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Educational differences in healthy, environmentally sustainable and safe food consumption among adults in the Netherlands

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Abstract

Objective: To assess the differences in healthy, environmentally sustainable and safe food consumption by education levels among adults aged 19–69 in the Netherlands.

Design: This study used data from the Dutch National Food Consumption Survey 2007–10. Food consumption data were obtained via two 24-h recalls. Food consumption data were linked to data on food composition, greenhouse gas emissions (GHGe) and concentrations of contaminants. The Dutch dietary guidelines (2015), dietary GHGe and dietary exposure to contaminants were used as indicators for healthy, environmentally sustainable and safe food consumption, respectively.

Setting: The Netherlands.

Participants: 2106 adults aged 19–69 years.

Results: High education groups consumed significantly more fruit (+28 g), vegetables (men +22 g; women +27 g) and fish (men +6 g; women +7 g), and significantly less meat (men –33 g; women –14 g) compared with low education groups. Overall, no educational differences were found in total GHGe, although its food sources differed. Exposure to contaminants showed some differences between education groups.

Conclusions: The consumption patterns differed by education groups, resulting in a more healthy diet, but equally environmentally sustainable diet among high compared with low education groups. Exposure to food contaminants differed between education groups, but was not above safe levels, except for acrylamide and aflatoxin B1. For these substances, a health risk could not be excluded for all education groups. These insights may be used in policy measures focusing on the improvement of a healthy diet for all.

Keywords
Educational level
Healthy food
Environmentally sustainable food
Food safety
Food consumption
24-h recall

Healthy, safe and environmentally sustainable consumption and production is important for human beings and the planet. In order to mitigate climate change, we need to consume and produce in a more environmentally sustainable manner. In the long term, the consumption of unsafe and unhealthy food might cause adverse health effects, varying from diarrhoea to several types of cancer[1].

Several studies have described the relationship between education level and health-related behaviours, including dietary habits[2,3]. According to several studies, the highly educated consume more healthy foods such as fruit and vegetables compared with less-educated ones[4,5]. Little is known regarding educational differences in other aspects of the diet, such as environmental sustainability and food safety. Friedl *et al.*[6] showed that people with low education level consumed more food that have a higher impact on the environment (e.g. meat products) compared with those with high education level. In contrast, Reynolds *et al.*[7] have shown that greenhouse gas emissions (GHGe) of the total diet are similar between income groups, although there are differences by types of meat. The relationship between education level and food safety is rather unknown. In previous Dutch National Food Consumption Surveys, differences in food consumption patterns between high and low education groups were observed[8]; differences in food safety, environmentally sustainable and healthy food consumption are, therefore, to be expected.

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To decrease inequalities in health between education groups, insights are necessary in the underlying factors, such as healthy and safe food consumption. Healthy food consumption is important for planetary health. More and more dietary guidelines target health as well as environmental aspects[9,10]. However, it is not yet known whether the environmental sustainability of diets differ for different education groups, and thus whether such guidelines can focus on the general population or should focus on specific subgroups of the population. This study aimed to describe the educational differences in healthy, environmentally sustainable and safe food consumption among adults aged 19–69 in the Netherlands.

Healthy food consumption was evaluated by the components of the Dutch Healthy Diet Index 2015 (DHD15 Index); environmentally sustainable consumption, by diet-related GHGe; and safe food consumption, by exposure to a selection of contaminants present in food. Microbiological food safety was not addressed in this study.

Methods

In the present study, data of the Dutch National Food Consumption Survey 2007–10 (DNFCS 2007–10) were used[8]. Details of the design and methodology of DNFCS 2007–10 have been described previously[8]. Briefly, the study population consisted of people living in the Netherlands aged 7–69 years. The sampling frame was a representative consumer panel from which sex- and age group-stratified random samples were taken. Data were collected between March 2007 and April 2010. Representativeness of the Dutch population was monitored and adjusted during recruitment, regarding age groups, region, urbanisation level and education level. In total, all data from this survey were included in the present analysis (1055 males and 1051 females aged 19–69 years). This age range was based on the age boundaries in the Dutch dietary reference values. Response rate for this age group was 70 %[8].

Dutch National Food Consumption Survey 2007–10 data collection

Data collection within DNFCS 2007–10 consisted of a questionnaire to obtain general information of the participants, including sociodemographic characteristics and lifestyle factors, and two non-consecutive 24-h dietary recalls. The sociodemographic characteristics included working status, income and highest obtained education level. Education level was categorised into low (primary school, lower vocational, low or intermediate general education), moderate (intermediate vocational education and higher general education) and high (higher vocational education and university). The lifestyle factors included alcohol consumption and general characteristics of the diet.

The 24-h recalls were conducted via computer-assisted telephone interviews using GloboDiet software (©International Agency for Research on Cancer; previously called EPIC-Soft©). The GloboDiet classification consists of seventeen main food groups (including seventy-two sub-groups)[11]. Interviewers were trained dieticians and called unannounced[8]. During these interviews, a detailed description of all foods (including beverages) and amounts consumed (by means of household measures, by weight or volume photographed from a delivered booklet) was collected. During the interviews, height and body weight (BW) was reported. BMI was calculated by dividing the BW (in kg) by height-squared (in m^2). All reported foods were matched to the codes in the Dutch Food Composition Database (NEVO-2011)[12], the so-called NEVO codes.

Healthiness of the diet

We used the Dutch dietary guidelines 2015 of the Health Council and an overall score, the DHD15 Index, to score the diet on healthiness using the food intakes of DNFCS 2007–10 (see Table 1)[9,13]. The index is a summary score based on fifteen single components, including fruit, vegetables, fish, wholegrain products, fats and oils, legumes, nuts, dairy intake, red meat and processed meat, sodium, coffee, tea, sweetened beverages, fruit juices and alcohol. As described by Looman *et al.*[13], some recommendations require a minimal intake (e.g. fruit, vegetables) or maximal intake (e.g. sodium); other recommendations an optimal intake (e.g. dairy products) or a replacement (e.g. fats and oils). For each recommendation, participants can proportionally score between 0 and 10 points, depending on the type of recommendation (minimum, maximum, optimal intake or replacement). For instance, in case of a minimum intake, a score of 10 points was allocated when the consumption was higher than or equal to the minimum intake (e.g. 200 g of fruits per d); no consumption was given 0 point. In case of a maximum intake, a score of 0 point was allocated when the consumption was higher or equal to the maximum intake (e.g. 6 g of salt per d); no consumption was given 0 point. In the present study, food intake relevant to each guideline was calculated as well as DHD15 Index per participant using the average of the two 24-h recalls.

Greenhouse gas emissions of diets

For assessing the environmental sustainability of foods consumed, indicators such as the use of energy, water and land, and GHGe were typically used. GHGe has been used as an indicator for the overall environmental impact in multiple studies[14–16], and consists of the emission of CO_2 equivalents (e.g. CO_2, NO_2 and CH_4) along the supply chain. In the present analysis, this indicator was used to assess the environmental sustainability of food. The data and methodology has been described in Temme *et al.*[15]. In summary, this was done by linking the values of GHGe

Table 1 Components of the Dutch dietary guidelines 2015 and their definition in the present study[9]*

Component†	Description of guideline	Definition‡ (amount consumed)
Vegetables	Eat at least 200 g of vegetables daily	Vegetables (g)
Fruit	Eat at least 200 g of fruit daily	Fruits (g)
Cereal products	Replace refined cereal products by wholegrain products	Cereals and cereal products (g)
Wholegrain products	Eat at least 90 g of brown bread, wholemeal bread or other wholegrain products daily	Wholegrain products[35] within cereals and cereal products (g)
Legumes	Eat legumes weekly	Legumes (g)
Nuts unsalted	Eat at least 15 g of unsalted nuts daily	Nuts unprocessed (g)
Dairy products	Take a few portions of dairy produce daily, including milk or yogurt	Dairy products (g)
Meat and meat products	Limit the consumption of red meat, particularly processed meat	Meat and meat products (g)
Red meat		Sum of fresh meat, game, processed meat and offal (g)
Processed meat		Processed meat (g)
Fish	Eat one serving of fish, preferably oily fish, weekly	Fish and fish products (g)
Fats	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats and vegetable oils	Fats (g)
Spreadable fat		NEVO codes with conditions (g): ≤16 en% SFA, ≤1 en% TFA, mono- and disaccharides ≤0·5 g, Na ≤160 mg within fats
Sugar-containing drinks	Minimise the consumption of sugar-containing beverages	Beverages defined by sugar content[35], such as soda, ice tea, vitaminised water and sport beverages within non-alcoholic beverages
Tea	Drink three cups of tea daily	Tea (g)
Coffee‡	Replace unfiltered coffee by filtered coffee	–
Alcohol	Do not drink alcohol or no more than one glass daily	Alcoholic beverages (g)
Salt	Limit salt intake to 6 g daily	Sodium intake of all foods based on NEVO (mg)

NOVO, Dutch Food Composition Database.
*Health Council of the Netherlands (2015), Dutch dietary guidelines 2015[9].
†The components of dietary guidelines were all used in the calculation of the Dutch Healthy Diet Index (2015, except for coffee).
‡No data was available on distinction between filtered or unfiltered coffee. This component was therefore excluded from the present analysis.

per NEVO code (Blonk dataset version 2014) to the food consumption data coded with NEVO codes. The GHGe data were calculated via life cycle assessment (LCA)[15]. All stages of a product's life – from primary production, processing, packaging, transportation, storage, preparation and cooking – were taken into account. Food waste was included by using food group-specific percentages for avoidable and unavoidable food losses throughout the food chain, including the consumer phase[15]. The LCA took into account the origin of foods as available on the Dutch market (e.g. share of imported foods)[17]. In total, 254 food products in the Blonk database were previously extrapolated to 1595 consumed food products in the food consumption database to quantify GHGe. Extrapolation was used based on ingredient composition and similarities in the type of food or production methods. In the present analysis, the GHGe of the overall diet was calculated. In addition, the GHGe of several food groups were described.

Chemical food safety

Chemical food safety deals with a wide range of substances present in food, including pesticides, food additives and contaminants. Contaminants are substances unintentionally present in food due to food processing (e.g. acrylamide, polycyclic aromatic hydrocarbons and 3-monochloropropane-1,2-diol (3-MCPD)), environmental contamination (e.g. dioxins, lead and cadmium), fungi (mycotoxins) or naturally (e.g. nitrate and arsenic). Based on current dietary patterns, the possible risks to public health are more frequently calculated for contaminants than for substances added by humans during food production or processing[18]. The use of the latter category of substances such as food additives, pesticides and veterinary drugs is legally regulated; these substances are only permitted if their addition might not constitute any risk to public health.

Food safety was evaluated in relation to education level for a selection of contaminants (see Table 2). For some of these contaminants, a potential health risk based on prior exposure assessments performed in the Netherlands could not be excluded[19–21]. Furthermore, for the selected contaminants, concentration data are readably available. Per contaminant, the food products that may contain the contaminant are also described in Table 2.

First, the average daily exposure to the different contaminants was calculated. Concentrations of aflatoxin B1, ochratoxin A (OTA), deoxynivalenol (DON), nitrate and acrylamide were obtained from Boon *et al.* and EFSA[22–26]. The concentration data of methylmercury was obtained from RIKILT and RIVM (2015) and EFSA[27,28], of lead from

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Table 2 Overview of chemical compounds and food products in which they may occur

Compound	Food products
Mycotoxins	
Aflatoxin B1[22]	Nuts, peanut butter, maize, sunflower seeds, rice
OTA[22]	Wheat, rye, raisins, nuts, biscuits, sunflower seeds
DON[22]	Wheat bread, wheat, biscuits, toast, pasta, maize
Process contaminants	
Acrylamide[22]	French fries, biscuits, crisps, Dutch spiced cake, peanut butter
3-MCPD[31]	Margarine and similar products, vegetable fats and oils, bread and rolls, fine bakery wares, preserved meat, gravy
Environmental contaminants	
Methylmercury[27]	Fish and shellfish, mushrooms, dried fruit
Lead[29]	Cereals, milk, fruit, meat, drinking water, vegetables, potatoes, eggs, rice
Naturally present	
Nitrate[22]	Potatoes, tap water, spinach, apple, banana, beetroot, cucumber, endive, green beans, cabbage, lettuce

3-MCPD, 3-monochloropropane-1,2-diol; DON, deoxynivalenol; OTA, ochratoxin A.

Boon *et al.* and EFSA[29,30] and of 3-MCPD from Boon and Te Biesebeek and EFSA[31,32]. The mean middle-bound concentrations (samples with an analysed level below the limit of detection or quantification assumed to contain the contaminant at half the relevant limit value) per food product were used. The analysed foods were subsequently matched – unweighted – to the relevant products or subgroups (seventy-two in total) of the GloboDiet classification. For instance, a concentration of 0·5 μg/kg OTA was assigned to biscuits (generic: subgroup biscuits), and a concentration of 10·7 μg/kg OTA was assigned to dried apricot (specific: product).

As differences in exposure to contaminants between education groups are only relevant if exposures result in potential health risks, the calculated exposures were compared with the relevant health-based guidance values (HBGV), or a margin of exposure (MOE) was calculated. HBGV is the maximum intake per unit of time, usually per day or week (such as the tolerable daily or weekly intake). The calculated exposure must be higher than HBGV for a potential health risk. MOE was calculated by dividing the lower limits of benchmark doses (BMDL) by the calculated exposure. BMDL represents doses in toxicity studies in which a percentage (e.g. 1, 5 and 10 %) increase in an adverse effect is observed. BMDL cannot be viewed as the maximum acceptable intake and is, therefore, evaluated via the calculation of MOE. For a potential health risk, MOE must exceed a minimum value, which can vary between 1 and 10 000, depending on the nature of the critical endpoint on which BMDL is based. HBGV or BMDL used in this study are listed in Table 3, including the minimum value of MOE for a negligible health risk.

Data analyses

In order to calculate the differences in healthy, environmentally sustainable and safe food consumption by education level, the mean consumption of components of the Dutch dietary guidelines 2015, and the mean emissions of CO_2 equivalents and mean exposure to contaminants over the two consumption days from the 24-h recalls were calculated per participant. For the contaminants, the mean exposure was divided by the self-reported BW of the participant in kilograms, as both HBGV and BMDL are expressed per kg BW (Table 3).

Mean consumption and emission levels were used as dependent variables in ANOVA to test on statistical significance between education groups. Education level was used as the independent variable. All statistical analyses were performed with SAS 9.3 (SAS Institute). A weighting factor was used to correct for small deviances in sociodemographic

Table 3 Health-based guidance values and BMDL of various contaminants[a], including the minimum margin of exposure (MOE) for a negligible health risk, if relevant

Contaminant	Type	Value	Unit	Minimum MOE	Source
Aflatoxin B1	$BMDL_{10}$	170	ng/kg BW per d	10 000	(24)
OTA	TWI	120*	ng/kg BW per week	–	(25)
DON	TDI	1	μg/kg BW per d	–	(41)
Acrylamide	$BMDL_{10}$	0·17	mg/kg BW per d	10 000	(23)
3-MCPD	TDI	2	μg/kg BW per d	–	(32)
Methylmercury	TWI	1·3*	μg/kg BW per week	–	(28)
Lead	$BMDL_{10}$	0·63	μg/kg BW per d	1†	(30)
Nitrate	ADI	3·7	mg/kg BW per d	–	(26)

3-MCPD, 3-monochloropropane-1,2-diol; ADI, acceptable daily intake; BMDL, lower limit of the benchmark dose; $BMDL_{10}$, lower limit of the 95 % CI of the estimated dose with a 10 % additional risk; BW, body weight; DON, deoxynivalenol; OTA, ochratoxin A; TDI, tolerable daily intake; TWI, tolerable weekly intake.
*For a comparison with calculated intakes per d, these health-based guidance values were divided by 7.
†The minimum value of MOE of 1 for lead is related to a very low potential health risk.

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characteristics (e.g. region, level of urbanisation), season and day of the week[8]. Since men and women have different energy intakes, the statistical analyses were performed separately for men and women[8]. It was assumed that a P-value <0·05 is statistically significant.

Results

On average, low-, moderate- and high-educated men were 45, 43 and 46 years old, respectively ($P = 0·002$). Low-, moderate- and high-educated women were aged on average 49, 40 and 43 years, respectively ($P < 0·0001$). The BMI of men did not differ between education groups (26 kg/m^2; $P > 0·05$). For women, the mean BMI of low, moderate and high education groups was 27, 26 and 25 kg/m^2, respectively ($P = 0·0007$) (see Table 4). The mean energy intake for men was 2687, 2638 and 2504 kcal for low, moderate and high education groups, respectively ($P = 0·008$). For women, the corresponding figures are 1915, 2001 and 1933 kcal, respectively ($P > 0·05$) (see Table 4).

Healthiness of the diet

Table 5 shows the results of healthy food consumption. For both men and women, the high education group consumed on average more vegetables and fruit than the low education group. Particularly, the consumption of fruit was approximately a quarter more in high than in low education group. In contrast, the low education group consumed significantly more meat and meat products than the high education group (men 148 *v.* 115 g, $P < 0·0001$; women 93 *v.* 79 g, $P = 0·02$). In line with this, the consumption of red meat was higher in low than high education group. Finally, salt consumption was lower in high-educated men compared with low-educated men (2995 *v.* 3174 mg, $P = 0·03$); salt consumption of moderate-educated women was higher compared with low-educated women (2466 *v.* 2330 mg, $P = 0·02$). Altogether, for both men and women, the high education group had a higher overall DHD15 Index score compared with the low education group (men 59 *v.* 53 points, $P < 0·0001$; women 69 *v.* 64 points, $P = 0·0002$).

Some educational differences were observed in men or women only. Among men, the consumption of wholegrain products was higher in the moderate and high education group compared with the low education group (114 and 113 *v.* 99 g, $P = 0·02$). Low-educated men consumed significantly more processed meat and sugar-containing beverages compared with high-educated men (processed meat 69 *v.* 48 g, $P < 0·0001$; sugar-containing beverages 344 *v.* 265 g, $P = 0·04$). Among women, the consumption of cereals and cereal products was significantly higher in moderate-educated than low-educated women (190 *v.* 167 g, $P = 0·0004$). Moreover, the consumption of non-alcoholic beverages and tea was significantly higher in high-educated compared with low-educated women (non-alcoholic beverages 1990 *v.* 1802 g, $P = 0·009$; tea 390 *v.* 283 g, $P = 0·01$).

Greenhouse gas emissions of the diet

The overall GHGe and the GHGe of food groups contributing most to total GHGe are shown in Table 6. The food groups contributing most are mainly animal-based products, including meat products, dairy products, fish and eggs. Beside these food groups, some plant-based food groups contribute to total GHGe, including cereal products, vegetables and (non-)alcoholic beverages. Overall, the GHGe for both men and women did not differ between education groups. However, the sources of GHGe are different between education groups. The GHGe through the consumption of vegetables and fruiting vegetables was approximately a quarter higher in high compared with low education group. Moreover, the GHGe via the consumption of fruit juices was about 33 % higher in high-educated men and 40 % in high-educated women compared with the low education groups. The GHGe of meat consumption did not differ between high and low education groups.

Also for GHGe, some educational differences were observed in men or women only. Among men, the GHGe of the consumption of soft drinks was higher in low-educated compared with high-educated men (0·16 *v.* 0·10, $P = 0·0001$). Among women, the GHGe via the consumption of eggs and cereals and cereal products was higher in moderate-educated compared with low-educated women (eggs 0·04 *v.* 0·03, $P = 0·0007$; cereals and cereal products 0·20 *v.* 0·17, $P = 0·0002$). In addition, the GHGe via fish consumption was also higher in high than low education group (women 0·10 *v.* 0·08 in kg CO_2 equivalents/d, $P = 0·03$).

Exposure to contaminants

The results in Table 7 show that the mean intake of 3-MCPD was significantly higher in low-educated compared with high-educated men (0·49 *v.* 0·39 µg/kg BW/d, $P = 0·002$). For women, the mean exposure to methylmercury was significantly higher in high-educated compared with low-educated women (0·13 *v.* 0·11 µg/kg BW/d, $P = 0·002$). Moreover, high-educated women had also a higher intake of lead (0·40 *v.* 0·32 µg/kg BW/d, $P < 0·0001$), aflatoxin B1 (0·0005 *v.* 0·0003 µg/kg BW/d, $P = 0·003$), DON (0·06 *v.* 0·05 µg/kg BW/d, $P = 0·01$) and OTA (0·06 *v.* 0·05 µg/kg BW /d, $P < ·0001$) compared with low-educated women. The mean intake of nitrate was higher in low-educated than in moderate-educated women (1·48 *v.* 1·33 mg/kg BW/d).

Compared with the relevant health limits, the mean intake of acrylamide and aflatoxin B1 of all education groups resulted in margins of exposure that are lower than

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Table 4 General characteristics (income, working status, age, BMI, intake of energy, proteins, fats and carbohydrates) for men and women aged 19–69 years by education level (weighted for sociodemographic factors, *n* 2106, DNFCS 2007–10)

	Men							Women						
	Low† (*n* 322)		Moderate† (*n* 487)		High† (*n* 246)			Low† (*n* 386)		Moderate† (*n* 448)		High† (*n* 217)		
	%		%		%		χ^2 *P*-value	%		%		%		χ^2 *P*-value
Income														
Low	44		42		14		<0·0001	36		46		18		<0·0001
Moderate	28		49		23			38		42		20		
High	6		34		60			23		31		46		
Working														
Yes	25		46		28		<0·0001	27		46		27		<0·0001
No	38		41		21			48		35		17		
	Mean	SE	Mean	SE	Mean	SE	ANOVA *P*-value	Mean	SE	Mean	SE	Mean	SE	ANOVA *P*-value
Age (years)	45	1	43*	1	46	1	0·002	49	1	40***	1	43***	1	<0·0001
BMI (kg/m^2)	26	0	26	0	26	0	NS	27	0	26**	0	25***	0	0·0007
Energy intake (kcal/d)	2687	44	2638	32	2504**	46	0·008	1915	28	2001	26	1933	35	NS
Proteins (g/d)	100	2	98	1	95	2	NS	74	1	76	1	74	2	NS
Fats (g/d)	106	2	103	2	96**	2	0·005	75	1	77	1	74	2	NS
Carbohydrates (g/d)	290	6	283	4	266**	6	0·006	209	3	226***	3	214	4	0·002

Significantly different from the low education group with *$P < 0·05$, idem with **$P < 0·01$, idem with ***$P < 0·001$.
†Education groups.

Table 5 Components of Dutch dietary guidelines 2015 (in g/d) for men and women aged 19–69 years by education level (weighted for sociodemographic factors, season, day of the week, per age-sex group, *n* 2106, DNFCS 2007–10)

	Men (*n* 1055)							Women (*n* 1051)						
	Low†		Moderate†		High†		*F* test	Low†		Moderate†		High†		*F* test
	Mean	SE	Mean	SE	Mean	SE	*P*-value	Mean	SE	Mean	SE	Mean	SE	*P*-value
Vegetables	124	5	125	6	146**	7	0·002	120	4	128	6	147***	7	0·001
Fruit	85	6	98	8	113**	9	0·01	111	6	116	9	139**	10	0·02
Cereals and cereal products	233	6	240	8	230	9	NS	167	4	190***	6	180	7	0·0004
Wholegrain products	99	5	114**	6	113*	7	0·02	77	3	79	4	83	5	NS
Legumes	5	1	2*	1	3	1	0·04	2	1	3	1	4	1	NS
Nuts unsalted	1	1	2	1	2	1	NS	2	0	2	1	2	1	NS
Dairy products	411	18	411	23	412	26	NS	331	13	339	17	340	20	NS
Cheese	37	2	38	3	42	3	NS	34	2	35	2	32	3	NS
Meat and meat products	148	5	133*	6	115***	7	<0·0001	93	3	88	4	79**	5	0·02
Red meat	129	5	114*	6	95***	7	<0·0001	79	3	72	4	66**	5	0·02
Processed meat	69	3	65	4	48***	5	<0·0001	39	2	39	3	34	3	NS
Fish and fish products	16	2	17	3	22	3	NS	14	2	15	2	21	3	NS
Fats	34	1	33	1	29**	2	0·006	23	1	22	1	20	1	NS
Spreadable fats	15	1	13	1	14	1	NS	10	1	9	1	10	1	NS
Non-alcoholic beverages	1632	43	1695	55	1748	62	NS	1802	38	1864	52	1990**	61	0·009
Sugar-containing drinks	344	23	330	29	265*	33	0·04	225	16	265	21	195*	25	0·01
Tea	164	20	189	26	198	29	NS	283	22	317	30	390**	36	0·01
Alcoholic beverages	314	31	356	39	299	44	NS	105	11	93	15	107	18	NS
Salt (mg Na)	3174	59	3190	76	2995*	86	0·03	2330	42	2466*	57	2314	67	0·02
DHD-15 Index	53	1	55	1	59***	1	<0·0001	64	1	65	1	69***	1	0·0002

Significantly different from the low education group with $^{*}P<0·05$, idem with $^{**}P<0·01$, idem with $^{***}P<0·001$.
†Education groups.

Table 6 Greenhouse gas emission (in kg CO_2 equivalents per d) for contributing food groups and for the overall diet for men and women aged 19–69 years by education level (weighted for demographic factors, season, day of the week, per age-sex group, *n* 2106, DNFCS 2007–10)

	Men (*n* 1055)							Women (*n* 1051)						
	Low†		Moderate†		High†		F-test	Low†		Moderate†		High†		F-test
	Mean	SE	Mean	SE	Mean	SE	*P*-value	Mean	SE	Mean	SE	Mean	SE	*P*-value
Meat and meat products	1·75	0·08	1·61	0·11	1·56	0·12	NS	1·18	0·06	1·10	0·08	1·09	0·09	NS
Beef	0·61	0·08	0·60	0·10	0·69	0·11	NS	0·53	0·05	0·44	0·07	0·54	0·09	NS
Dairy products	0·99	0·04	1·01	0·04	1·06	0·05	NS	0·85	0·03	0·90	0·04	0·85	0·04	NS
Cheese	0·45	0·03	0·47	0·03	0·51	0·04	NS	0·42	0·02	0·44	0·03	0·39	0·03	NS
Milk and yoghurt‡	0·49	0·02	0·48	0·03	0·48	0·04	NS	0·38	0·02	0·39	0·02	0·40	0·03	NS
Fish	0·07	0·01	0·08	0·01	0·11	0·02	NS	0·06	0·01	0·07	0·01	0·10**	0·01	0·03
Eggs	0·04	0·00	0·04	0·01	0·04	0·01	NS	0·03	0·00	0·04*	0·00	0·03	0·01	0·0007
Cereals and cereal products	0·24	0·01	0·25	0·01	0·24	0·01	NS	0·17	0·01	0·20***	0·01	0·18	0·01	0·0002
Bread	0·14	0·00	0·14	0·00	0·13	0·01	NS	0·10	0·00	0·10	0·00	0·10	0·00	NS
Vegetables	0·16	0·01	0·17	0·01	0·20**	0·01	0·003	0·16	0·01	0·17	0·01	0·20**	0·01	0·02
Fruiting vegetables	0·07	0·01	0·07	0·01	0·09*	0·01	0·04	0·07	0·00	0·08*	0·01	0·09**	0·01	0·02
Non-alcoholic beverages	0·46	0·01	0·45	0·02	0·43	0·02	NS	0·41	0·01	0·41	0·01	0·44	0·02	NS
Fruit juices	0·06	0·01	0·06	0·01	0·08*	0·01	0·01	0·05	0·01	0·06	0·01	0·07*	0·01	0·05
Soft drinks	0·16	0·01	0·14	0·01	0·10***	0·01	0·0001	0·10	0·01	0·11	0·01	0·09	0·01	NS
Alcoholic beverages	0·23	0·02	0·26	0·03	0·25	0·03	NS	0·11	0·01	0·10	0·01	0·13	0·02	NS
Overall	4·92	0·10	4·80	0·13	4·80	0·15	NS	3·75	0·07	3·77	0·10	3·79	0·12	NS

Significantly different from the low education group with $^{*}P<0·05$, idem with $^{**}P<0·01$, idem with $^{***}P<0·001$.
†Education groups.
‡Milk including milk beverages.

the minimal level above which the health risk is negligible. For the other contaminants, the mean intakes were either lower than the relevant HBGV or resulted in margins of exposure that are sufficiently high in all education groups (see Table 3)[33].

Discussion

This is the first study that simultaneously describes differences in healthy, environmentally sustainable and safe food consumption across education groups in the same

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Table 7 Exposure to contaminants for men and women aged 19–69 years by education level (weighted for sociodemographic factors, season, day of the week, per age-sex group, *n* 2106, DNFCS 2007–10)†

	Men (*n* 1055)							Women (*n* 1051)						
	Low‡		Moderate‡		High‡		F-test	Low‡		Moderate‡		High‡		F-test
	Mean	SE	Mean	SE	Mean	SE	*P*-value	Mean	SE	Mean	SE	Mean	SE	*P*-value
Aflatoxin B1 (µg/kg BW per d)	0·0004	0·00	0·0005	0·00	0·0006	0·00	NS	0·0003	0·00	0·0005**	0·00	0·0005 *	0·00	0·003
OTA (µg/kg BW per d)	0·02	0·00	0·03	0·00	0·03	0·00	NS	0·04	0·00	0·05	0·00	0·06***	0·00	<0·0001
DON (µg/kg BW per d)	0·05	0·00	0·05	0·00	0·05	0·00	NS	0·05	0·00	0·05**	0·00	0·06*	0·00	0·01
Acrylamide (µg/kg BW per d)	0·33	0·01	0·35	0·01	0·31	0·01	NS	0·32	0·01	0·30	0·01	0·29	0·01	NS
3-MCPD (µg/kg BW per d)	0·49	0·02	0·43*	0·01	0·39***	0·02	0·002	0·43	0·02	0·40	0·01	0·37	0·02	NS
Methylmercury (µg/kg BW per d)	0·11	0·00	0·11	0·00	0·12	0·01	NS	0·11	0·00	0·12	0·00	0·13***	0·00	0·002
Lead (µg/kg BW per d)	0·33	0·01	0·35	0·01	0·35	0·01	NS	0·32	0·01	0·35**	0·01	0·40***	0·01	<0·0001
Nitrate (mg/kg BW/d)	1·47	0·06	1·38	0·04	1·52	0·07	NS	1·48	0·06	1·33*	0·04	1·62	0·08	0·001

3-MCPD, 3-monochloropropane-1,2-diol; BW, body weight; DON, deoxynivalenol; OTA, ochratoxin A.
Significantly different from the low education group with $*P<0·05$, idem with $**P<0·01$, idem with $***P<0·001$.
†Low education level used as the reference group.
‡Education groups.

population. We expected differences in food consumption patterns between high and low education groups, and therefore we expected differences in food safety, environmental sustainability and healthy food consumption in high compared with low education groups. The results showed educational differences in several indicators of healthy and environmentally sustainable food consumption. Differences in education level are both favourable and unfavourable in the domains of healthy and environmentally sustainable food consumption. Overall, the high-educated group showed higher adherence to the Dutch dietary guidelines compared with the low-educated group. The high education group consumed more fruits and vegetables and less meat and fats than the low education group. In addition, no differences were found between the GHGe of high and low education groups. Regarding contaminant exposure, among men, the mean intake of 3-MCPD was estimated to be lower in high compared with low education group. Among women, the mean intakes of methylmercury, lead, aflatoxin B1, DON and OTA were estimated to be higher in high compared with low education group. The mean intakes in all education groups were lower than the relevant HBGV or resulted in margins of exposure that are sufficiently high, except for acrylamide and aflatoxin B1.

The total GHGe did not differ between education groups, However, the contributing food groups differed between high and low education groups due to different food consumption patterns. These results are in line with Reynolds *et al.*[7]. In the present study, the consumption of fruit, vegetables and fish was higher in high compared with low education group. Therefore, the GHGe of these food groups was higher in high education group. In contrast, the consumption of meat was lower in the high education group. The GHGe due to half-and-half minced meat, pork meat and processed meat consumption was significantly lower in high-educated compared with low-educated men. For women, the GHGe of processed meat consumption was significantly lower in high-educated. In this way, the overall effects on GHGe are diminished. For food safety, differences in the intake of contaminants could also be explained by differences in food consumption patterns. High-educated men had a lower consumption of margarines than low-educated men. As margarines is one of the main contributors to the intake of 3-MCPD, the mean intake of this contaminant was estimated to be lower in high compared with low education group. The consumption of fruits and vegetables was significantly higher in high-educated compared with low-educated women. Fruits and vegetables contribute both to the intake of lead; therefore, the mean lead intake was estimated to be higher in high compared with low education group.

Previous research has shown that the high education group consume more fruit and vegetables than the low education group[4]. In line with the present analysis, Darmon and Drewnoski[34] have found that the high education group consume more fish (Denmark, the Netherlands and France), whereas the low education group consume more fats (Denmark, the Netherlands). A study by Hulshof *et al.* has shown that the high education group consume less potatoes and meat than the low education group (the Netherlands)[35,36].

With respect to environmentally sustainable food consumption, GHGe was used as an indicator. Insufficient data were available on water use and energy expenditures as well as other environmental aspects[37]. Additional research is needed to estimate the impact on, for example, water use and energy expenditures and how this may affect the results. Data was available on land use[16]; however, previous studies have shown that GHGe and land use

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are highly correlated and lead to similar conclusions[38]. Also in other studies, GHGe was often used as an indicator for environmental sustainability[39].

In relation to safe food consumption, only indicative intake estimates were calculated to obtain mean intake levels of contaminants for the different education groups. These mean intakes were estimated by linking the concentration data and food consumption data to food subgroups, and thus ignoring the variations in contamination levels within these food groups. However, all contaminants examined in this study exert their possible adverse effects on health over a longer period of time, from several years up to life-long. For this type of assessments, mean concentrations are usually used because it may be assumed that fluctuations in concentrations will level out in the long run. Personal preferences for certain (brands of) foods containing higher mean levels of contaminants were not considered in this study.

Previous research studying the intakes of contaminants via food in the Netherlands in more detail based their conclusions of food safety on the whole population's intake distribution[19–21,27,31]. The mean intake estimates of different contaminants in the present analysis showed a similar trend compared with these studies. The intakes of aflatoxin B1 and acrylamide resulted in insufficiently large margins of exposure in all education groups (see Table 7). The percentages of individuals who did not exceed the MOE of 10 000 in aflatoxin B1 were 73, 80 and 82 % for low-, moderate- and high-educated men, respectively, and 73, 78 and 84 % for low-, moderate- and high-educated women, respectively. For acrylamide, the corresponding percentages ranged from 98 to 99 % in all education groups, both men and women. For these two contaminants, a possible health risk could not be excluded. For other contaminants, the mean intakes of all education groups were below HBGV or resulted in insufficiently high MOE (see Table 7). However, based on the mean intakes, it was not possible to conclude if there is a public health concern for these contaminants. For that, the whole exposure distribution should be considered. For lead and OTA, a possible health concern could not be excluded in previous studies at the upper part of exposure distribution[19,21].

In this study, only a selected number of contaminants were taken into account. Due to the differences in food consumption patterns in low compared with high education group, the intakes of other chemicals were less likely to differ between education groups. However, no data was directly available for these analyses. If food consumption differences between educational groups will also result in differences in safe food consumption, it needs further research.

DNFCS 2007–10 represents the consumption behaviours of adults aged 19–69 in the Netherlands. A weight factor was used to correct for small deviances in representativeness for the Dutch population. Food consumption was assessed by two 24-h recalls per participant, and on average, energy intake was underreported. The proportion of low reporters on energy intake was 17 %, whereas the proportion of high reporters was 1·5 %[8]. This was not taken into account. Furthermore, the energy intake of highly educated men was lower compared with low-educated men. In the present analysis, the food consumption data was not adjusted for energy intake. Energy intake might explain some of the differences found between the education groups. Nevertheless, the aim of this study was to describe the differences in healthy, environmentally sustainable and food safety between education groups. Further research is needed to examine the factors that explain these differences.

We used the mean intake of two 24-h recalls as a measure of dietary intake, which may be subject to day-to-day variation. On the group level, the within-person variation tends to be cancelled out, and only the precision of mean intake estimates is affected. With the sample size of over 2000 men and women in DNFCS 2007–10, relevant differences can be observed.

To decrease health inequalities between education groups, insights are necessary in different aspects of food consumption (e.g. healthy, environmentally sustainable and food safety). Besides education level, other factors such as lifestyle factors (e.g. smoking), obesity and price of the diet might play a role in these inequalities[40,41].

Both the databases on food safety (concentrations used) and environmental sustainability were based on rough estimations. It was possible that the exposure to food contaminants was overestimated (by using extrapolation) and underestimated for environmental sustainability. The database for environmental sustainability includes uncertainties about shares and amounts of fertilisers and variability in energy inputs during processing, which may underestimate environmental sustainability. However, these uncertainties and variabilities relate to the nature of the data affecting food safety values and environmental variables, so that results by population groups are equally subjected to bias. Therefore, comparison between population groups is possible. Future researches should reduce uncertainties and include variability in dietary model estimates.

Overall, this is the first study to provide an insight into educational differences in healthy, environmentally sustainable and safe food consumption. The consumption patterns differed by education groups, resulting in a more healthy but equally environmentally sustainable diet among high compared with low education group. Exposure to food contaminants differed between education groups, but were not above safety levels, except for acrylamide and aflatoxin B1. For these substances, a health risk could not be excluded for all education groups. The results suggest that healthy, environmental sustainability and safe food consumption should be considered in policy measures and addressed by other researchers. Hence, the insights of this study may be useful in drafting policy measures focusing on improving healthy, safe and sustainable diets for all.

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