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Food Groups as the Source of Retinoids, Carotenoids, and Vitamin A in Finland

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Summary: The average retinoid, carotenoid, and vitamin A (RE, retinol equivalents) intake of the Finnish population was determined. The food consumption data were derived mainly from the national food balance sheets (for 1987). In this study, the average Finnish diet was composed twice a year, and the retinoid and carotenoid composition was analysed using high-performance liquid chromatography (HPLC). The intake of retinoids and carotenoids was also calculated using the most recent Finnish analytical data on food composition. The vitamin A content of beef, chicken and pork liver, all of which contribute of the vitamin A intake, at different times of the year was determined. The β-carotene intake in Finland varied between 1700 and 2100 μg/day, depending on the season. It is obvious that liver consumption plays a significant role in the vitamin A intake. Since the concentration of retinoids in liver, and especially in pork liver, is extremely high, the average vitamin A intake of the Finnish population may exceed 3000 RE/day. If liver consumption (3.7 g/day) is excluded, the average daily vitamin A intake in Finland is 970–1200 RE, a value in better agreement with the recommended daily allowances.

Introduction

According to the results of basic dietary surveys carried out in Finland during the 1967–1976, the daily vitamin A intake of Finnish men was between 1180 and 1650 RE (retinol equivalents) and that of women 1280–1590 RE [6, 12, 20]. It was reported later that the average vitamin A intake of men and women was 1320 and 1190 RE/day, respectively [23]. However, because high-performance liquid chromatography (HPLC) has improved the methods for analysing carotenoids and retinoids revised data on vitamin A intake in Finland are needed.

In the present study, national food consumption data (food balance sheets) were preferred to dietary recall or records, since vitamin A is a nutrient requiring, on the average, 433 days [2] in order to predict individual's usual intake. Because liver, carrot and butter usually contribute the most to vitamin A intake in the western world [18],

information is needed about the impact of the seasonal variation of carotenoids and retinoids in these particular foods. The carotenoid content in different cultural varieties of carrot (*Daucus carota* L.) [7] as well as the seasonal variation of the carotenoid content in carrot [11] have been reported elsewhere. In this study, the vitamin A content of beef, chicken and pork liver and of butter was determined at different times of the year.

This study also included tocopherol, tocotrienol, fat and fatty acid, cholesterol, protein and amino acid, and selenium composition analyses of the average Finnish diet. These data will be reported elsewhere.

Materials and Methods

Diets

The average food consumption data of the Finnish population (4.9 million) were derived mainly from the food balance sheets for 1987 [1]. More detailed information was obtained from the national household survey, from the foreign trade figures, from agricultural organizations and fisheries, on the basis of cereal milling practices, from the meat industry, and from the food industy. The total number of food items included in the average Finnish diet was 75. Only the edible part of the food was taken into account. The food items not included in the average diet were sugar, honey, molasses, beverages, dried peas, and nuts, all of these being food items with no or minor value as a source of vitamin A. The average daily energy consumption was 11.7 MJ.

The sampling system was a so-called market basket method designed to produce composite samples of each of the 75 food samples. Most of the food samples represent a composite of eight to ten subsamples of commercial products bought from eight to ten different stores of four wholesale food chains in the Helsinki area. Fillets of Baltic herring, sea perch and rainbow trout were obtained from Kalakomppania Ltd, Helsinki. The amount of industrially used margarines consumed daily was a gift from Raision Tehtaat Ltd, Turku and Paasivaara Ltd, Helsinki; a pooled sample of six margarines was formed. Pork liver was obtained from the local slaughterhouse. The edible part of the food items was then combined, according to the daily food consumption, to form seven food groups and to form the whole diet.

In order to estimate the seasonal variation of the intake of retinoids and carotenoids, the composition of the average diet and the analyses were done both in spring (April–May) and autumn (August) of 1989. For comparison, the retinoid and carotenoid intake was calculated using the most recent Finnish analytical data [8–11, 14–16].

Liver and butter

Beef, chicken and pork liver and butter were purchased several times during one year. Beef and chicken livers were acquired in the same way the diet samples. Pork liver was obtained from the local slaughterhouse, and butter was a gift from the Valio Finnish Cooperative Dairies Association, Helsinki.

Analytical Methods

The carotenoids (α-carotene, β-carotene, lutein and lycopene) and retinoids (all-*trans*-retinol, 13-*cis*-retinol and 3,4-didehydro-retinol) were isolated from diets and foods by room temperature saponification, which was followed by solvent extraction. The composition of carotenoids and retinoids was determined using high-performance liquid chromatography (HPLC). The methods used have been described by HEINONEN *et al* [8–11] and OLLILAINEN *et al* [14–16]. The individual values of carotenoids and retinoids were converted into retinol equivalents (RE) according to the Food and Nutrition Board [5] (see Tab. I and II).

Table I: Food groups as the source of carotenoids and retinoids (μg/100 g), and vitamin A (RE, μg/100 g) in Finland.

Food group		Lutein	α-Carotene	β-Carotene	Lycopene	All-trans-retinol	13-cis-retinol	3,4-Didehydro-retinol	RE[1]
Cereals	s[2]	190	–[3]	–	–	–	–	–	–
	a[4]	160	–	–	–	–	–	–	–
Vegetables	s	tr[5]	170	570	84	–	–	–	110
	a	20	250	610	110	–	–	–	110
Fruits and berries	s	29	–	61	–	–	–	–	10
	a	25	29	62	–	–	–	–	13
Meat, with liver	s	–	–	67	–	590	12	–	610
	a	–	–	27	–	740	23	–	760
Meat, without liver	s	–	–	tr	–	12	tr	–	12
	a	–	–	tr	–	12	–	–	12
Fish	s	7.1	–	–	–	42	8.0	–	48
	a	8.0	–	–	–	30	13	27	51
Dairy products and egg	s	16	–	tr	–	40	–	–	40
	a	16	–	25	–	60	5.3	–	68
Dietary fats	s	14	–	220	–	630	12	–	680
	a	17	–	310	–	600	37	–	680
Whole diet	s	44	14	43	–	130	21	–	150
	a	36	31	92	–	92	9.1	–	120

[1] Retinol equivalents, μg/100 g = μg all-trans-retinol + 0.75 (μg 13-cis-retinol) + 0.40 (μg 3,4-didehydro-retinol) + 0.167 (μg β-carotene) + 0.083 (μg α-carotene)
[2] analyzed in spring
[3] not detected at a detection limit of 0.5 μg/100 g
[4] analyzed in autumn
[5] traces

Results and Discussion

Food intake based on food balance sheets is slightly overestimated because the household food losses and wastes are not substracted from the intake data. In Sweden, BECKER and JONSSON [3] estimated that this food waste was at maximum 10–15%. However, this figure includes the unedible part of food, such as meat bones, vegetable skins, fruit peels, and egg shells, which were excluded in the present study. The effect of food processing, which most likely diminishes the intake value of vitamin A, was not included in the calculations.

The retinoid and carotenoid data is presented both on the weight basis, μg/100 g (Tab. I) and on the daily intake basis (Tab. II). According to this study, it can be stated that the results of the food composition study [8–11, 14–16] are up-to-date and accurate. The calculated intakes of vitamin A (3100 RE/day) and β-carotene (2000 μg/day) were in accordance with the analytical values (2300–3100 RE/day and 1700–2100 μg/day, respectively) (Tab. II).

Using food balance sheets (for 1985) and specific food composition tables compiled at the Department of Nutrition, University of Helsinki, MANNI [13] calculated that the vitamin A intake of the Finnish population was 3000 RE/day. The vitamin A intake value (2300–3100 RE/day, depending on the season) of the present study is in accor-

Table II: Food groups as the source of carotenoids and retinoids (μg/day), and vitamin A (RE, μday) in Finland. The intake was both calculated using the most recent food composition data [8–11, 14–16] and analyzed twice a year

Food group		Lutein	α-Carotene	β-Carotene	Lycopene	All-trans-retinol	13-cis-retinol	3,4-Didehydro-retinol	RE[1]
Cereals (200[4])	s[2]	390	–[3]	–	–	–	–	–	–
	a[5]	310	–	–	–	–	–	–	–
	c[6]	430	–	8.3	–	–	–	–	1.4
Vegetables (263)	s	tr[7]	460	1500	220	–	–	–	290
	a	53	650	1600	300	–	–	–	320
	c	200	97	1700	–	–	–	–	290
Fruits and berries (186)	s	54	–	110	–	–	–	–	18
	a	47	53	110	–	–	–	–	23
	c	88	9.6	49	–	–	–	–	9.0
Meat, with liver (149)	s	1.2	–	8.7	–	2100	36	–	2100
	a	–	–	40	–	1100	34	–	1100
	c	1.2	–	29	–	2200	35	–	2200
Meat, without liver (145)	s	–	–	tr	–	17	tr	–	17
	a	–	–	tr	–	18	–	–	18
	c	–	–	11	–	26	–	–	28
Fish (51)	s	3.6	–	–	–	21	4.0	–	24
	a	4.0	–	–	–	15	6.3	14	25
	c	–	–	–	–	4.1	–	3.6	5.6
Dairy products and egg (709)	s	110	–	tr	–	270	–	–	270
	a	110	–	180	–	430	38	–	490
	c	180	–	130	–	310	27	–	350
Dietary fats (54)	s	7.8	–	120	–	340	6.5	–	360
	a	9.0	–	170	–	320	20	–	360
	c	–	–	120	–	270	–	–	290
Total, with liver (1612)	s	570	460	1700	220	2700	47	–	3100
	a	530	700	2100	300	1900	98	14	2300
	c	900	110	2000	–	2800	62	3.6	3100
Total, without liver (1608)	s	570	460	1700	220	650	11	–	990
	a	530	700	2100	300	780	64	14	1200
	c	900	110	2000	–	630	27	3.6	970
Whole diet (1612)	s	710	230	690	–	2100	330	–	2500
	a	580	500	1500	–	1500	150	–	1900
	c	890	110	2000	–	2800	63	–	3200

[1] Retinol equivalents, μg/100 g = μg all-trans-retinol + 0.75 (μg 13-cis-retinol) + 0.40 (μg 3,4-didehydroretinol) + 0.167 (μg β-carotene) + 0.083 (μg α-carotene)

[2] analyzed in spring

[3] not detected at a detection limit of 0.5 μg/100 g

[4] amount consumed, g/day

[5] analyzed in autumn

[6] calculated values

[7] traces

dance with her results. On the other hand, market basket studies yield higher intake values than studies [6, 12, 20, 22] using dietary recall or dietary history. In addition, in MANNI's [13] study the high intake value most likely resulted from overestimation of the offal consumption in the food balance sheets, and was not caused by the extremely high retinoid content of liver. In the present study, preformed vitamin A accounted for 82–90% (1900–2800 RE) of the total daily intake of vitamin A in Finland.

It is obvious that liver consumption plays a significant role in the vitamin A intake. It also seems that the vitamin A value in liver has been grossly underestimated in many food composition tables [14, 17, 19, 21]. Although the amount of liver consumed daily (3.7 g) is small, liver contributes to ca. 40–70% of the average vitamin A intake in Finland. The vitamin A (retinoid) content of pork liver, in particular, is extremely high (31.9–97.6 mg/100 g), and seems to vary from one season to another (Tab. III). On the other hand, it should be noted that these liver samples represented only southern Finland and therefore these values might not correspond to the Finnish average. The most probable reason for this high amount lies in the feeding practices of animals: pigs are fed overdoses of vitamin A.

If the liver consumption is ignored, the average daily vitamin A intake in Finland is 970–1200 RE. This amount agrees better with the recommended dietary allowances [4, 5]. Dairy products and eggs, dietary fats and vegetables provide 95% of the daily intake of vitamin A (Fig. 1). Apart from liver, the most important dietary sources of vitamin A in Finland are carrot and butter. In carrot, the vitamin A value ranges from 1200 to 2300 RE (μg/100 g), depending on the time of the year and the cultural variety [7, 11]. On the contrary, the vitamin A concentration in butter (Tab. IV) varies only little throughout the year. If liver is excluded from the calculations, carrot carotenoids account for one-fourth and butter carotenoids and retinoids for one-fifth of the total vitamin A intake of Finns.

When a large amount (1612 g) of 75 different food items is mixed together and then analysed for carotenoids and retinoids, the values obtained most likely are smaller than those for individual food items or food groups. This was clearly evident when the intake values of β-carotene were investigated (Tab. II). According to the individual food group analyses, the β-carotene intake varied from 1700 to 2100 μg/day, but the whole diet

Table III: The vitamin A content of liver at different times of the year (RE, retinol equivalents, mean and standard deviation)

Month	Vitamin A (RE, mg/100 g ± SD fresh weight)		
	Chicken liver	Beef liver	Pork liver
October	–	28.2 ± 2.5	86.7 ± 5.2
December	–	39.3 ± 1.7	–
March	–	18.4 ± 1.7	97.6 ± 13.7
April	33.2 ± 0.8	19.6 ± 0.4	–
June	–	22.9 ± 0.2	39.4 ± 0.3
August	40.0 ± 1.1	28.2 ± 1.0	31.9 ± 0.3
September	–	32.1 ± 1.2	57.3 ± 1.3
Mean value	36.6	27.0	62.6

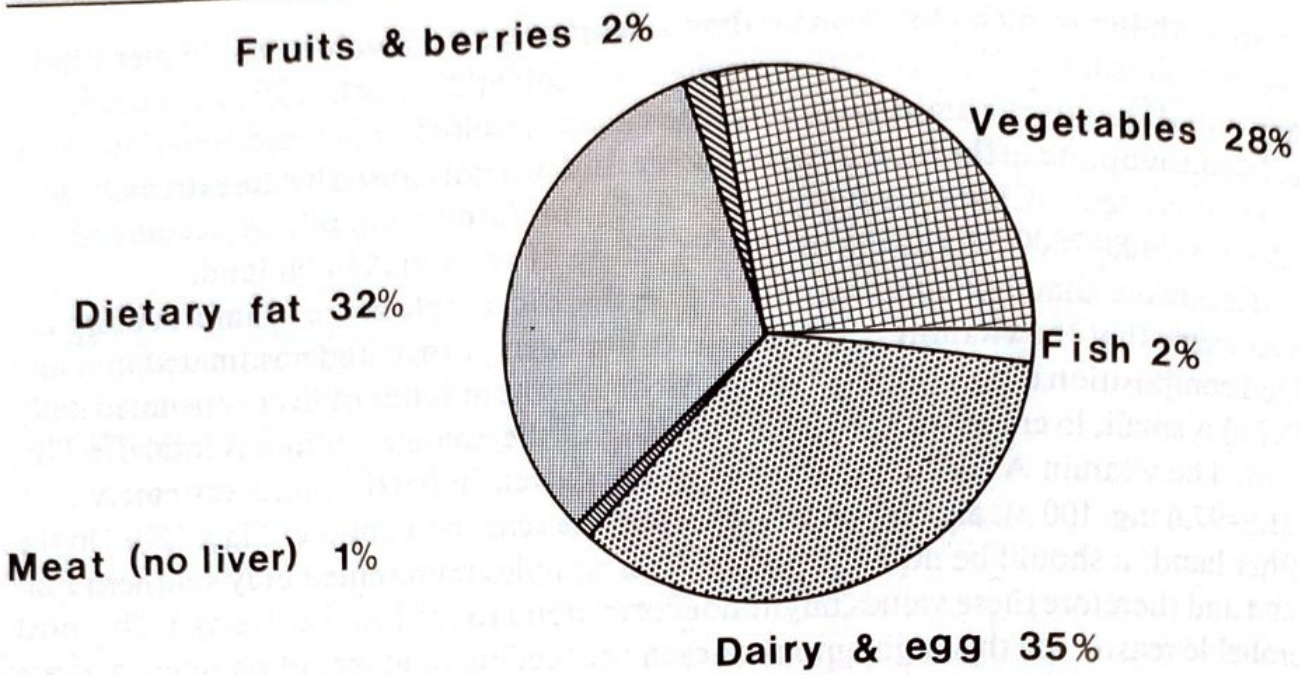

Figure 1: Food groups as the source of vitamin A (percentages of retinol equivalents, liver excluded) in Finland.

Table IV: The vitamin A content of butter at different times of the year (RE, retinol equivalents, mean and standard deviation)

Month	Vitamin A (RE, µg/100 g ± SD fresh weight)
August	1100 ± 20
October	990 ± 30
February	1100 ± 20
April	700 ± 20
July	1100 ± 6
Mean value	1000

seemed to contain only 690–1500 µg/day of β-carotene. The discrepancy was caused by loss of sensitivity in detecting vitamin A compounds present in small quantities. In addition, the lack of homogeneity when preparing the whole diet sample may have caused analytical deviation. Thus, results obtained by analysing individual food groups are of greater reliability than those obtained by analysing the whole diet.

The average β-carotene intake in Finland varies between 1700–2100 µg/day, depending on the season. Vegetables contribute the most (77–86%) to the β-carotene intake, carrot being the most important source. The total intake of carotenoids varied between 2900 and 3600 µg/day of which amount 70–77% was due to α-carotene and β-carotene. More than 10% of the vitamin A intake in Finland is derived from carotenoids. When determining the dietary carotenoid intake, liver is not a problem, since pork and chicken liver contain only retinoids, and beef liver only a relatively small amount of β-carotene.

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