdered form.

[2] Yeast is devoid of vitamin E potency, as is evidenced by its use at a 10% level in the basal diet used in the standard vitamin E bioassay procedure. However, yeast fat does have reducing substances present which are measured as apparent tocopherols by the chemical method.

wheat germ oils have from 55 to 70% of their total vitamin E as α-tocopherol. The samples of margarine tested apparently were manufactured largely from vegetable oils, judging by the relatively high concentration of total tocopherols. Also, because of the low value found for the ratio of α- to total tocopherol, these oils were probably soy or corn oils, or both.

Miscellaneous

A knowledge of the concentration of tocopherol in the miscellaneous list of foods in table 5 is helpful in making dietary analyses for vitamin E. Chocolate is the only food on the list especially rich in this vitamin. Chocolate as candy bars, which sometimes make up as much as 10% of the caloric content of diets (McCay et al., '45), would supply an appreciable and probably significant quantity of α-tocopherol to the consumer.

The high value for peanuts (table 5), 9.3 mg of tocopherols per 100 gm, of which about 50% is α-tocopherol, establishes it as an excellent food source of vitamin E and arouses interest in the vitamin E content of other nuts. Lundborg ('45) found 11.2 mg of total tocopherol per 100 gm of peanuts, and Emmerie and Engel ('43) report high tocopherol values for beechnut and palm oils, indicating that the original nuts were probably rich sources of vitamin E.

DISCUSSION

With values available for the vitamin E content of foods, it is a temptation to evaluate various standard diets to obtain an estimate of the human daily intake of this vitamin, or more significantly, of α-tocopherol. Hickman and Harris ('46) have already speculated that the daily dietary intake for individuals may range between 1.5 and 44 mg of *d*, α-tocopherol (3 to 88 mg of mixed natural tocopherols), depending upon socio-economic status. In Holland, Engel ('46) calculated that an average of 15.7 mg (a range of from 10.7 to 23.9 mg) of total tocopherols were consumed daily. This amounts to about 8 mg of *d*, α-tocopherol, assuming that approximately 50% of the natural mixed tocopherols in foods are in the α- form. Quaife, Swanson, Dju and Harris ('49) reported an estimated daily intake of α-tocopherol of from 4 to 9 mg for individuals on reducing, low-sodium, or diabetic-type diets, or those receiving only the basic foods recommended by the National Research Council. For in-

dividuals on a "fattening" diet, an intake of from 10 to 27 mg of α-tocopherol was estimated.

A slightly different approach to an estimation of per capita food consumption may be made from data compiled by the United States Department of Agriculture ('44). The sum total of all of the foods sold commercially in the United States, divided by the population, gives values for each of

TABLE 6

Vitamin E content of the average daily per capita food consumption in the U. S. in 1948 (U.S.D.A., '49)

COMMODITY	AVERAGE CONSUMPTION	VITAMIN E INTAKE	
		Total tocopherol	α-Tocopherol
	gm/day	*mg/day*	*mg/day*
Fats and oils, incl. butter	80.8	14.42	7.87
Grain products	212.5	2.85	1.78
Meat, poultry and fish	196.4	1.17	0.99
Potatoes and sweet potatoes	142.9	0.87	0.84
Eggs	58.4	1.16	0.68
Dairy products, excl. butter	535.6	0.58	0.58
Green leafy and yellow vegetables	141.7	1.15	0.50
Dried peas, beans and nuts	19.9	1.23	0.43
Citrus fruits and tomatoes	130.5	0.38	0.35
Other vegetables and fruits	290.8	0.17	0.12
Coffee, tea and cocoa	23.6	0.13	0.06
Sugar and syrups	131.7	0.00	0.00
Totals	1,964.8	24.12	14.20 (59% of total tocopherols)

the foods which, if used as consumption values, must be accepted as maximum. This is true because much of the foodstuff sold is not actually consumed but is lost during transportation or display in retail stores, or wasted during preparation and cooking. Nevertheless, the average individual food consumption calculated in this way would furnish about 19 mg (17.5 I. U.) of α-tocopherol daily. Thus, this value would seem to be the maximum obtainable by the

average American. More recent government values for average per capita food consumption (U. S. Dept. of Agriculture, '49) indicate that 14 mg (13 I.U.) of α-tocopherol is a more likely value for the mean daily intake of vitamin E, since it is based on directly measured per capita food consumption as shown in table 6.

SUMMARY AND CONCLUSIONS

Commonly used foods, typified by those available in Rochester, N. Y., have been chemically analyzed for their total tocopherol and α-tocopherol content.

On the basis of the results obtained, the average per capita consumption of vitamin E in the United States has been estimated as 14 mg of *d*, α-tocopherol (13 I.U.) daily.

The richest dietary sources of vitamin E are certain of the vegetable oils. Cereal products and eggs are next in order of nutritional importance. Vegetables supply very little of the daily intake of vitamin E, both because of their low concentration of total tocopherols and because in most instances a large portion of the tocopherols present are the relatively inactive, non-α-tocopherols. Animal products, similarly, are rather poor sources of vitamin E because of their quite low and variable concentration of total tocopherols, practically all of which, however, is α-tocopherol.

The tocopherol concentration in animal products is probably directly proportional to the level of vitamin E in the diet of the animals from which they come and, inversely, to the severity of processing and length of storage to which they are subjected.

The value of cereal products as a source of vitamin E certainly depends upon the extent and severity of the milling process which they undergo prior to consumption.

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