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Dietary intakes and lifestyle factors of a vegan population in Germany: results from the German Vegan Study

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Objective: Evaluation of dietary intakes and lifestyle factors of German vegans.
Design: Cross-sectional study.
Settings: Germany.
Subjects: Subjects were recruited through journal advertisements. Of 868 volunteers, only 154 participated in all study segments (pre- and main questionnaire, two 9-day food frequency questionnaires, blood sampling) and fulfilled the following study criteria: vegan dietary intake at least 1 year prior to study start, minimum age of 18 y, no pregnancy or childbirth during the last 12 months.
Interventions: No interventions.
Results: All the 154 subjects had a comparatively low BMI (median 21.2 kg/m^2), with an extremely low mean consumption of alcohol (0.77 $\pm$ 3.14 g/day) and tobacco (96.8% were nonsmokers). Mean energy intake (total collective: 8.23 $\pm$ 2.77 MJ) was higher in strict vegans than in moderate ones. Mean carbohydrate, fat, and protein intakes in proportion to energy (total collective: 57.1:29.7:11.6%) agreed with current recommendations. Recommended intakes for vitamins and minerals were attained through diet, except for calcium (median intake: 81.1% of recommendation), iodine (median: 40.6%), and cobalamin (median: 8.8%). For the male subgroup, the intake of a small amount of food of animal origin improved vitamin and mineral nutrient densities (except for zinc), whereas this was not the case for the female subgroup (except for calcium).
Conclusion: In order to reach favourable vitamin and mineral intakes, vegans should consider taking supplements containing riboflavin, cobalamin, calcium, and iodine. Intake of total energy and protein should also be improved.
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Introduction

It has been suggested and meanwhile could be shown by various studies that a diet rich in plant foods compared to an omnivorous diet offers many health benefits that is, a lower incidence of chronic degenerative diseases such as cancer (eg, colon cancer) (Havala & Dwyer, 1993; Frentzel-Beyme & Chang-Claude, 1994), type II diabetes, obesity, and hypertension, especially among vegetarians (Rottka, 1990). In contrast, extreme forms of vegetarianism may lead to an inadequate intake of energy, protein, as well as certain minerals and vitamins. Vegetarian and vegan diets have been reported to be associated with deficiencies of cobalamin and vitamin D, riboflavin, calcium, iron, and zinc (Rottka, 1990; Havala & Dwyer, 1993; Dwyer, 1999).

Although a great number of studies on vegetarian nutrition have been published during the last years, knowledge on adequacy and nutritional effects of vegan diets is still limited—mainly because the several types of vegetarianism had not been differentiated in studies. The German Vegan Study (GVS) was designed to fill the datagap. It is the first German study that deals with a larger vegan population. The aim of the study was to collect data on lifestyle factors and dietary intake as well as information related to health. Data

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were obtained from 'strict' vegans (SV, no consumption of any animal-derived food products) as well as from 'moderate' vegans (MV, no meat consumption; intake of dairy products and eggs below 5% of the total energy intake).

Methods

In pilot studies, all GVS questionnaires were tested and optimized concerning easy handling, practicability, and understandability.

Subjects: recruitment and screening

This study was conducted in accordance with the Helsinki Declaration of 1964 as amended in 1996. Since there was no intervention, the Ethics Commission of the State of Lower Saxony decided that an ethical approval was not required. All subjects were volunteers that gave written consent prior to participation.

Subjects were recruited by advertisements in various journals read by the vegetarian and vegan population. In all, 868 persons answered and 654 subjects filled out the pre-questionnaire (questions regarding: date of birth, gender, duration of vegan dietary intake, inclusion of milk and other dairy products, eggs, fish, poultry and meat, and the kind of diet before adopting a vegan diet); 239 had to be excluded because of meat consumption. Of the remaining 415 persons, 376 filled out the main questionnaire (questions regarding: anthropometric and socioeconomic data, duration of vegan dietary intake, inclusion of milk and other dairy products, eggs, fish, poultry and meat, kind of diet before adopting a vegan diet, changes in health when adopting a vegan diet, history of diseases and allergies, lifestyle factors, and nutritional knowledge); 23 had to be excluded for the same reason. Two food frequency questionnaires were sent (autumn 1994 and spring 1995); 279 and 287, respectively, were returned, a total of 256 people filled out both forms, and three people had to be excluded because of meat consumption. In all, 212 people participated in the blood analyses (May/June 1995). A total of 154 people took part in all study segments (questionnaires, FFQ and blood sampling) and fulfilled the following study criteria: 'strict' vegan dietary intake (SV, $n=98$) or 'moderate' vegan dietary intake (MV, $n=56$) 1 year prior to the start of the study, a minimum age of 18 y, no pregnancy or childbirth during the last 12 months.

All subjects were screened for health status by means of a questionnaire. Weight and height measurements were taken for calculation of the body mass index (BMI). Waist line and hip measurements were taken with a measuring tape for the calculation of waist-to-hip ratio (WHR). The FAO/WHO/UNU equation (FAO/WHO/UNU expert consultation, 1985, including only weight) was used to calculate the BMR. A Futrex 5000 Body Composition Analyzer was used to determine body fat mass by the infrared method. Lifestyle factors (except alcohol consumption; FFQ) were evaluated by means of the main questionnaire.

Dietary data collection

Each subject was asked to complete two estimated 9-day food frequency questionnaires (FFQ; including 199 vegan foods and 7 non-vegan foods (eggs, butter, milk, and other diary products)). In order to minimize seasonal differences, one FFQ had to be completed in autumn and the other in spring. The first two days of each 9-day FFQ were seen as a training phase and were excluded from the analyses, while the following 7 days were included. In the FFQ, common household measures and their equivalent in grams or millilitres were given for each food item. In some cases, portion sizes were made clear with photos or comments (ie, nine strawberries with the size of walnuts weigh 150 g, one orange with the size of a tennis ball equals 250 g). In addition, participants were asked for copies of recipes of homemade vegan dishes.

A slight modification of the validated FFQ used in the Giessen Raw Food Study (Strassner, 1998) has been used in the GVS for data collection. The original FFQ has been complemented for vegan foods; foods of animal origin—except eggs, butter, milk, and dairy products were excluded.

As there was no adequate software or database for vegan nutrition to calculate the amounts of ingested nutrients, we developed a piece of software (Paradox database) on the basis of the German nutrient database (BLS II.2). Missing nutritional information of vegan foods and dishes was obtained from the food manufactures. Since the given information mostly regarded the content of protein, fat, carbohydrates, dietary fibre, and energy and only in few cases provided further information about the content of minerals and vitamins, missing values were set as zero. In the end, 245 foods were registered in the database.

Direct, semiquantitative methods—similar to the one used—have been validated with weighed records (Giessen Raw Food Study, Wholesome Nutrition Study), and seem to be as precise as weighed records (main nutrients and energy intake) but tend to slightly overestimate intakes of minerals and vitamins (Hoffmann *et al*, 1994; Strassner, 1998).

Statistical analyses

A statistical analysis programme (SPSS 10.0.7) was used to analyse the data. Results are represented as means±s.d. (energy intake from food of animal origin, dietary intake, energy intake as contributions of nutrients, nutrient intake, nutrient density) and median plus 5-/95-percentiles (age, BMI, body fat mass, WHR), respectively. Normal distribution of data was checked by using the Kolmogorov–Smirnov test. In the case of skewness, the Mann-Whitney U-test was used to reveal significant differences between the two subgroups (SV and MV).

Given normal distribution, the independent-sample *t*-test was used. Dealing with nominal data, the χ^2 test was employed to evaluate statistically significant differences. Partial correlation was used to detect associations between BMI and daily energy intake while controlling for protein intake. Statistical significance was set at the 0.05 level.

Results

General characteristics

Of the recruited subjects, 56.5% were females. There was no significant difference in sex distribution between the subgroups SV and MV ($P = 0.07$, χ^2).

The two subgroups did not differ in anthropometric data, except for body fat mass ($P = 0.021$, *t*-test) and WHR ($P = 0.049$; Mann-Whitney U-test) (Table 1). When taking sex distribution into account, statistically significant differences exist for body fat mass between the female SV and MV subgroups ($P = 0.011$, *t*-test).

Lifestyle factors

Of 154 participants, 139 stated to be vegans for *ethical* ($n = 64$) or *health* ($n = 75$) reasons. There was a statistically significant difference between the subgroups SV and MV ($P = 0.008$, χ^2): 54.5% of the SV reported ethical reasons and 68.6% of the MV reported health reasons for choosing a vegan lifestyle. Other reasons were of less importance (taste and aesthetics $n = 7$, hygiene $n = 2$, ecology $n = 1$, social reasons $n = 1$, and other unspecified reasons $n = 2$).

Only 3% of the participants *smoked*. One moderate and three strict vegans smoked 2–10 cigarettes/day and only one moderate vegan smoked 11–30 cigarettes/day at the time of data collection. Analysis of the FFQ showed that 72.7% of the SV drank no *alcohol* at all, 26% consumed less than 15 g/day, and 1.3% drank more than 15 g/day. Median alcohol consumption of the vegans consuming alcohol was extremely low (SV: 0.89 g/day) (5-/95-percentiles: 0.06–25.78 g/day); MV: 1.38 g/day (5-/95-percentiles: 0.04–21.18 g/day). *Physical activity* was reported to be low or middle by 49.4%, high by 22.7%, and rare or never by 27.9% of the subjects. *Time for relaxation* was found to be less than 0.5 h/day for 24.0% of GVS participants, less than 1 h for 13.6%, less than 2 h for 12.3% and more than 2 h for 7.8%; whereas 20.1% reported not to relax and 22.1% gave no answer. Most common for relaxation was meditation ($n = 17$), autogenic training ($n = 23$) and yoga ($n = 19$) as well as prayers and reading the bible ($n = 17$). Of the GVS participants, 35.1% were Seventh-Day Adventists, 29.2% were Christians, and 24.7% stated to belong to no *religious faith*. However, all study participants that reported prayers and reading the bible for relaxation were Adventists.

The mean time of duration that the vegan diet was followed was nearly statistically significantly different ($P = 0.058$, Mann-Whitney U-test) between the two subgroups: SV followed a vegan diet for 4.3 y and MV for 3.4 y. Correlation (Spearman) of *duration of vegan diet* to subgroup allocation was weak and almost statistically significant ($P = 0.057$, $r_s = 0.153$).

Table 1 General characteristics (median, 5-/95-percentile) of the vegan subgroups

		SV (n=*98*)	*MV* (n=*56*)
Sex	♂	48	19
	♀	50	37
Age (y)	♂	42.4 (21.8–75.5)	45.2 (24.4–72.9)
	♀	42.4 (24.4–75.0)	44.5 (25.9–71.0)
	Both	42.4 (23.3–74.3)	44.9 (25.8–70.7)
Body mass index (kg/m^2)	♂	22.2 (17.5–26.4)	21.2 (18.0–26.7)
	♀	20.5 (16.5–25.3)	21.1 (17.7–25.2)
	Both	21.2 (17.3–26.2)	21.2 (17.8–24.7)
Body fat mass (%)	♂	16.3 (7.18–25.4)	16.6 (5.1–25.5)
	♀*	27.0 (13.9–34.1)	29.1 (20.2–36.1)
	Both*	21.1 (8.5–33.0)	25.9 (7.45–33.3)
Waist-to-hip ratio	♂	0.87 (0.76–0.96)	0.84 (0.76–0.98)
	♀	0.78 (0.69–0.86)	0.77 (0.72–0.96)
	Both**	0.82 (0.7–0.95)	0.78 (0.72–0.96)

*$P \leq 0.05$, *t*-test.
**$P \leq 0.05$, Mann-Whitney U-test.

Dietary intakes

Just as the notion of vegetarianism covers a very varied set of dietary practices (ie lacto-ovo-vegetarians, lacto-vegetarians, etc), we detected a wide variety of self-claimed 'vegans' in dietary behaviour—although all study volunteers (868) had claimed to be vegans. Subjects consuming even small amounts of meat, fish, or poultry were excluded from the analyses. Participants consuming a small amount of eggs, milk, and other dairy products were included and grouped as moderate vegans under the condition that the proportion of energy intake from foods of animal origin was less than 5%. Most subjects (74.4%) who included dairy products and eggs in their diet reported to follow nearly vegan dietary guidelines of Diamond and Diamond (1986, pp 175–208) or Bruker (1987, pp 324–333). Energy intake from dairy products and eggs was far below the consumption usually found in lacto-ovo-vegetarians (Table 2).

Vegetables and fruits were the dominating foods consumed, followed by bread and pastries (85%:15%), cereals and nutriments, potatoes and soy products, whereas fats and oils as well as sweets and sugar-rich products were consumed sparingly. This is particularly evident when the data are compared to the food patterns of the average German consumer, as investigated in the German Nutrition Survey (GNS) (Table 3). Significant differences between SV and MV were found for the consumption of soy and soy products, citrus and tropical fruits (only fresh fruits; juices from these fruits are included in the nonalcoholic drinks group), sandwich spreads as well as the consumption of alcohol. With their food choice, the study participants met the current dietary guidelines of the German Nutrition Society (DGE, 2000). The low consumption of coffee, tea, and alcoholic drinks is worth noting.

Surveying pasta and rice consumption, the GVS participants tended to eat more whole grain pasta (20.6 ± 33.0 g/day)

Table 2 Energy intake from animal-derived foods (mean ± s.d.)

	SV (n=98)	*MV* (n=56)
Energy intake from animal food (kJ/day)	0.00	85.2 ± 78.6
Energy intake from animal food (energy %/day)	0.00	1.24 ± 1.19
Eggs (g/day)	0.00	0.88 ± 3.31
Butter (g/day)	0.00	1.84 ± 2.26
Cheese and quark (curd cheese) (g/day)	0.00	1.4 ± 3.78
Milk and dairy products (g/day)	0.00	4.72 ± 8.93

and whole grain rice (9.80 ± 15.9 g/day) than their white substitutes (5.17 ± 14.4 and 2.26 ± 7.36 g/day respectively). Legumes (other than soy) were consumed at an amount of 10.3 g/day (± 12.9g/day). The mean (± s.d.) intake of berries was 18.6 g/day (± 32.5 g/day).

Dietary supplements

Out of 154 GVS participants, a total of 71 persons took dietary supplements. There was no statistically significant difference found regarding the prevalence of taking supplements or not, neither between strict (user: 48.0%) and moderate vegans (user: 42.9%; $P=0.541$, χ^2) nor between females (user: 50.6%) and men (user: 40.3%; $P=0.205$, χ^2). Furthermore, there was no association between prevalence of taking supplements and age to detect ($r_s=0.134$, $P=0.098$). The number of consumed products varied from 1 to 8. Again the difference between the subgroups was neither significant for SV and MV ($P=0.307$, Mann–Whitney U-test) nor females and males ($P=0.813$, Mann–Whitney U-test) regarding the number of products taken. Supplement intake was considered to be regular and frequent at a level of taking one product three times a week or more: significant differences were neither computed between SV and MV nor between women and men.

Nutritional intake

The distribution of the mean daily energy intake (in proportion to total energy intake) of nutrients (carbohydrates, fat, protein, and alcohol) is shown in Table 4. Statistically significant differences between strict and moderate vegans were computed for energy intake ($P=0.033$, *t*-test), energy intake from protein in proportion to total energy intake ($P=0.011$, *t*-test), and protein intake ($P=0.009$, Mann-Whitney U-test). As expected, energy intake was higher for men than for women ($P=0.000$, *t*-test). Since there was a higher percentage of men in the SV than in the MV subgroup (49.0% *vs* 33.9%), significant differences in energy intake were calculated for each gender separately. And in fact, when gender was considered, the significant differences of energy intake between the SV and the MV subgroup disappeared (women: $P=0.287$, *t*-test; men: $P=0.308$, *t*-test). While differences in the male subgroup were not statistically significant, the female subgroup showed significant differences for the protein

Table 3 Food intake of strict and moderate vegans of the GVS and the participants of the GNS

Food group, mean in g/day	*SV* (n=98)	*MV* (n=56)	P*	*GVS* (n=154)	*GNS* (n=1988)
Meat	—	—	—	—	79.8
Meat products and sausages	—	—	—	—	68.0
Fish and seafood	—	—	—	—	16.5
Eggs	—	0.88 ± 3.31	0.000	0.32 ± 2.03	29.8
Milk and dairy products	—	4.72 ± 8.93	0.000	1.72 ± 5.82	169.1
Cheese	—	1.4 ± 3.78	0.000	0.51 ± 2.37	42.2
Butter	—	1.84 ± 2.26	0.000	0.70 ± 1.62	18.4
Fat and oil	17.5 ± 20.8	11.6 ± 10.6	n.s.	15.4 ± 17.9	20.3
Bread and pastries	171 ± 122	149 ± 147	n.s	163 ± 114	218
Cereal products and nutriments	112 ± 81.1	92.7 ± 90.0	n.s.	105 ± 84.7	38.9
Potatoes	110 ± 97.2	99.2 ± 82.8	n.s.	106 ± 92.1	100.5
Vegetables (except potatoes)	678 ± 290	657 ± 243	n.s.	670 ± 273	150.4
Fresh regional fruits	331 ± 250	329 ± 233	n.s.	330 ± 243	70.8
Fresh citrus and tropical fruits	374 ± 368	442 ± 341	0.038	398 ± 359	41.6
Fruit products	63.3 ± 58.4	51.4 ± 28.6	n.s.	59.0 ± 52.2	7.7
Nuts and seeds	35.5 ± 33.7	26.0 ± 22.1	n.s.	32.1 ± 30.3	No data
Soy	102 ± 99.1	56.8 ± 85.4	0.000	85.8 ± 96.6	No data
Sandwich spread	3.99 ± 6.87	1.82 ± 3.39	0.013	3.20 ± 5.93	8.9
Sugar	1.09 ± 2.91	0.25 ± 0.54	n.s.	0.79 ± 2.37	10.3
Sweets	11.8 ± 14.3	10.4 ± 8.97	n.s.	11.3 ± 12.6	21.9
Spices and herbs	0.11 ± 0.94	$1.27\times10^{-2}\pm9.45\times10^{-2}$	n.s.	$7.42\times10^{-2}\pm0.76$	9.2
Alcoholic drinks	13.0 ± 77.0	12.5 ± 38.7	0.018	12.8 ± 65.5	307.9
Nonalcoholic beverages (except coffee and tea)	1051 ± 622	1040 ± 739	n.s.	1047 ± 665	547.2
Coffee	25.6 ± 82.1	20.2 ± 66.9	n.s.	23.6 ± 76.8	411.4
Tea	55.6 ± 164	60.0 ± 256	n.s.	57.2 ± 201	87.3

*Mann-Whitney U-test for differences between SV and MV.
n.s.=non-significant.

Table 4 Contribution of nutrients to energy intake (mean ± s.d.)

Nutrient intake		*SV* (n=98)	*MV* (n=56)
Energy	♂	10.0 ± 3.17	9.18 ± 2.42
(MJ/d)	♀	7.23 ± 1.97	6.79 ± 1.73
	Both*	8.59 ± 2.97	7.60 ± 2.28
Protein	♂	0.95 ± 0.37	0.92 ± 0.32
(g/kg body weight and day)	♀*	0.94 ± 0.3	0.75 ± 0.23
	Both*	0.94 ± 0.34	0.81 ± 0.27
Carbohydrates	♂	55.8 ± 7.95	57.9 ± 5.76
(energy%)	♀	56.9 ± 7.56	58.4 ± 7.54
	Both	56.4 ± 7.74	58.2 ± 6.94
Protein	♂	11.4 ± 2.10	11.4 ± 1.97
(energy%)	♀*	12.4 ± 2.01	10.8 ± 1.85
	Both*	11.9 ± 2.11	11.2 ± 1.90
Fat	♂	31.4 ± 8.61	28.7 ± 5.58
(energy%)	♀	29.2 ± 7.76	28.8 ± 7.73
	Both	30.3 ± 8.22	28.8 ± 7.02
Alcohol	♂	0.13 ± 0.52	0.70 ± 1.88
(energy%)	♀	0.32 ± 1.48	0.17 ± 0.31
	Both	0.22 ± 1.11	0.35 ± 1.13

*$P \leq 0.05$, Mann–Whitney U-test.
**$P \leq 0.05$, *t*-test.

intake when women with strict vegan dietary habits were compared with women that comsumed a moderate vegan diet. The stricter diet contained less protein when expressed as energy% ($P=0.000$, *t*-test) and also when the absolute values (protein intake in g/day and kg body weight ($P=0.003$, *t*-test)) were considered.

The mean energy intake was at a low level. The recommended amounts of 11.7 MJ/day for the males and 9.0 MJ/day for the females (age group 25–51, physical activity level (PAL) was considered to be middle; DGE, 2000, pp 25 ff) were not met by 77.6% of the males and 84.0% of the females. A positive correlation was found between the estimated energy intake (EI) as calculated by means of FFQ and basal metabolic rate (BMR) for the whole GVS collective ($r_s=0.490$, $P=0.000$). Taking gender-specific differences into consideration, correlations were not significant anymore. In the male subgroup a trend for a significant inverse correlation was found for EI/BMR and classified BMI ($r_s=-0.216$, $P=0.079$). However, significant associations between EI/BMR and age, dietary subgroup allocation, gender, duration of vegan nutrition, and BMI were not computed. The mean EI/BMR ratio was lower for women (1.30 ± 0.34) than men (1.41 ± 0.49) (non-significant difference: Mann–Whitney U-test, $P=0.104$). Protein intake was also at a low level. The recommended amounts of 0.8 g/kg body weight and day were not attained by 31.3% of the males and 41.4% of the females. After controlling for protein intake, a positive correlation was found between BMI and energy intake with $r=0.4434$ ($P=0.000$). The mean fat intake in proportion to energy intake was slightly below the recommended level of 30%. Of the total energy intake, 6% were derived from saturated fatty acids, 12.4% from monounsaturated fatty acids, and 8.2% from polyunsaturated fatty acids (SV: 5.9, 12.5, and 9.1%; MV: 6.2, 12.3, and 7.8%). The mean sucrose intake was 48.9 g/day (±23.7 g/day) in the study collective; this amount equals 10.3% of energy intake. Mean carbohydrate, fat, and protein intake in proportion to energy intake (total collective: 57.1%: 29.7%: 11.6%) was in accordance with the current recommendations of the German Nutrition Society (DGE, 2000). Energy intake from alcohol was at a very low level.

Mean daily intakes of dietary fibre, minerals and vitamins (Table 5) and nutrient densities (Table 6) show statistically significant differences between the subgroups SV and MV for nutrient densities of ascorbic acid ($P=0.002$, *t*-test), retinol-equivalents ($P=0.017$, Mann-Whitney U-test), and potassium ($P=0.008$, *t*-test). Significant differences were found between women with strict and moderate vegan food habits for nutrient densities of thiamine ($P=0.032$, Mann-Whitney U-test), niacin ($P=0.003$, *t*-test), ascorbic acid ($P=0.001$, *t*-test), sodium ($P=0.020$, *t*-test), and phosphorus ($P=0.018$, *t*-test).

Of all GVS participants, 20.1% had a zinc intake below the recommendation. Riboflavin intake was lower than recommended for 48% and calcium intake for 76% of the GVS participants. Only 5.3 and 1.3% of the GVS participants reached the recommended intake for cobalamin and iodine, respectively (Figure 1, Table 6).

Discussion

In the GVS, subjects were subdivided into two subgroups—SV and MV—on the basis of their food intake. The subgroups of the GVS participants did not differ in anthropometric data, except for body fat mass and WHR (Table 2). Compared to the GNS (cross-sectional study, 1988 omnivores, age ≥18 y), which was representative of the average German population, the GVS group had a lower mean BMI (Schneider *et al*, 1992, p 59). In the GNS, 45% of the men and 29% of the women had a BMI between 25 and 30 kg/m^2. In our study, only 10.4% of the GVS men and 11.5% of the GVS women had a BMI between 25 and 30 kg/m^2. A BMI higher than 30 kg/m^2 was not observed among our participants, but was prevalent among 17% of the GNS participants. Just as a high BMI is a risk factor, a low BMI can be an indicator for malnutrition or unhealthy physical conditions or can lead to unhealthy physical conditions. Therefore, it is worth noting that 25.3% of our participants were underweight (males: BMI ≤ 20 kg/m^2 = 25.4%; females: BMI ≤ 19 kg/m^2 = 25.3%). These findings, that is, the low median BMI of 21.2 kg/m^2 (mean: 21.3 kg/m^2), are consistent with the findings in other vegerarian or vegan studies that report a mean BMI between 20.7 and 22.6 kg/m^2 (Rottka, 1990; Janelle & Barr, 1995; Wilson & Ball, 1999; Lightowler & Davies, 2000).

The main reasons for adopting a vegan lifestyle were health (48.7%) and ethic (41.6%) considerations. Ross (1991) found similar results, but ethical reasons were predominant in his study. Beardsworth and Keil (1992) showed that moral motivations were the primary reason. The mean time of duration that the vegan diet was practised was longer in SV than in MV. These findings agree with the experience that

Table 5 Mean daily nutrient intake (mean ± s.d.) for the participants of the GVS[a]

Nutrient		SV (n=98)	MV (n=56)	DGE[b]
Dietary fibre	♂	66.2±25.5	60.1±14.0	≥30
(g/day)	♀	41.3±15.5	50.1±14.4	
Sodium	♂	2.31±1.19	2.03±1.05	0.55
(g/day)	♀	2.02±0.86	1.60±0.81	
Potassium	♂	5.46±2.03	5.25±1.49	2.00
(g/day)	♀	4.46±1.35	4.54±1.48	
Calcium	♂	915±346	889±340	1000
(mg/day)	♀	790±249	784±243	
Phosphorus	♂	1601±528	1450±400	700
(mg/day)	♀	1251±1187	1079±340	
Magnesium	♂	706±224	666±189	350
(mg/day)	♀	585±168	525±149	300
Iron	♂	24.8±8.03	23.0±5.23	10
(mg/day)	♀	20.1±5.65	18.5±5.10	15
Iodine	♂	87.6±30.6	93.7±27.8	200
(mg/day)	♀	82.0±34.4	78.0±25.6	
Zinc	♂	13.5±4.48	12.0±3.47	10
(mg/day)	♀	10.5±3.43	9.26±3.10	7
Copper	♂	3.72±1.25	3.39±0.91	1.0–1.5
(mg/day)	♀	2.98±0.89	2.69±0.75	
Manganese	♂	10.4±3.88	8.94±2.84	2.0–5.0
(mg/day)	♀	7.95±2.77	7.20±3.44	
Thiamine	♂	2.16±0.71	1.99±0.58	1.2
(mg/day)	♀	1.77±0.65	1.44±0.40	1.0
Riboflavin	♂	1.53±0.65	1.44±0.35	1.4
(mg/day)	♀	1.26±0.67	1.20±0.36	1.2
Niacin	♂	29.7±9.66	28.0±9.03	16
(mg/day)	♀	23.7±6.74	20.3±5.60	13
Pyridoxine	♂	2.97±1.04	2.95±0.93	1.5
(mg/day)	♀	2.55±0.89	2.42±0.79	1.2
Cobalamin	♂	0.84±1.21	0.87±1.24	3.0
(μg/day)	♀	0.78±2.14	0.25±0.30	
Folate	♂	571±208	527±127	400
(μg/day)	♀	482±133	467±141	
Retinol equivalents	♂	2.00±1.20	1.94±0.79	100
(mg/day)	♀	1.82±0.97	2.09±1.09	
Ascorbic acid	♂	353±248	318±153	100
(mg/day)	♀	274±133	358±196	
Vitamin D	♂	0.78±0.71	0.89±0.89	100
(μg/day)	♀	0.50±0.55	0.56±0.44	
Vitamin E	♂	31.8±15.2	23.6±8.17	100
(mg/day)	♀	19.8±7.76	19.0±7.79	

[a]Data excludes vitamin and mineral intake via supplements.
[b]DGE=Deutsche Gesellschaft für Ernährung (German Nutrition Society) : Reference values of nutritional intake, 2000; age group: 25–51 y.

Table 6 Nutrient density of the food[a] (mean ± s.d.) consumed by the partipants of the GVS and recommended amounts

Nutrient		SV (n=98)	MV (n=56)	DGE[b]
Sodium	♂	0.24±0.12	0.22±0.1	—
(g/MJ)	♀*	0.29±0.13	0.23±0.1	
	Both	0.26±0.13	0.23±0.1	
Potassuim	♂	0.55±0.11	0.58±0.12	—
(g/MJ)	♀	0.62±0.12	0.67±0.12	
	Both*	0.58±0.12	0.64±0.13	
Calcium	♂	92.4±22.5	98.2±34.0	98
(mg/MJ)	♀	113±34.0	118±35.0	128
	Both	103±30.6	111±35.7	
Phosphorus	♂	162±28.2	160±26.6	—
(mg/MJ)	♀*	174±30.2	159±28.6	
	Both	168±29.8	159±27.7	
Magnesuim	♂	71.5±12.1	73.1±12.7	34
(mg/MJ)	♀	81.8±13.0	77.9±13.2	38
	Both	76.8±13.6	76.3±13.1	
Iron	♂	2.51±0.42	2.56±0.40	1.0
(mg/MJ)	♀	2.83±0.42	2.73±0.37	1.9
	Both	2.67±0.45	2.67±0.38	
Iodine	♂	8.91±2.31	10.9±5.01	20
(μg/MJ)	♀	11.8±5.21	11.7±3.45	26
	Both	10.4±4.29	11.4±4.02	
Zinc	♂	1.37±0.29	1.34±0.31	1.0
(mg/MJ)	♀	1.46±0.29	1.36±0.30	0.9
	Both	1.42±0.29	1.35±0.3	
Copper	♂	0.37±0.06	0.37±0.05	—
(mg/MJ)	♀	0.41±0.06	0.4±0.05	
	Both	0.39±0.06	0.39±0.05	
Manganese	♂	1.05±0.29	1.0±0.23	—
(mg/MJ)	♀	1.11±0.28	1.08±0.54	
	Both	1.08±0.28	1.05±0.46	
Thiamine	♂	0.22±0.05	0.22±0.05	—
(mg/MJ)	♀**	0.25±0.09	0.21±0.03	
	Both	0.23±0.08	0.22±0.04	
Riboflavin	♂	0.15±0.03	0.16±0.03	—
(mg/MJ)	♀	0.18±0.04	0.18±0.03	
	Both	0.16±0.04	0.17±0.03	
Niacin	♂	3.0±0.51	3.03±0.38	—
(mg/MJ)	♀*	3.3±0.51	2.99±0.37	
	Both	3.15±0.53	3.01±0.37	
Ascorbic acid	♂	34.3±19.4	35.5±17.1	—
(mg/MJ)	♀*	38.3±17.6	52.8±22.8	
	Both*	36.3±18.6	46.9±22.5	
Cobalamin	♂	0.09±0.13	0.09±0.11	0.29
(μg/MJ)	♀	0.11±0.23	0.04±0.04	0.38
	Both	0.1±0.19	0.05±0.07	
Folate	♂	57.6±12.9	58.9±12.4	39
(μg/MJ)	♀	68.6±18.4	69.0±13.9	51
	Both	63.2±16.8	65.6±14.1	
Pyridoxine	♂	0.30±0.06	0.32±0.06	0.15
(mg/MJ)	♀	0.35±0.08	0.36±0.07	0.15
	Both	0.33±0.08	0.34±0.06	

[a,b]See Table 5.
*$P<0.05$, *t*-test.
**$P<0.05$, Mann–Whitney *U*-test.

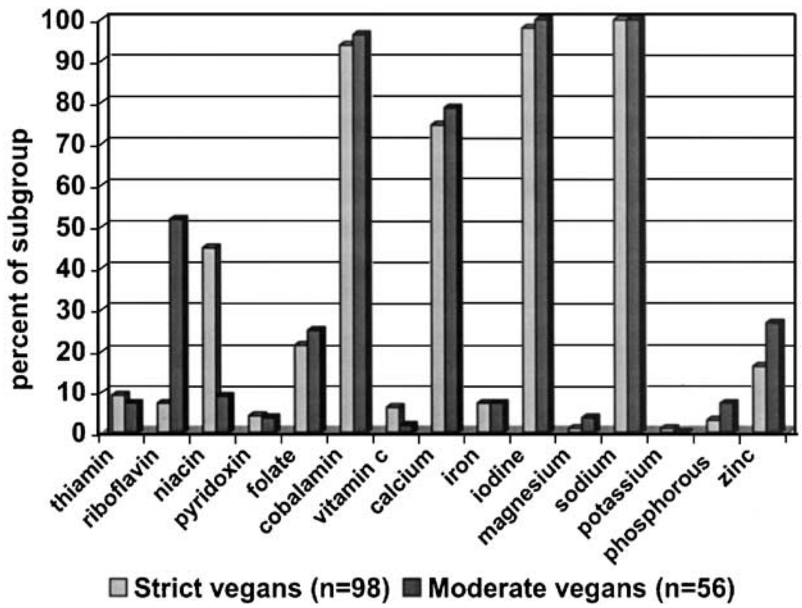

Figure 1 Proportion (%) of study participants with vitamin and mineral intakes below the current recommendations. (Data does not include intakes via supplements).

each vegan has his/her own career that usually progressively moves along the vegetarian (vegan) scale, from a more moderate to a stricter vegetarian or vegan form, respectively (Beardsworth & Keil, 1991).

Compared to the average population, vegetarians practise a healthier lifestyle. They seldom smoke and they drink less alcohol compared to omnivorous subjects, and physical activity is often higher (McKenzie, 1967; Rottka, 1990; Heseker *et al*, 1994, p 42; Dwyer, 1999). These statements are supported by our data. Only 3% of the participants smoked, whereas about 45.5% of the men and 37.5% of the women smoked in the German average polpulation (Heseker *et al*, 1994, p 21). In our study group, 37.3% of the males and 40.2% of the females reported drinking no alcohol at all (average population 14.9% male and 31.8% female). Of our subjects, 26% consumed less than 15 g alcohol/day (average population: 45.2% male and 57.4% female) and 1.3% drank more than 15 g/day (average population: 39.9% male and 10.8% female) (Heseker *et al*, 1994, p 43). Median alcohol consumption of those who consumed alcohol was extremely low. The longing for a healthier lifestyle is often associated with the intake of dietary supplements. Schutz *et al* (1982), Griffith and Innes (1983), and Kirk *et al* (1999) report frequency of (omnivorous) supplement users at a level of 66.6% (seven Western states), 59.3% (UK), and 60.0% (women in UK), respectively. The National Diet and Nutrition Survey of British Adults reports—in contrast to those high levels—that 17% of the female population add vitamin and/or mineral supplements to their diet (as cited by Kirk *et al*, 1999). In Germany, the consumption of dietary supplements has increased in the past decade (Fischer & Döring, 1999), but data from recent German studies still show a lower prevalence of supplement use than was prevalent in the USA and UK 20 y ago: 23.5% (data sampling: 1990–1992; Bodenbach & Weinkauf, 1997) and 38% for men and 48% for women (data sampling: 1998; Beitz *et al*, 2002). Wolters and Hahn (2000) reported a prevalence of supplement use of 36.1% in Lower Saxony, Germany (data sampling: 1998): more women (40.4%) than men (31.5%) used supplements. A total of 46.1% of GVS participants used some form of food supplements. These findings (ie, the higher prevalence of using dietary supplements) correspond with data from other studies, where vegetarians/vegans tend to add more frequently dietary supplements to their diet than omnivores (Draper *et al*, 1993; Kirk *et al*, 1999). Especially cobalamin and some kind of minerals (like calcium and iodine) are recommended to be added to vegetarian/vegan diets (The British Dietetic Association, 1999). Therefore, the chosen range of products fit the recommendations: multiple minerals, ascorbic acid, and cobalamin products were taken among users most frequently (each product: 29.6% of users), followed by calcium (22.5%). Predominantly vegetables and fruits were consumed by the participants of our study, with a mean amount of 1458 g/day (78% of indigested food), which is 5.5 times higher than the amount eaten by the average population (24% of ingested food) (Heseker *et al*, 1994, p 97). The vegans still reached only about 75% of the amount that is reported for a study group eating only raw food, where vegetables and fruits make up 95% of the total consumed food (Strassner, 1998). Consumption of cereal products, vegetables, fruits, and non-alcoholic beverages was higher in our group than in the average population (Heseker *et al*, 1994, p 97). In contrast, consumption of fats and oils, spreads, sugar, sweets, spices and herbs, alcoholic drinks, coffee, and tea is higher in the average population. Statistically significant differences between our groups were found for intake of soy and soy products, citrus and tropical fruits, sandwich spreads, and consumption of alcohol (Table 3).

A common problem in surveys is the under-reporting of total food intake indicated by a low computed energy intake. This seems to be the case in the GVS as well: most males (77.6%) and females (88.5%) did not reach the current recommended daily amount of 12.0 and 9.5 MJ, respectively (DGE, 2000). Even when lower values were taken as a reference (10.2 MJ (males; PAL 1.4) and 7.3 MJ (females; PAL 1.3), the energy intake of 61.2 and 64.4%, respectively, was still beneath these recommendations. The mean energy intake was higher in the SV subgroup (8.59 MJ) than in the MV subgroup (7.60 MJ). Evaluating the energy intake for each gender separately, significant differences neither occurred between strict and moderate female vegans nor between strict and moderate male vegans.

Strict and moderate vegans had a lower mean energy intake than the average population (10.1 MJ) (Heseker *et al*, 1994, p 123) and a lower energy intake compared to other published vegan data (Roshanai & Sanders, 1984; Rana and Sanders, 1986; Sanders & Key, 1987; Thorogood *et al*, 1990; Appleby *et al*, 1999; Wilson & Ball, 1999; Lightowler & Davies, 2000).

The major problem in surveys is to establish a measuring instrument that is, on the one hand, valid and, on the other hand, capable of resulting in a high compliance. Weighing records are generally known as the 'gold standard' (ie exact results), but they are strongly reactive and the effort for participants is high, which can result in a low compliance or maybe result in unusual, less complex dietary patterns. Direct, semiquantitative methods like the FFQ used are easier to handle, which can result in a higher compliance, but can be less accurate. The validation (standard: weighed records) of two FFQs similar to the one used showed that the calculated intake of energy and main nutrients was quite similar for both methods (Hoffmann *et al*, 1994; Strassner, 1998). The ratio between estimated intakes (EI) and basal metabolic rate (BMR) is capable of indicating under- or overestimation of energy intakes. BMR can be predicted by means of different equations. The Harris–Benedict equation (1919) is said to overestimate BMR by 10–15% (Daly *et al*, 1985; Garrel *et al*, 1996), while the Shofield and the FAO/WHO/UNU equation is said to be more precise (Garrel *et al*, 1996). In this study, the FAO/WHO/UNU equation (FAO/WHO/UNU expert Consultation, 1985, including only weight) was used to calculate BMR. A positive correlation was found between energy intake as calculated by means of FFQ and BMR for the whole GVS collective ($r_s = 0.490$, $P = 0.000$).

The mean EI/BMR ratio was non significantly lower for women than for men and leads also to the suggestion that energy intake has been under-reported, when taking the established cutoff point of 1.35 (Goldberg *et al*, 1991) into consideration. For 47.8% of men and 60.9% of women, EI/BMR was below this computed value. A cutoff point for under-reporting of 1.10 was used in the NSIFCS (as cited by McGowan *et al*, 2001); after all 23.4% of all GVS participants (20.9% of men, 25.3% of women) had an EI/BMR below this value. Protein intake was also at a low level. Energy intake in proportion to total energy intake from saturated, monounsaturated, and polyunsaturated fatty acids was in agreement with current recommendations. Both groups met the current recommendation of consuming more than 50% of their energy from carbohydrates, 10–15% from protein, and up to 30% from dietary fat. The mean intake of dietary fibre (SV 58.6 g/day; MV 53.5 g/day) is nearly twice as high as in the average population (27.4 g/day; Heseker *et al*, 1994, p 179) and higher than in most other published vegan data (Roshanai & Sanders, 1984; Rana and Sanders, 1986; Sanders & Key, 1987; Janelle & Barr, 1995; Appleby *et al*, 1999; Wilson & Ball, 1999). Our study subjects fulfilled the recommendations of the German Society of Nutrition (DGE, 2000) for mineral and vitamin intake via diet, except for calcium, iodine, and cobalamin (Table 5). The same is true for nutrient densities (Table 6)—only moderate vegan men had a slightly higher calcium intake (Δ 0.2 mg/MJ).

Compared to the average population (Heseker *et al*, 1994, pp 260f), participants of our study consumed a diet with a higher nutrient density, except for cobalamin, sodium, and iodine. Ascorbic acid intake was higher for MV, but both had a higher intake than the recommended amount (factor 3.1–3.4). These findings clearly reflect the choice of food and dishes related to the diet. Cobalamin as well as iodine is ingested mainly with food of animal origin—foods that vegans exclude from their diet. The low intake of sodium can be an indicator for a lower consumption of salt and pickled products or an indicator for a higher health consciousness, which is related to a lower salt intake. Generally speaking, moderate vegan men consumed food with higher nutrient densities of vitamins and minerals (except for sodium, phosphorus, zinc, and manganese) than strict vegan men. However, differences between SV and MV were not statistically significant for the male subgroup (Table 6). Focusing on the female subgroup, nutrient densities were higher in the diet of strict vegan women (except for potassium, calcium, ascorbic acid, folate, and pyridoxine) compared to the moderate vegan females. The differences were statistically significant for sodium, phosphorus, thiamine, niacin, and ascorbic acid. The experience that a small amount of food of animal origin in the daily diet can improve the supply of nutrients that are rare in plant food agrees with our findings for the male subgroup—except for zinc—but disagrees for the female subgroup—except for calcium.

The nutrient density of iron was higher than recommended in about 93% of the total group. Main sources for iron were sources such as vegetables, fruits as well as cereal products that contain non-haem iron. Further research will show whether bioavailability of iron from these sources was high enough to result in acceptable concentrations for haematological parameters. The mean cobalamin intake of all our study subjects was under 20% of the recommended amount (3 μg/day). This low amount appears less dramatic when the recommendations of North America (2 μg/day) or the WHO (1 μg/day) are used as the basis. The same is true for other nutrients. The main sources for cobalamin were (fortified) nonalcoholic drinks, (fortified) cereals and cereal products, vegetables, and soy products. The calculated intake of cobalamin might be too high—for the real content of the vitamin in several foods especially those found in vegan nutrition remains doubtful. It is mainly unknown to what extent fortified products contain cobalamin or cobalamin analogues, so that further research has to focus on the cobalamin status of vegans.

Conclusions

Our data show that the participants of the GVS had an above average healthy lifestyle and consumed a well-balanced diet with high nutrient densities, although the intakes of calcium, iodine and cobalamin need to be improved. Strict vegans should consider taking supplements that contain those vitamins and minerals that are absent or are generally low in a plant-based diet. Nearly a quarter of our study subjects were classified as underweight. Therefore, intake of total energy and protein needs to be improved as well. Further analyses of the blood samples will show whether the vitamin and mineral intakes are sufficient to result in acceptable plasma levels. This will be the content of another publication.

References

Appleby PN, Thorogood M, Mann JI & Key TJA (1999): The Oxford Vegetarian Study: an overview. *Am. J. Clin. Nutr.* **70**(Suppl): S525–S531.

Beardsworth A & Keil T (1991): Health-related beliefs and dietary practices among vegetarians and vegans: a qualitative study. *Health Educ. J.* **50**, 38–42.

Beardsworth A & Keil T (1992): The vegetarian option: varieties, conversions, motives and careers. *Sociol. Rev.* **38**, 253–293.

Beitz R, Mensink GBM, Fischer B & Thamm M (2002): Vitamins—dietary intake and intake from dietary supplements in Germany. *Eur. J. Clin. Nutr.* **56**, 539–545.

Bodenbach S & Weinkauf B (1997): Die Einnahme von Vitaminpräparaten in Deutschland. *Z. Ernährungswiss.* **36**, 57–58.

Bruker MO (1987): *Unsere Nahrung—unser Schicksal*. Lahnstein: EMU-VerlagsGmbH, 18. Auflage.

Daly JM, Heymsfield SB, Head CA, Harvey LP, Nixon DW, Katzeff H & Grossmann GD (1985): Human energy requirements: overestimation by widely used prediction equation. *Am. J. Clin. Nutr.* **42**, 1170–1174.

DGE (Deutsche Gesellschaft für Ernährung) (2000): *Referenzwerte für die Nährstoffzufuhr*. Frankfurt am Main: Umschau/Braus.

Diamond H & Diamond M (1986): *Fit fürs Leben—Fit for Life*. München: Goldmann.

Draper A, Lewis J, Malhorta N & Wheeler E (1993): The energy and nutrient intakes of different types of vegetarian: a case for supplements? *Br. J. Nutr.* **69**, 3–19.

Dwyer J (1999): Convergence of plant-rich and plant-only diets. *Am. J. Clin. Nutr.* **70**(Suppl), 620S–622S.

FAO/WHO/UNU Expert Consultation (1985): *Energy and Protein Requirements*. Technical Report Series No. 724. Geneva: World Health Organization.

Fischer B & Döring A (1999): Häufigkeit der Einnahme von Vitamin- und Mineralstoffpräparaten. Vergleich nationaler und internationaler Studien. *Ernähr.-Umsch.* **46**, 44–47.

Frentzel-Beyme R & Chang-Claude J (1994): Vegetarian diets and colon cancer: the German experience. *Am. J. Clin. Nutr.* **59**(Suppl), 1143S–1152S.

Garrel DR, Jobin N & de Jonge LH (1996): Should we still use the Harris and Benedict equations? *Nutr. Clin. Pract.* **11**, 99–103.

Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, Prentice AM (1991): Critical evaluation of energyintake data using fundamental principles of energy physiology: l. Derivation of cut-off limits to identify under-recording. *Eur. J. Clin. Nutr.* **45,** 569–581.

Griffith PR & Innes FC (1983): The relationship of socio-economic factors to the use of vitamin supplements in the city of Windsor. *Nutr. Res.* **3**, 445–455.

Havala S & Dwyer J (1993): Position of the American Dietetic Association: vegetarian diets. *JAMA* **93**, 1317–1319.

Heseker H, Adolf T, Eberhardt W, Hartmann S, Herwig A, Kübler W, Matiaske B, Moch KJ, Nitsche A, Schneider R, Zipp A (1994): Lebensmittel- und Nährstoffaufnahme Erwachsener in der Bundesrepublik Deutschland. *VERA-Schriftenreihe*, Hrsg. Kübler W, Anders HJ, Heeschen W, Kohlmeier M, Band III. Niederkleen: Dr. Fleck Wissenschaftlicher Fachverlag.

Hoffmann I, Kohl M, Groeneveld M & Leitzmann C (1994): Development and validation of a new instrument to measure food intake. *Am. J. Clin. Nutr.* **59**(Suppl), 284S.

Janelle KC & Barr SI (1995): Nutrient intakes and eating behaviour scores of vegetarian and nonvegetarian women. *JAMA* **95**, 180–189.

Kirk SFL, Cade JE, Barrett JH & Conner M (1999): Diet and lifestyle characteristics associated with dietary supplement use in women. *Public Health Nutr.* **2**, 69–73.

McGowan MJ, Harrington KE, Kiely M, Robson PJ, Livingstone MB & Gibney MJ (2001): An evaluation of energy intakes and the ratio of energy intake to estimated basal metabolic rate (EI/BMRest) in the North/South Ireland Food Consumption Survey. *Public Health Nutr.* **4**, 1043–1050.

McKenzie JC (1967): Social and economic implications of minority food habits. *Proc. Nutr. Soc.* **26**, 197–205.

Lightowler HJ & Davies GJ (2000): Micronutrient intakes in a group of UK vegans and the contribution of self-selected dietary supplements. *J. Roy. Soc. Promotion Health* **120**, 117–124.

Rana SK & Sanders TAB (1986): Taurine concentrations in the diet, plasma, urine and breast milk of vegans compared with omnivores. *Br. J. Nutr.* **56**, 17–27.

Roshanai F & Sanders TAB (1984): Assessment of fatty acid intakes in vegans and omnivores. *Hum. Nutr.: Appl. Nutr.* **38A**, 345–354.

Ross H (1991): *Zum Motivationsprofil der Vegetarier in drei europäischen Sprachräumen*. Inaugural Dissertation, Westfälische Wilhelms-Universität Münster.

Rottka H (1990): Health and vegetarian life style. *Bibl. Nutr. Dieta*. **45**, 176–194.

Sanders TAB & Key TJA (1987): Blood pressure, plasma renin activity and aldosterone concentrations in vegans and omnivore controls. *Hum. Nutr.: Appl. Nutr.* **41A**, 204–211.

Schneider R, Eberhardt W, Heseker H, Moch KJ (1992): Die VERA-Stichprobe im Vergleich mit Volkszählung, Mikrozensus und anderen nationalen Untersuchungen. *VERA-Schriftenreihe*, Hrsg.: Kübler W, Anders HJ, Heeschen W, Kohlmeier M, Band II. Niederkleen: Dr. Fleck Wissenschaftlicher Fachverlag.

Schutz HG, Read M, Bendel R, Bhalla VS, Harrill I, Monagle E, Sheehan ET & Standal BR (1982): Food supplement usage in seven Western states. *Am. J. Clin. Nutr.* **36**, 897–901.

Strassner C (1998): Ernähren sich Rohköstler gesünder? Die Gießener Rohkost-Studie. Heidelberg: Verlag für Medizin und Gesundheit.

The British Dietetic Association (1999): Position Paper approved by the Council of the British Dietetic Association on 13 January 1999: Vitamin and mineral supplementation. *J. Hum. Nutr. Diet.* **12**, 171–178.

Thorogood M, Roe L, McPherson K & Mann J (1990): Dietary intake and plasma lipid levels: lessons from a study of the diet of health conscious groups. *Br. Med. J.* **300**, 1297–1301.

Wilson AK & Ball MJ (1999): Nutrient intake and iron status of Australian male vegetarians. *Eur. J. Clin. Nutr.* **53**, 189–194.

Wolters M & Hahn A (2000): Nahrungsergänzungsmittel – Eine Bestandsaufnahme. I. Einordnung, Marktsituation und Verbraucherverhalten. *ERNO* **1**, 167–175.