Are more environmentally sustainable diets with less meat and dairy nutritionally adequate?

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Abstract

Objective: Our current food consumption patterns, and in particular our meat and dairy intakes, cause high environmental pressure. The present modelling study investigates the impact of diets with less or no meat and dairy foods on nutrient intakes and assesses nutritional adequacy by comparing these diets with dietary reference intakes.
Design: Environmental impact and nutrient intakes were assessed for the observed consumption pattern (reference) and two replacement scenarios. For the replacement scenarios, 30 % or 100 % of meat and dairy consumption (in grams) was replaced with plant-based alternatives and nutrient intakes, greenhouse gas emissions and land use were calculated.
Setting: The Netherlands.
Subjects: Dutch adults (*n* 2102) aged 19–69 years.
Results: Replacing 30 % of meat and dairy with plant-based alternatives did not substantially alter percentages below the Estimated Average Requirement (EAR) for all studied nutrients. In the 100 % replacement scenario, SFA intake decreased on average by ~35 % and Na intake by ~8 %. Median Ca intakes were below the Adequate Intake. Estimated habitual fibre, Fe and vitamin D intakes were higher; however, non-haem Fe had lower bioavailability. For Zn, thiamin and vitamin B_{12}, 10–31 % and for vitamin A, 60 % of adults had intakes below the EAR.
Conclusions: Diets with all meat and dairy replaced with plant-based foods lowered environmental impacts by >40 %. Estimated intakes of Zn, thiamin, vitamins A and B_{12}, and probably Ca, were below recommendations. Replacing 30 % was beneficial for SFA, Na, fibre and vitamin D intakes, neutral for other nutrients, while reducing environmental impacts by 14 %.

The limited resources on our planet and the world's growing population increase the need for sustainable food consumption[1,2]. The food supply chain is a major cause of greenhouse gas (GHG) emissions[3]. The livestock sector accounts for 14·5 % of human-induced GHG emissions and therefore plays an important role in climate change[4]. Meat and dairy products account for approximately 40 % of all food-related emissions[5]. One of the goals for 2030, set by the European Commission, is to reduce domestic EU emissions to at least 40 % below 1990 levels[6].

Dietary changes could play an important role in reaching environmental goals. Diets with less meat and dairy could potentially lower diet-related GHG emissions by up to 50 % in affluent countries via reductions in these products of 0–10 % when balancing energy intake with energy requirements, 0–35 % when eating a healthy diet and 25–55 % for vegan diets[7]. More plant-based diets are also linked to health benefits, such as a lower risk of CHD and type 2 diabetes[8–10]. However, others have found that

diets of high nutritional quality containing more plant foods had higher GHG emissions in self-selected French diets[11]. A healthier diet is thus not necessarily an environmentally friendlier diet. Although the evidence base for sustainable healthy diets is still under development, consensus among several health councils is that we should shift towards diets with fewer animal products and more plant-based foods[12,13].

However, not many studies have evaluated the nutritional effects of shifting towards more sustainable diets on a population level or they included only a small range of nutrients. Reducing meat and dairy consumption may potentially pose nutritional challenges for some key nutrients, such as Ca, Fe, Zn and vitamin B_{12}[5,14,15]. On the other hand, high intakes of meat and dairy products are associated with unfavourably high intakes of SFA and Na, intakes of which currently exceed the recommendations for Dutch adults[16]. When adapting to more plant-based diets, attention to adequate thiamin, vitamin B_{12}

and Zn intakes among young Dutch children is warranted[17]. Although it is expected that the effects for adults are similar, this has not yet been investigated.

The present paper examines the effects on nutrient intakes when shifting towards more plant-based diets to gain insight into possibly too low or too high intakes among certain subgroups of the Dutch adult population. Habitual intakes of energy, protein, SFA, fibre, Na, Ca, Fe, Zn, thiamin, riboflavin, vitamins A, B_{12} and D were evaluated for the current diet (reference), using data from the Dutch National Food Consumption Survey 2007–2010 (DNFCS), as well as for 'less meat and dairy' (30 %) and 'no meat and dairy' (100 %) scenarios. These intakes were compared with age- and gender-specific Dietary Reference Intakes (DRI).

Methods

Food consumption data for the reference scenario

Food consumption data for the observed consumption pattern (reference) were obtained from the DNFCS 2007–2010[16]. Food consumption data were based on two 24 h recalls that were conducted by dietitians on separate days about 4 weeks apart with the use of EPIC-Soft® program (currently known as GloboDiet)[16]. Dietary supplement use was assessed on the recalled days and with an additional questionnaire. Food composition data were taken from the extended Dutch Food Composition Table (NEVO-table 2011/3.0)[18]. The study population is a representative sample of the Dutch population with respect to age, gender, region, degree of urbanisation and educational level. The overall response was 69 % (n 3819)[19]. For the present study, we included all men and women aged 19–69 years (n 2107). Those who consumed only meal replacers (for weight reduction; n 1) or those who were lactating and thus had different nutrient requirements (n 4) were excluded. Calculations were based on 2102 individuals (1055 men and 1047 women).

Replacement scenarios

In the 'less meat and dairy' scenario, we replaced 30 % of meat and dairy products (e.g. cheese and milk) consumed in the DNFCS with plant-based alternatives of the same quantity (in grams). The 'no meat and dairy' scenario replaced 100 % of the consumed meat and dairy products with plant-based alternatives. Only foods that fully or predominantly consist of meat or dairy foods were replaced; for example, ready-to-eat porridge with milk was not replaced but a glass of milk was. The 'no meat and dairy' scenario can therefore still contain a small quantity of animal foods. Consumption of foods other than meat and dairy was assumed not to change. This also applied to fish and eggs.

To stay close to the current eating habits, replacement foods were foods with similar use in terms of consumption occasion. For instance, cheese consumed as a snack during the evening was replaced by a snack without meat or dairy and not by a sandwich filling. Moreover, replacement foods were of equal quantity as the original food consumed and had to be more environmentally sustainable (taking CO_2 equivalents and land use as indicators) than meat and dairy (Table 1). Replacement foods currently available in the Netherlands were chosen from the Dutch Food Composition Database (NEVO-online 2013/4.0)[20].

To model the replacement scenarios, a random number between 0 and 1 was allocated to each product consumed in the reference scenario and for each person on each observed day using the statistical software package SAS version 9.3. Milk products such as drinks, yoghurts and custards were replaced one-on-one by a soya-based drink, yoghurt or dessert. In the 'no meat and dairy' scenario, all dairy products were replaced and in the 'less meat and dairy' scenario only the dairy products with a number in the range 0·000–0·300 were replaced with a dairy substitute. For meat consumed at dinner, and meat and cheese as sandwich filling or snack, various substitutes were available. For replacing meat at dinner, three categories were

Table 1 Methods for assignment of replacement foods

Consumed meat and dairy products in DNFCS 2007–2010	Plant-based alternatives

Dairy products
    e.g. milk, yoghurt, custard, whipped cream and coffee milk
	Soya-based drinks and desserts
	    One-on-one replacement with soya-based drinks, yoghurt, dessert, dairy-free cream

Meat and cheese sandwich fillings
    e.g. soft and hard cheeses and various meat products
	Variety of plant-based sandwich fillings
	    33·3 % vegetarian fillings (e.g. vegetarian ham)
	    33·3 % sweet fillings (e.g. apple syrup)
	    33·3 % savoury fillings (e.g. peanut butter)

Meat at dinner
    e.g. large variety of meat products
	Variety of plant-based substitutes
	    57 % vegetarian meat (e.g. vegetarian hamburger)
	    14 % pulses (e.g. chickpeas)
	    29 % soya products (e.g. tofu)

Meat and cheese evening snacks
    e.g. soft and hard cheeses and various meat products
	Variety of snacks without meat and dairy
	    50 % sweet snacks (e.g. sweet popcorn)
	    50 % savoury snacks (e.g. falafel)

(Replaced with the same quantity (in grams))

DNFCS, Dutch National Food Consumption Survey.

used: vegetarian meat, pulses and soya products. These are also considered suitable meat substitutes according to the Netherlands Nutrition Centre[21]. In the 'no meat and dairy' scenario, 57 % (four times per week) of meat replacement was allocated to vegetarian meat replacers such as vegetarian burgers, 29 % (twice per week) to soya products and 14 % (once per week) to pulses. In the 'no meat and dairy' scenario, vegetarian meat was chosen as a substitute if the allocated number fell within the range 0·000–0·570. If the number fell in the range 0·571–0·710 pulses were chosen, and in the range 0·711–1·000 soya products were selected. In the 'less meat and dairy' scenario, these ranges were 0·000–0·171, 0·172–0·213 and 0·214–0·300, respectively, since only 30 % of the consumed products were replaced. For sandwich filling, three categories were determined: vegetarian fillings (e.g. vegetarian pâté), sweet fillings (e.g. honey and jam) and savoury fillings (peanut butter and sandwich spread). All categories had a one-third chance of being chosen and consisted of a variety of substitutes. Meat and cheese consumed during the evening were considered to be a snack and therefore replaced with a plant-based snack. These were savoury snacks (e.g. falafel) or sweet snacks (e.g. sweet popcorn) and had a probability of 0·5 in the 'no meat and dairy' scenario and of 0·15 in the 'less meat and dairy' scenario. In case a subdivision per category was made, the probability for each substitute was the same. For example, the probability of selecting honey or jam was identical. The number allocation was repeated ten times for each scenario. Since the differences in mean nutrient intakes between these replicates was very small (CV < 1 %), one allocation was randomly chosen to represent that scenario.

Habitual intake distributions

The main interest is in the long-term nutrient intake, also called the habitual or usual intake; therefore a statistical model was applied to two 24 h recalls per person, which accounted for the intra-individual variation (day-to-day variation). With SPADE (Statistical Program to Assess Dietary Exposure, version 2.29.01), habitual nutrient intake was modelled as a function of age for men and women separately[22]. Habitual intake distributions for energy and macronutrients were estimated using the one-part model (for components consumed on a daily basis by all subjects). Habitual distributions for vitamins and minerals from food sources and dietary supplements combined were estimated with a three-part model, as described by Verkaik-Kloosterman *et al.*[23]. In this model, the habitual intake from food sources was estimated separately for users and non-users of dietary supplements to retain potential differences in dietary intake between these groups. For the users of dietary supplements, also the habitual intake from supplements was estimated. The habitual intakes from food sources and dietary supplements were combined for users of dietary supplements to get the total habitual intake. Combining the habitual intake distributions of non-users and users of dietary

supplements provides the habitual intake distribution for the total population. Individuals were considered as potential supplement users based on the dietary supplement questionnaire and/or supplement use during the two recalled days. Individuals were assigned as potential supplement users separately for each nutrient. Supplement use in the replacement scenarios was assumed to be equal to the reference scenario.

Dietary Reference Intakes

The population's habitual nutrient intake distributions for the reference and replacement scenarios were compared with the DRI. In order to evaluate whether intakes are adequate on a population level, the Estimated Average Requirement (EAR) cut-point method was used as described by Carriquiry[24]. To exclude modelling uncertainties, the intake was considered adequate when the 95 % confidence limit of the proportion below the EAR included 2·5 % or less[25]. For fibre, Ca, thiamin (51–69 years) and vitamin D, an Adequate Intake (AI) was available, which allows for only a qualitative evaluation of the intake[26]. In some cases, also a Tolerable Upper Intake Level (UL) was available, which is the maximum level of daily intake likely to pose no risk or adverse effects[27]. The proportion of adults with intakes below the EAR and/or above the UL was calculated. The recommendations were obtained from dietary reference values of the Health Council of the Netherlands (for energy, protein, SFA[28], fibre[29], Ca, thiamin and riboflavin[30], vitamin A[31], vitamin B_{12}[32] and vitamin D[33]), the Nordic Nutrition Recommendations (for Zn and Fe[12]), and the European Food Safety Authority (for the UL of Zn and vitamins A and D[34,35]). Since the Dutch Food Composition Table[18] did not distinguish between free and intrinsic sugars, the change in mono- and disaccharide content of the scenarios was used as a proxy for free sugar intake, but could therefore not be compared with the DRI.

Environmental impact of foods

Two indicators were used for the evaluation of environmental impacts: GHG emission (kg CO_2-eq/d) and land use ($m^2 \times$ year/d). GHG emission is an indicator for global warming potential[2] and in the present study covers not only CO_2 emissions through the use of fossil fuels, but also CH_4 and N_2O emissions expressed as CO_2 equivalents (CO_2-eq). Land use covers the surface needed for the production of food during a certain period of time[36]. The environmental impacts were estimated via life cycle assessments by Blonk Consultants (data set version 2012). In life cycle assessment, the total amount of emissions and resources used are calculated throughout the whole life cycle of a product (i.e. cradle to grave assessment). Environmental data were accessible for 254 frequently consumed food items covering about 80 % of the total food weight (in g/d) consumed in the DNFCS. Extrapolations were made to >1300 other food codes by an experienced

dietitian, based on similarities in type of food, production system and ingredient composition. Transport from grocery store to home was not included due to large variations. Besides, this transport can be considered the same for different products[36]. The life cycle assessment data were combined with the food consumption data to calculate daily GHG emissions and land use for each of our subjects.

Statistical analysis

Habitual nutrient intakes and environmental impact distributions were modelled using SPADE. Mean habitual nutrient intakes (with 95 % CI) are presented for each nutrient, or as a median for nutrients when compared with an AI. All analyses on habitual nutrient intakes and environmental indicators were performed for men and women separately. The results are presented for the age groups 19–30, 31–50 and 51–69 years. A weighting factor was included to account for small deviances in socio-demographic characteristics, days of the week and season of data collection, to make the results representative for the Dutch adult population, for every day of the week and every season. The 95 % CI were computed using the bootstrap method with 200 iterations. Significant differences between scenarios were evaluated by non-overlapping 95 % CI. In general, nutrient distributions tend to be non-symmetrical. Therefore, plots were used to visually check whether the confidence bounds of the distributions overlapped over the whole range of percentiles. Although the mean point estimates may be significantly different, there might still be some overlap at the highest and lowest percentiles.

Results

Nutrient composition and environmental impact per food item

Meat causes higher GHG emissions and land use than meat alternatives (Table 2). However, the variation between different kinds of meat products was large, with for example lower impacts for chicken (4·6 CO_2-eq/kg) than for beef (19·6 CO_2-eq/kg). GHG emissions of meat replacers ranged from 1·5 to 2·2 CO_2-eq/kg. Average land use and GHG emissions for 1 kg of cow's milk were almost twice as high as for 1 kg of soya drink (Table 3).

Energy content varied between the various products, but was more or less similar for meat/dairy and their alternatives (Tables 2 and 3). Based on the DNFCS 2007–2010, meat and dairy products were consumed much more frequently than vegetarian meat substitutes and soya products. Vegetarian meat substitutes contained less vitamins A and D and Zn than meat. Pulses do not contain vitamin B_{12} and have lower protein content than meat. On the other hand, fibre content was higher in vegetarian meat and pulses than in meat products and cheese. Na content of commercially available meat replacements was relatively high compared with pulses and soya products.

Most of the commercially available meat replacements are enriched with Fe and vitamin B_{12}[37], and dairy replacements may be enriched with Ca, riboflavin and vitamins B_{12} and D[38]. Soya drinks contain more vitamin D than cow's milk. Sugar content of dairy replacements was somewhat higher in some of the variants. In our population, cheese was the most consumed sandwich filling as well as the most consumed animal-based snack after dinner. Furthermore, plant-based sandwich fillings such as peanut butter and sweet snacks such as Dutch spiced bread were frequently consumed in the reference scenario. Some sandwich fillings such as chocolate sprinkles and apple syrup contain (non-haem) Fe, but also have high sugar contents.

Environmental impact of a day's consumption

In the reference scenario, the average habitual GHG emission was 4·3 kg CO_2-eq/person per d; the 5th–95th percentile ranged from 3·2 to 6·8 kg CO_2-eq/d for men and from 2·5 to 5·1 kg CO_2-eq/d for women. Habitual land use was 4·4 m^2/person per d. Men's daily diet generally had a higher environmental impact than women's diet in all scenarios. In the 'less meat and dairy' scenario, GHG emissions and land use were both reduced by on average 14 % compared with the reference scenario. In the 'no meat and dairy' scenario, GHG emissions and land use were reduced by 47 % and 41 %, on average, respectively. The reduction potential was more or less similar for men and women.

Nutritional value of a day's consumption

The 'less meat and dairy' scenario showed the same trend for the shift in nutrient intakes as the 'no meat and dairy' scenario, but with a smaller deviation from the reference (Fig. 1).

In general, macro- and micronutrient intakes were higher for men than for women. The average habitual energy intake for men in the reference scenario was approximately 11·0 MJ/d and for women this was 8·4 MJ/d, depending on the age category (Table 4). The replacement scenarios did not alter energy intake significantly. The habitual daily protein intake in the reference scenario was 98 g for men and 76 g for women. Even though protein intake decreased to 77 g/d for men and 60 g/d for women in the 'no meat and dairy' scenario, the percentage below the EAR remained low (3 % below the corresponding EAR for women and 1 % for men). In the reference scenario, almost all Dutch adults had a habitual SFA intake above the UL of 10 E% (percentage of daily energy intake). In the 'no meat and dairy' scenario, SFA intake decreased significantly by 35–36 %, which resulted in a lower proportion of the population with too high intakes (19 % above the UL for men compared with 97 % in the reference scenario). The mean habitual mono- and disaccharide intakes (as a proxy for sugar) increased by 6 % and 16–18 % in the 'less meat and dairy' and 'no meat

Table 2 Average daily consumption (frequency and amount in grams) in the reference scenario of the top three most consumed products (based on total quantity) consisting of meat or dairy, their corresponding environmental impact per kilogram of product and their corresponding nutritional composition per 100 g of product

Product	Frequency of consumption*	Average portion size (g)	GHG emissions (kg CO_2-eq)	Land use (m² × year)	Energy (kJ)	Protein (g)	SFA (g)	Monodisacc. (g)	Fibre (g)	Na (mg)	Ca (mg)	Fe (mg)	Zinc (mg)	Vitamin A (µg RAE)	Thiamin (mg)	Riboflavin (mg)	Vitamin B_{12} (µg)	Vitamin D (µg)
Meat																		
Chicken fillet	226	90	4·6	6·9	464	23·3	0·5	0·0	0·0	53	6	0·6	0·65	30	0·08	0·03	0·20	2·5
Minced meat, beef/pork	181	82	15·5	17·8	969	19·2	6·9	0·3	0·3	177	9	1·3	3·22	16	0·27	0·13	1·25	0·3
Minced meat, beef	139	85	19·6	23·0	937	18·9	7·0	0·2	0·3	110	8	2·0	4·33	18	0·03	0·13	1·90	0·1
Dairy																		
Milk, semi-skimmed	1360	186	1·3	0·8	192	3·4	1·0	4·6	0·0	39	122	0·0	0·41	16	0·03	0·18	0·45	0·0
Yoghurt, low fat	262	197	1·2	0·8	161	4·2	0·2	4·1	0·0	42	150	0·0	0·61	2	0·02	0·17	0·27	0·0
Buttermilk	195	265	1·5	1·0	131	3·0	0·2	3·6	0·0	37	108	0·0	0·41	2	0·02	0·15	0·13	0·0
Sandwich filling†																		
Cheese, Gouda 48 +	1269	33	12·3	7·6	1526	22·8	19·8	0·0	0·0	760	815	0·2	3·47	332	0·01	0·29	1·97	0·2
Ham, shoulder, medium fat	256	28	5·4	6·1	556	16·4	2·1	0·6	0·4	1120	9	0·8	2·20	1	0·41	0·17	0·44	0·0
Cheese, 30 +	224	29	12·3	7·6	1205	30·4	12·1	0·0	0·0	735	1045	0·2	4·71	178	0·02	0·33	1·57	0·2
Snacks during evening‡																		
Cheese, Gouda 48 +	107	33	12·3	7·6	1526	22·8	19·8	0·0	0·0	760	815	0·2	3·47	332	0·01	0·29	1·97	0·2
Croquette, meat ragoût	23	46	11·9	11·1	813	7·5	4·6	1·5	1·3	521	21	1·7	1·40	3	0·04	0·01	0·51	0·7
Frikandel (deep-fried sausage)	11	74	5·9	7·3	1006	14·5	6·1	1·5	1·1	853	86	2·0	1·00	27	0·07	0·10	–	0·6

GHG, greenhouse gas; CO_2-eq, CO_2 equivalents; monodisacc., mono- and disaccharides; RAE, retinol activity equivalents.
– means not available in NEVO-online (2013)[20].
*Based on the number of consumers of the product in the Dutch National Food Consumption Survey 2007–2010 (n 2102).
†Most consumed meat and cheese as sandwich filling.
‡Most consumed snacks during the evening.

Table 3 Average daily consumption (frequency and amount in grams) in the reference scenario of the top three most consumed meat and dairy substitutes, their corresponding environmental impact per kilogram of product and their corresponding nutritional composition per 100 g of product

Product	Frequency of consumption*	Average portion size (g)	GHG emissions (kg CO_2-eq)	Land use ($m^2 \times$ year)	Energy (kJ)	Protein (g)	SFA (g)	Monodisacc. (g)	Fibre (g)	Na (mg)	Ca (mg)	Fe (mg)	Zn (mg)	Vitamin A (µg RAE)	Thiamin (mg)	Riboflavin (mg)	Vitamin B$_{12}$ (µg)	Vitamin D (µg)
Meat substitutes																		
Vegetarian meat																		
Vegetable burger	4	88	1·5	1·7	904	11·6	1·2	4·4	3·7	634	0	2·3†	–	0	–	0·14	0·25†	0·0
Mincemeat balls (veg)	3	83	2·2	2·7	741	17·0	1·0	1·3	3	695	75	2·1†	0·10	0	0·10	0·14	0·15†	0·0
Mincemeat (veg)	3	65	2·2	2·7	571	19·1	0·1	3·1	5·7	585	0	2·1†	0·01	0	0·13	0·15	0·26†	0·0
Pulses																		
Brown beans	28	126	1·3	1·2	458	6·7	0·1	1·6	8·1	230	39	1·5	0·56	0	0·06	0·04	0·00	0·0
Beans in tomato sauce	13	138	1·3	1·0	385	5·6	0·1	4·1	5·2	360	58	1·8	0·61	6	0·06	0·04	0·00	0·0
Chickpeas	6	52	1·3	2·8	517	7·6	0·4	0·0	6·7	8	46	1·8	1·70	2	0·05	0·03	0·00	0·0
Soya products																		
Tahoe/tofu	5	69	1·6	2·2	472	11·6	1·0	1·0	0·3	6	188	2·2	1·10	19	0·07	0·02	0·00	0·0
Tempe	1	68	1·6	2·2	624	12·2	1·1	5·6	5·6	8	91	2·0	1·30	2	0·05	0·25	0·00	0·0
Dairy substitutes																		
Soya drink, light	14	194	0·4	0·5	119	2·1	0·2	1·7	1·0†	40	120†	0·2	0·15	0	0·00	0·21†	0·38†	0·8†
Breakfast drink, fruit-based	11	244	0·6	0·1	219	0·4	0·0	10·4	0·7	2	6	0·3	–	0	0·20†	0·01	0·00	0·0
Soya drink, several flavours	8	272	0·4	0·5	251	2·9	0·3	7·5	0·6	68	120†	0·3	0·23	1	0·02	0·21†	0·38†	0·8†
Plant-based sandwich fillings																		
Vegetarian fillings																		
Vegetable paste	3	30	1·3	2·8	915	7·5	2·7	7·6	–	461	–	0·0	–	–	1·00	2·00	0·00	–
Luncheon meat (veg)	3	17	1·5	1·7	1354	15·0	3·2	0·0	1·0	815	1	2·1†	0·01	0	0·08	0·09	0·15†	0·0
Pâté (veg)	2	40	1·5	1·7	1274	7·8	3·2	1·4	1·9	700	39	2·1†	0·04	0	0·06	0·08	0·15†	0·0
Sweet fillings																		
Jam	265	28	2·3	0·6	1044	0·3	0·0	52·3	0·9	10	8	0·4	0·04	7	0·01	0·01	0·00	0·0
Chocolate sprinkles, dark	183	15	2·2	1·2	1887	5·8	9·0	60·5	6·6	27	36	8·1	1·27	4	0·02	0·05	0·21	0·0
Apple syrup	118	25	1·3	0·7	1001	1·9	0·0	55·1	4·0	36	30	11·3	0·79	0	0·04	0·10	0·00	0·0
Savoury fillings																		
Peanut butter	198	28	1·7	5·1	2792	22·4	8·3	4·4	8·0	250	50	1·4	2·30	0	0·10	0·10	0·00	0·0
Sandwich spread, original	40	28	0·7	1·5	975	1·6	1·2	14·0	0·8	532	56	2·0	–	44	0·02	0·02	–	0·1
Snack substitutes																		
Sweet snacks																		
Dutch spiced bread	265	28	1·2	2·0	1325	3·0	0·2	37·4	3·5	238	17	0·7	0·65	0	0·02	0·03	0·00	0·1
Popcorn (sweet)	3	25	0·9	3·7	1649	9·9	0·8	24·0	3·8	2	8	0·9	0·08	4	0·30	0·09	0·00	0·0
Dried fruits	1	14	0·5	0·6	1128	2·0	0·0	50·8	12·4	14	68	1·8	0·43	56	0·04	0·09	0·00	0·0
Savoury snacks																		
Sausage (veg)	2	75	1·5	1·7	1074	13·3	2·4	1·8	0·6	773	20	2·1†	–	0	–	0·14	0·15†	0·0
Falafel	2	47	1·3	2·8	893	7·0	1·4	3·0	5·5	475	27	2·1†	0·85	1	0·07	0·03	0·15†	0·0
Nuggets (veg)	0	0	1·5	1·7	1064	15·0	2·3	1·0	2·0	600	67	2·1†	0·10	0	0·11	0·14	0·15†	0·0

GHG, greenhouse gas; CO_2-eq, CO_2 equivalents; monodisacc, mono- and disaccharides; RAE, retinol activity equivalents; veg, vegetarian.
– means not available in NEVO-online (2013)[20].
*Based on the number of consumers of the product in the Dutch National Food Consumption Survey 2007–2010 (*n* 2102).
†Fortified with vitamins and/or minerals.

and dairy' scenario, respectively, compared with the reference. Mean mono- and disaccharide intakes varied around 23 E% for men and 26 E% for women in the 'no meat and dairy' scenario compared with 20 E% and 22 E% in the reference scenario. Partial – or full – replacement of meat and dairy with plant-based substitutes increased daily fibre intake among men and women, but the habitual median intake remained below the AI. Habitual Na intake decreased slightly, but only significantly among men in the 'no meat and dairy' scenario (−9 %).

Micronutrients

The observed median habitual Ca intake varied around 1128 mg/d for men and 989 mg/d for women depending on age (Table 5). In the 'no meat and dairy' scenario, median Ca intake decreased significantly by 25 % to 839 mg/d for men and 737 mg/d for women. The median Ca intake in the replacement scenarios was below the AI for most age–gender categories. In the reference scenario, daily habitual Fe intake was 10·3–12·8 mg/d depending on age and gender. In the 'less meat and dairy' and 'no meat and dairy' scenarios, habitual Fe intake increased by 7 % and 21 % for men and 6 % and 19 % for women, respectively. Among women of fertile age, this higher Fe intake decreased the proportion of women with intakes below the corresponding EAR. The mean habitual Zn intake in the reference scenario ranged from 11·0 to 13·3 mg/d. Zn intake already decreased significantly by 10–12 % in the 'less meat and dairy' scenario. However, the risk of inadequate intakes remained low (1 % below the EAR). Habitual Zn intake in the 'no meat and dairy' scenario decreased by 29 % for women and 45 % for men, leading to higher proportions of the population with intake below the corresponding EAR (21 % for women and 24 % for men). No adults exceeded the UL of 2500 mg/d.

Mean habitual intake of total vitamin A was approximately 995 μg RAE (retinol activity equivalents)/d for men and 897 μg RAE/d for women in the reference scenario. Vitamin A intake decreased significantly in the 'no meat and dairy' scenario, leading to 64 % of men and 58 % of women having an intake below the corresponding EAR. The risk of excessive vitamin A intake remained low: 2–5 % for women aged 51–69 years and 0 % for other age–gender categories (data not shown). Daily habitual intake of thiamin did not change significantly over the three scenarios for adults aged 19–50 years. However, in the 'no meat and dairy' scenario, 28–31 % of women aged 19–50 years had an intake below the EAR, whereas the percentage in men was 10–12 % below the EAR. Daily intake of riboflavin did not change significantly from the reference and risk of inadequate intake remained relatively low in both replacement scenarios, with a maximum of 10 % below the EAR for men in the 'no meat and dairy' scenario. Mean habitual vitamin B_{12} intake decreased significantly for men (−41 %), but not significantly for women (−27 %), in the 'no meat and dairy' scenario

compared with the reference. Especially for women, the confidence bounds around the mean habitual vitamin B_{12} intake were large. For both genders, the proportion of adults with an intake below the corresponding EAR increased from 0–1 % in the reference scenario to 23–29 % in the 'no meat and dairy' scenario. The median habitual intake of vitamin D increased significantly by 32–34 % in the 'no meat and dairy' scenario compared with the reference, but remained below the AI of 10 μg/d for all age–gender groups. There was no risk of excessive vitamin D intake in any scenario (0 % above the UL).

Discussion

The present study evaluated the nutrient intakes of adults when meat and dairy products were partially or fully replaced by plant-based alternatives. The 'less meat and dairy' scenario (30 % replacement) did not substantially alter percentages below the EAR over the range of nutrients in all age–gender groups compared with the reference, while lowering GHG emissions and land use of daily diets by ∼14 %. The 'no meat and dairy' scenario (100 % replacement) was nutritionally inadequate with respect to vitamin A, thiamin, vitamin B_{12} and Zn intakes, despite reducing environmental impacts by >40 %. When replacing meat and dairy foods with plant-based alternatives in these scenarios, intakes of SFA, fibre, Na and vitamin D were more in line with dietary recommendations.

Nutritional adequacy of dietary scenarios

In the present study, nutritional adequacy was assessed by comparing the population's habitual nutrient intakes with age- and gender-specific DRI. No additional biomarkers were measured. This study therefore has more of a signalling function to assess the risks and benefits on a population level when shifting towards more plant-based diets. It should be noted that the EAR cut-point method is valid for all nutrients in the study except for Fe, where the true prevalence of inadequate intake may be underestimated for women of fertile age due to different requirements[24].

Replacing all meat and dairy in the diet with plant-based alternatives increased the risk of inadequate micronutrient intakes for Zn, thiamin and vitamin B_{12}, with up to 10–31 % of adults having intakes below the EAR. For vitamin A, about 60 % of the population had intakes below the EAR (16–19 % were below the EAR in the reference scenario). For Ca, the median intakes were below the AI in both replacement scenarios. These results are in line with previous dietary simulations[17,39]. Even though protein intake was reduced by ∼20 % in the 'no meat and dairy' scenario, protein intakes were still adequate on a population level. Protein requirements may be 20 % higher among vegetarians due to the lower protein quality of plant sources as compared with animal sources[28]. Although not studied, we expect that the provision of essential amino acids is sufficient due to the variety of plant-based proteins in the
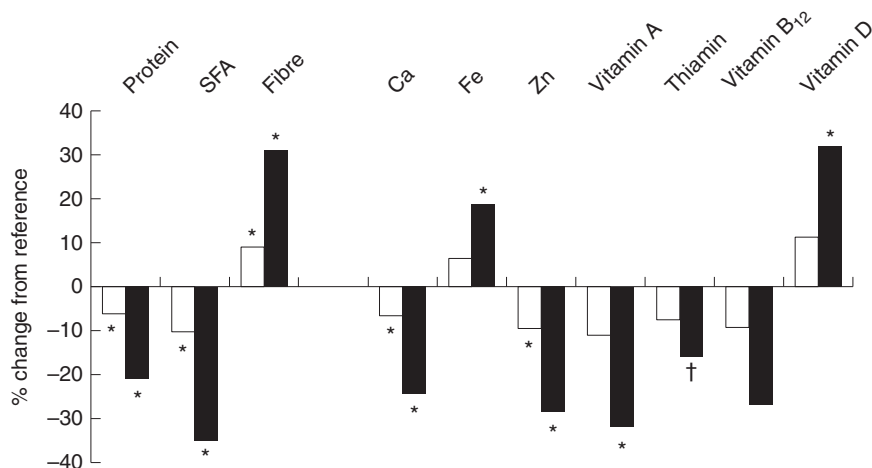
Fig. 1 Percentage change in nutrient intakes for the 'less meat and dairy' (□) and 'no meat and dairy' (■) scenarios compared with the reference scenario in Dutch women aged 19–69 years (*n* 1047). The percentage change in nutrient intakes for men is comparable. *Significantly different from the reference scenario based on the 95 % CI around the habitual intake; †significant only for the age group 51–69 years

replacement scenarios and the high levels of daily protein intake.

Shifting to diets with fewer animal products and more plant-based foods is in accordance with advice from various health councils[40,41] and could in our scenarios reduce intakes of SFA and Na, while increasing fibre and vitamin D intakes. Diets low in SFA and high in fibre are, in the long term, associated with a reduced risk of CVD, cancer and obesity[42–44]. Particularly the 'no meat and dairy' scenario could reduce SFA intake by about 35 % and increase fibre intake by >30 %. Na intake could not, however, be compared directly with the dietary guidelines because salt added to foods during preparation or at the table was not included[20]. Assuming that the amounts of added salt were similar in every scenario, the Na intakes in the 'no meat and dairy' scenario were significantly lower compared with the reference scenario. Although reduced, the mean Na intakes were still above the recommendation of <2 g/d[45] in the replacement scenarios. The increase in vitamin D intakes in the replacement scenarios is likely due to the fortification of dairy replacements (Table 3).

The risk of inadequate intakes of vitamin A, thiamin, vitamin B_{12}, Zn and probably Ca warrants attention. These micronutrients can also be derived from plant sources (albeit in smaller amounts/lower bioavailability) except for vitamin B_{12}. Vitamin B_{12}, in its natural form, is present mainly in foods of animal origin[32]. Some plant foods such as a few types of edible algae and mushrooms are known to contain vitamin B_{12}, but their biological activity and effect on B_{12} status in man are inconclusive[46]. When no animal foods are consumed, the intake depends largely on fortified foods and/or dietary supplements. The percentage reduction in vitamin B_{12} intake was larger in men's diet (−41 %) than in women's diet (−27 %) in the 'no meat and dairy' scenario, likely due to the higher meat consumption among men in the reference scenario

(185 g/d for men and 119 g/d for women; DNFCS 2007–2010). Based on serum vitamin B_{12} levels, individuals who follow a vegan diet and do not take vitamin B_{12} supplements, or eat foods enriched with this vitamin, were more prone to vitamin B_{12} deficiency than those adhering to other vegetarian diets[15]. Vitamin A intake in Western countries mostly results from consumption of milk, butter, cheese, eggs, liver and fatty fish, but it can also be synthesised from plant foods (in the form of carotenoids) naturally present in green leafy vegetables (as well as carrots), and yellow and orange fruits. Vitamin A is also present in enriched margarines in the Netherlands[31]. The EAR for vitamin A is based on adequate liver stores and it is yet unknown whether intakes below this EAR will result in health problems[31]. Thiamin can be obtained from meat and dairy products, but also from cereal products[12]. Ca intake decreased by 25 % in the 'no meat and dairy' scenario, but only a qualitative assessment could be made by comparison to an AI. Large Ca sources are milk and dairy products that account for 58 % of Ca intake in the Dutch population, while cereal products (8 %) and vegetables (5 %) have a small contribution[16]. In the 'less meat and dairy' scenario, Zn intake remained adequate; however, the 'no meat and dairy' scenario showed that 21–24 % of the population would have intakes below the EAR. Sources of Zn are meat and milk products, but also wholegrain cereals[12]; however, bioavailability of the latter may be reduced considerably by phytic acid[14].

Bioavailability of micronutrients

When eating a largely plant-based diet, a potential concern is the lower bioavailability of Fe and Zn. Absorption may be reduced when increasing phytate-containing pulses and whole grains in the diet[14,47]. Fe requirements for vegetarians may be up to 80 % higher than for people who eat a mixed Western diet[48]. Although vegetarians have

Table 4 Habitual intakes of energy, macronutrients and sodium, and the evaluation in different meat and dairy replacement scenarios, among Dutch adults (1055 men and 1047 women) aged 19–69 years, weighted for sociodemographic factors, season and day of the week. Results are presented as point estimates with their 95 % CI

		Reference scenario				'Less meat and dairy' scenario				'No meat and dairy' scenario			
		No replacement				30 % replacement*				100 % replacement*			
				Evaluation				Evaluation				Evaluation	
Nutrient/Gender	Recommendation	Mean	95 % CI	Estimate	95 % CI	Mean	95 % CI	Estimate	95 % CI	Mean	95 % CI	Estimate	95 % CI
Energy (MJ/d)†,‡													
Men	11·0–12·9 (EAR)	11·0[a]	10·8, 11·9			10·9[a]	10·8, 11·8			10·8[a]	10·6, 11·6		
Women	9·0–10·2 (EAR)	8·4[a]	8·1, 8·5			8·4[a]	8·1, 8·6			8·3[a]	8·0, 8·4		
Protein (g)‡				% < EAR				% < EAR				% < EAR	
Men	45–47 (EAR)	98[a]	96, 106	0	0, 0	92[a]	90, 100	0	0, 0	77[b]	75, 83	1	0, 2
Women	39–40 (EAR)	76[a]	74, 78	0	0, 1	71[b]	69, 73	0	0, 1	60[c]	58, 61	3	2, 5
SFA (E%)‡				% > UL				% > UL				% > UL	
Men	10 (UL)	14[a]	13, 15	97	92, 100	12[a]	11, 13	89	77, 95	9[b]	8, 9	19	8, 24
Women	10 (UL)	13[a]	13, 14	91	88, 95	12[b]	11, 12	79	75, 86	9[c]	8, 9	17	12, 24
Mono- and disaccharides (E%)													
Men	–	20[a]	19, 20			21[a]	20, 21			23[b]	22, 24		
Women	–	22[a]	21, 23			23[a,b]	22, 24			26[b]	24, 26		
Fibre (g/MJ)§				Adequacy				Adequacy				Adequacy	
Men	3·4 (AI)	2·1¶[a]	2·1, 2·2	ns		2·4¶[b]	2·3, 2·4	ns		2·9[c]	2·9, 3·0	ns	
Women	3·4 (AI)	2·3¶[a]	2·3, 2·4	ns		2·6¶[b]	2·5, 2·6	ns		3·1[c]	3·1, 3·2	ns	
Na (g/d)‖													
Men	–	3·1[a]	3·1, 3·3			3·1[a]	3·1, 3·2			2·9[b]	2·9, 3·0		
Women	–	2·4[a]	2·4, 2·5			2·3[a,b]	2·3, 2·4			2·2[b]	2·2, 2·3		

E%, percentage of daily energy intake; EAR, Estimated Average Requirement; UL, Tolerable Upper Intake Level; AI, Adequate Intake; ns, median intake is below corresponding AI and therefore no statement about the adequacy can be made.

[a,b,c]Mean/median values between scenarios with unlike superscript letters were significantly different (based on the 95 % CI around the point estimate as estimated using 200 bootstrap samples).

*Replacement of meat and cheese as sandwich filling and snack, meat for dinner and dairy drinks and desserts by plant-derived substitutes.

†Average energy intake varies with age and gender and is based on a moderately active lifestyle (physical activity level = 1·7). Due to the high correlation between energy intakes and requirements, no statement about adequacy could be made[24].

‡EAR for energy and protein and UL for SFA from the Health Council of the Netherlands (2001)[28].

§AI for fibre from the Health Council of the Netherlands (2006)[29].

‖Na intake is based on prepared and unprepared products as presented in NEVO-online (2013)[20]. Commercially available meat replacers generally contain Na, whereas meats may or may not include (added) Na depending on whether the calculations are based on prepared or unprepared products. No direct comparison with daily recommendations could be made.

¶Median point estimate.

Table 5 Habitual micronutrient intakes, and the evaluation for different meat and dairy replacement scenarios, among Dutch adults (1055 men and 1047 women) aged 19–69 years, weighted for socio-demographic factors, season and day of the week. Results are presented as point estimates and between brackets with their 95 % CI

Nutrient/gender	Age group (years)	Recommendation		Reference scenario — No replacement		Evaluation				'Less meat and dairy' scenario — 30 % replacement*		Evaluation				'No meat and dairy' scenario — 100 % replacement*		Evaluation			
				Mean	95 % CI	Estimate	95 % CI	Estimate	95 % CI	Mean	95 % CI	Estimate	95 % CI	Estimate	95 % CI	Mean	95 % CI	Estimate	95 % CI	Estimate	95 % CI
Ca (mg/d)		AI§	UL§			Adequacy		% > UL				Adequacy		% > UL				Adequacy		% > UL	
Men	19–69	1000/1100	2500	1128¶[a]	1101, 1160	ns		0	0, 0	1044¶[b]	1010, 1069	ns		0	0, 0	839¶[c]	810, 860	ns		0	0, 0
Women	19–69	1000/1100	2500	989¶[a]	964, 1014	ns		0	0, 0	920¶[b]	897, 947	ns		0	0, 0	737¶[c]	719, 763	ns		0	0, 0
Fe (mg/d)†		EAR‡				% < EAR						% < EAR						% < EAR			
Men	19–69	7		12·8[a]	12·5, 13·1	1	1, 3			13·7[b]	13·3, 13·9	1	0, 1			15·4[c]	15·0, 15·7	0	0, 0		
Women	19–30	10		10·3[a]	9·8, 10·8	57	53, 64			10·7[a]	10·3, 11·2	49	44, 54			12·5[b]	11·9, 12·9	26	20, 31		
	31–50	10		11·7[a]	11·3, 12·6	40	34, 44			12·5[a]	12·0, 13·3	30	22, 33			14·0[b]	13·5, 14·9	14	9, 16		
	51–69	6		12·2[a]	11·6, 12·8	0	0, 1			13·1[a]	12·3, 13·4	0	0, 1			14·2[b]	13·7, 14·9	0	0, 0		
Zn (mg/d)		EAR‡	UL‖			% < EAR		% > UL				% < EAR		% > UL				% < EAR		% > UL	
Men	19–69	6	25	13·3[a]	12·9, 13·6	0	0, 0	2	1, 2	11·7[b]	11·3, 11·9	1	0, 1	1	0, 2	7·9[c]	7·6, 8·1	24	20, 27	0	0, 1
Women	19–69	5	25	11·0[a]	10·7, 11·4	0	0, 1	1	0, 1	10·0[b]	9·6, 10·2	1	0, 2	1	0, 1	7·3[c]	7·0, 7·5	21	18, 23	0	0, 1
Vitamin A (µg RAE/d)		EAR§				% < EAR						% < EAR						% < EAR			
Men	19–69	620/610		995[a]	948, 1068	16	11, 20			883[a]	844, 961	25	20, 30			596[b]	574, 632	64	60, 67		
Women	19–69	530		897[a]	844, 968	19	14, 23			798[a]	760, 850	27	22, 31			612[b]	573, 657	58	54, 62		
Thiamin (mg/d)		EAR§	AI§			% < EAR		Adequacy				% < EAR		Adequacy				% < EAR		Adequacy	
Men	19–30	0·8		1·64[a]	1·49, 2·04	1	0, 3			1·53[a]	1·39, 1·97	3	1, 6			1·34[a]	1·16, 1·76	10	8, 18		
	31–50	0·8		1·88[a]	1·55, 2·75	2	0, 4			1·85[a]	1·46, 2·65	4	2, 7			1·63[a]	1·26, 2·42	12	7, 16		
	51–69		1·1	1·36¶[a]	1·29, 1·42			ad		1·26¶[a]	1·19, 1·31			ad		1·06¶[b]	1·01, 1·10			ns	
Women	19–30	0·8		1·98[a]	1·37, 2·34	14	8, 19			1·59[a]	1·31, 2·40	17	11, 23			1·63[a]	1·17, 2·15	31	24, 38		
	31–50	0·8		2·08[a]	1·54, 2·65	12	7, 14			2·07[a]	1·46, 2·58	15	10, 19			1·84[a]	1·33, 2·41	28	21, 32		
	51–69		1·1	1·27¶[a]	1·20, 1·34			ad		1·19¶[a]	1·13, 1·26			ad		1·04¶[b]	0·97, 1·10			ns	
Riboflavin (mg/d)		EAR§				% < EAR						% < EAR						% < EAR			
Men	19–69	1·1		2·23[a]	2·05, 2·41	7	4, 10			2·13[a]	2·02, 2·40	8	5, 10			2·25[a]	2·00, 2·40	10	6, 12		
Women	19–69	0·8		2·60[a]	2·02, 3·03	3	2, 5			2·66[a]	2·03, 3·18	3	1, 5			2·40[a]	2·00, 3·08	5	3, 7		
Vitamin B$_{12}$ (µg/d)		EAR§				% < EAR						% < EAR						% < EAR			
Men	19–69	2		5·83[a]	5·65, 6·27	0	0, 1			5·07[b]	4·94, 5·51	1	0, 2			3·44[c]	3·21, 3·77	23	18, 27		
Women	19–69	2		6·02[a]	5·27, 6·84	1	0, 3			5·46[a]	4·77, 6·31	4	2, 6			4·39[a]	3·58, 5·45	29	24, 33		
Vitamin D (µg/d)		AI§	UL‖			Adequacy		% > UL				Adequacy		% > UL				Adequacy		% > UL	
Men	19–69	10	100	4·2¶[a]	4·1, 4·4	ns		0	0, 0	4·6¶[b]	4·5, 4·8	ns		0	0, 0	5·7¶[c]	5·4, 5·9	ns		0	0, 0
Women	19–69	10	100	3·5¶[a]	3·3, 3·7	ns		0	0, 0	3·9¶[a]	3·7, 4·1	ns		0	0, 0	4·8¶[b]	4·6, 5·0	ns		0	0, 0

RAE, retinol activity equivalents; EAR, Estimated Average Requirement; AI, Adequate Intake; UL, Tolerable Upper Intake Level; ad, low risk of inadequate intake; ns, no statement could be made about the adequacy since the median intake is below the AI.

[a,b,c]Mean/median values between scenarios with unlike superscript letters were significantly different (based on the 95 % CI around the mean as estimated using 200 bootstrap samples).

*Replacement of meat and cheese as sandwich filling and snack, meat for dinner and dairy drinks and desserts by plant-derived substitutes.

†Fe intake was estimated without taking into account difference in bioavailability between animal and plant sources.

‡EAR for Fe and Zn from the Nordic Council of Ministers (2014)[12].

§Dietary Reference Intakes for Ca, thiamin and riboflavin from the Health Council of the Netherlands (2000)[30], EAR for vitamin A from the Health Council of the Netherlands (2008)[31], EAR for vitamin B$_{12}$ from the Health Council of the Netherlands (2003)[32] and AI for vitamin D from the Health Council of the Netherlands (2012)[33].

‖UL for Zn from the European Food Safety Authority (2006)[34] and for vitamin D from the European Food Safety Authority (2012)[35].

¶Median point estimate.

lower Fe stores, no adverse health effects from decreased Fe and Zn absorption have been demonstrated with varied vegetarian diets in developed countries[14]. The increase in total Fe intake in our replacement scenarios is probably due to non-haem Fe in fortified meat replacers (Table 3). For vegetarian cereal-based diets, it is advised to increase Zn intake by 25–30 %[12]. Due to a reduced bioavailability of Zn and Fe, it may be necessary to adjust DRI when shifting towards more plant-based consumption patterns.

Methodological considerations and limitations

Inherent to the study design, the choice of substitutes and their corresponding composition remain crucial for the nutritional intake estimations made in the different scenarios. Plant-based alternatives were chosen from the point of view of reducing environmental impact as well as staying as close as possible to the current Dutch eating habits per consumption occasion. Most people in the Netherlands eat bread with sandwich fillings for breakfast and lunch, and a hot meal for dinner. From a taste perspective, replacing meat during dinner with dishes made with pulses, tofu or vegetarian meat replacements results in similar savoury taste. However, for the meat and cheese sandwich fillings, finding plant-based alternatives with a similar taste profile was more difficult. Two-thirds of the animal-based sandwich fillings were replaced with sweet fillings such as chocolate sprinkles and apple syrup and one-third by savoury sandwich fillings such as peanut butter. This choice affected sugar intake levels. Although foods with sugar have lower environmental impacts compared with meat and cheese, recent nutrition recommendations advise limiting free sugars below 10 % of total energy intake[49]. An increase in mono- and disaccharide intakes (used as a proxy for free sugars) of 3–4 E % as in the 'no meat and dairy' scenario can be prevented by choosing more recently available plant-based fillings (and snacks) with low sugar content such as hummus.

Another possible limitation is that replacements were made based on equal food weights, which may be realistic for meat replacements during dinner and replacement of sandwich fillings but not for replacement with popcorn because of differences in food volumes. Although affordability of the diets was not assessed in our study, others observed that a higher adherence to a healthy diet was associated with higher dietary costs[50,51].

Diet optimisation

Our 'no meat and dairy' scenario was not optimal for certain micronutrient intakes. Recent diet optimisation modelling studies showed that GHG emission reductions of ≤30 %[52] or ≤40 %[53] were compatible with nutrient recommendations without major changes to the diet. These studies suggest that relatively large reductions can be achieved without completely omitting meat and dairy, while remaining adequate, by for example reducing animal products, shifting towards types of meat product with lower emissions (e.g. chicken and certain types of fish), increasing fruit, vegetables and cereal consumption, and reducing snacks[52,53]. When implementing more plant-based diets, attention to certain foods may help to cover micronutrient intakes. Yellow and orange fruits, green leafy vegetables, legumes, nuts and seeds, wholegrain cereals and soya products in the diet can contribute to intakes of vitamin A (in the form of carotenoids), thiamin, Ca and Zn[54–56]. Moreover, fortified foods and dietary supplements can be helpful in meeting recommendations for vitamin B_{12} [15]. Variation in meat replacements is essential due to varying nutrient contents; for example, pulses do not contain vitamin B_{12}, but have lower Na content than commercial meat replacements. In addition, choosing sandwich fillings and snacks with low sugar contents should prevent an increase in free sugar intake. Overall, when replacing only 30 % of animal products with plant-based foods there is no immediate need for concern about inadequate intakes and for food tailoring in this Dutch adult population, in line with previous studies[52,53].

Conclusions

Diets with all meat and dairy replaced with plant-based foods lowered environmental impacts by >40 %. Intakes of Zn, thiamin, vitamins A and B_{12}, and probably Ca, were below recommendations in this scenario. Replacing 30 % was beneficial for SFA, Na, fibre and vitamin D intakes, neutral for other nutrients, while reducing environmental impacts by 14 %. From the 30 % replacement scenario, it can be concluded that there is room to reduce meat and dairy intakes without compromising nutritional adequacy of the diet. This would benefit environmental sustainability.

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