Nutritional Impact of Replacing Meat and Dairy Products with Plant-Based Substitutes

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Research Article

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Abstract

Background

An increasing number of people adhere to plant-based diets and the marked for plant-based meat and dairy substitute products is rapidly expanding. However, few studies have examined the nutritional impact of replacing meat and dairy products with plant-based substitutes. Thus, the present study aimed to assess the consumption of plant-based meat and dairy substitutes in vegans, lacto-ovo vegetarians and pescatarians in Norway and examine the total intake of macronutrients and salt from substitute products.

Method

The study had a cross-sectional design, using single twenty-four-hour dietary recall to assess intake of macronutrients and salt in 158 participants (18–60 years); vegans (n = 88), lacto-ovo vegetarians (n = 43) and pescatarians (n = 28) living in the eastern part of Norway.

Results

In total 90%, 68% and 64% of the vegans, vegetarians and pescatarians, respectively, consumed meat or dairy substitutes. The main raw ingredient in the substitute products were soy, followed by oat and peas. Overall, substitute products contributed to 12% of the total energy and 16% of the total salt intake in the diet. The substitute products contributed to a higher intake of saturated fatty acids (SFA) in vegans (27% of total SFA intake,) than both lacto-ovo vegetarians (10%) and pescatarians (8%). Moreover, substitute products contributed to a higher intake of proteins in vegans (19%,) compared to pescatarians (7%,). The total macronutrient intake was within NNR recommendations, presenting a favorable distribution of fatty acids in addition to high levels of dietary fiber.

Conclusion

The high consumption of meat and dairy substitutes indicate that these products are regularly included in Norwegian plant-based diets. Substitute products may contribute to the total intake of fat, SFA and protein in vegans.

Introduction

Plant-based diets are rapidly gaining popularity in the western world [1]. In Norway, it is estimated that approximately 1% of the population adhere to a vegan diet, 4% to a vegetarian diet and 7% to a flexitarian or semi-vegetarian diet [2]. According to the Vegan Society, the number of vegans in the United Kingdom quadrupled from 2014 to 2019 reaching 600.000 (1.16% of the population) in 2019 [3]. In Germany, 2.9% classifies themselves as vegan and 4.3% as vegetarian [3], and in the United States 3% of the population were vegans and 5% vegetarians in 2018 [4]. In Western societies, including Norway, common reasons for adhering to plant-based diets are putative health benefits, and environmental animal welfare concerns [5, 6],

Plant-based diets are generally associated with health benefits and reduced risk for several chronic diseases [7–9]. Traditionally plant-based diets contain ample amounts of vegetables, legumes, whole grains, nuts and seeds [10], which contribute to a beneficial nutrient profile with low levels of saturated fat and salt, and high levels of dietary

fibers and polyunsaturated fat [10, 11]. A well-planned plant-based diet can be both healthy and nutritionally adequate through all stages of life, including childhood and pregnancy [10, 12]. However, vegans may have an increased risk of deficiencies in certain nutrients that are mainly found in animal-source foods, such as B_{12} [13, 14], iodine [15–18] vitamin D [14, 19], zinc [13, 16–18, 20], iron [21, 22], and n-3 fatty acids [23, 24]. For vegans to meet their requirements of B_{12}, iodine and vitamin D, the Norwegian Directorate of Health recommends use of supplements, and vegans are also advised to monitor their intake of vitamin B2 (riboflavin), calcium, zinc and selenium [25]. Although, iron is a nutrient of concern in plant-based diets, a recent Norwegian study found sufficient iron status in vegans, vegetarians and pescatarians [26]

Today, a wide selection of plant-based products intended to mimic the function, taste and texture of meat and dairy in the diet are easily available [27, 28]. However, knowledge about the nutritional quality of plant-based substitutes and associated health effects are limited [29]. Previous studies have suggested wide variations in nutritional quality between and within different categories of meat and dairy substitutes [30–34]. Although raw ingredients in plant-based substitutes, such as soy, oats and various legumes, may be associated with positive health effects, this may not necessarily apply to the final products [35]. During food processing, nutrients such as vitamins, minerals and trace elements may be lost [31], and less healthy ingredients such as salt, sugar, and saturated fats may be added, altering the nutrient value of the final product [36]. In addition, the limited knowledge of nutritional impact due to non-nutrient additives (flavoring agents, emulsifiers, antioxidants etc.) have been questioned [37].

Whereas multiple studies have examined the nutrient intake associated with consumption of plant-based diets, few studies have specifically investigated the consumption of meat and dairy substitutes in vegans, lacto-ovo vegetarians and pescatarians. Furthermore, there is a lack of studies assessing the contribution to actual nutrient intake from the substitute products. This study therefore aims to assess the consumption of plant-based meat and dairy substitutes in vegans, lacto-ovo vegetarians and pescatarians in Norway and examine the total intake of macronutrients and salt from substitute products.

Methods

This cross- sectional study included participants from larger study of vegans, lacto-ovo vegetarians and pescatarians in Norway (n = 207, age range 18–60 years) [15]. Participants were recruited to the study by convenience sampling and snowball sampling methods. Recruitment has been described in detail in a previous paper by Groufh-Jacobsen et al. [15]. Included participants answered an electronic questionnaire which assessed background information (gender, age, marital status, education, country of birth, smoking, weight, height etc.), and dietary practices.

Participants who provided written consent to be contacted in a prior study, received an invitation to participate by text message. A total of 166 out of 192 invited individuals agreed to participate, and 161 completed the study (participation rate 84%). The main reason for not completing the study after acceptance, was missing the call at the scheduled interview appointment and failing to answer contact to reschedule. Further three participants were excluded during data-analyses due to consumption of meat or fasting.

Thus, the final sample in the present study consisted of 158 participants, including 83 vegans, 47 lacto-ovo vegetarians and 28 pescatarians. Classification into the respective diet groups was based on foods included in the diet, assessed in the electronic questionnaire. Participants who answered “never” for consumption of all animal sources foods were classified as vegans. Further, participants who reported inclusion of milk and dairy product and /or eggs as “seldom”, “sometimes” or “often” were classified as lacto-ovo vegetarians, hereafter referred to as

vegetarians. Finally, those who reported to include fish or shellfish were classified as pescatarians. Participants who answered to include poultry or meat was excluded from the analysis.

Data collection

Data on total dietary intake was collected from January 2020 to June 2020 using single, 24-hour dietary recall (24h). One 24h was conducted over phone with each participant as semi-structured interviews based on the multiple pass method [38]. To ensure records of food intake from both workdays and weekend days the 24h were conducted on different weekdays. All interviews were performed by the same researcher, and the information consecutively logged in written records.

In the 24h, participants were first asked to broadly list all foods and beverages consumed throughout the previous day. Subsequently, they were asked to provide descriptions of quantity given in household measures, sizes of glasses, bowls, and plates, in addition to the size and share of whole product, portion or recipe, the number of pieces/products, intake in centimeters of product, i.e., cucumber or celery and in some cases quantity in grams. Participants were then prompted to describe all items in terms of product type or brand, whether the food was organic, methods of preparation, content of fat, sugar or whole meal i.e., percentage of whole meal in bread or pasta. Participants were also asked to list all ingredients in composite foods or dishes and if possible, also describe the quantity. In cases where a specific recipe had been used, the recipe was searched online for the participants to confirm identification of the correct recipe. The participants were subsequently asked if they had made any changes to the recipe in quantity or type of ingredients, and to describe consumed quantity in terms of share of the total recipe. During the final stages of the interview, questions aimed at helping participants remember additional intake were asked including any consumption of snack in between meals, such as salty snacks, fruits, nuts or sweets. Finally, all participants were asked to list all dietary supplements used the last 24-hours.

Data coding

Intake of all foods and beverages obtained in the 24h was coded using the Norwegian Food Composition Table (FCT) [39]. All reported food items were assigned a food code corresponding to a food or beverage registered in the FCT. In cases where no comparable food or beverage could be found in the FCT, the Swedish Food Composition Database (Livsmedelsdatabasen) [40] or the Dutch Food Composition Database (NEVO) [41], were searched for suitable matches, and this applied to products such as hemp seeds, goji berries, psyllium husk and sweet chili sauce. If no suitable match could be found in either database, the nutritional content was recorded from the nutrition label on the package, or from the manufacturer's websites, and the product assigned an individual food code. This applied to most dietary supplements and some foods and beverages, mainly plant-based substitutes for meat or dairy not found in either of the food composition databases, or products often included in plant-based diets i.e., nutritional yeast.

All foods and beverages consumed by each participant during the 24h survey period, were converted into grams of edible portions. To standardize the nutrient calculation, an online diet-registration tool (Kostholdsplanleggeren) [42] and a booklet guide, both based on the Norwegian Food Composition Table [43], were used. Whenever the quantity of products was described in another measure than found in the online diet-registration tool or the booklet guide, the following conversions were applied: 1 deciliter = 7 tablespoons, 1 tablespoon = 3 teaspoons. In cases where the participant described quantity as share of a product, but did not know the total weight, amount or size of the whole product, this information was obtained from the producer's website, online stores, or the package of a physical product. If no information of quantity or weight of food items was available, the foods were weighed by one of the

researchers for an approximate calculation. The mean of two weightings were used for each product, and all products were weighed by the same researcher on the same kitchen scale. Weighing applied to products such as different dried berries and fruits, coconut flakes and different types of plant-based spreads.

Standardized recipes were developed for composite foods and dishes that was not described in sufficient detail to identify all ingredients and the quantity of intake. This applied to most of the take-away or restaurant dishes as well as the vegetarian or vegan versions of foods or dishes traditionally made with meat, dairy or egg, i.e., different baked goods, pizza, pancakes, waffles, vegan spring rolls and kebab. The recipes were based on recipes available online and accommodated to include ingredients described by participants for each composite dish (e.g., replacement of soy milk instead of cow's milk, rapeseed oil instead of butter, plant-based cheese instead of regular cheese).

Classification of meat and dairy substitutes and raw ingredients

Plant-based products mimicking meat or dairy products were defined as meat or dairy substitutes. The definition did not include tofu or seitan in its original form, but more highly processed products using these ingredients such as patés made from tofu or sausages made from seitan. All substitutes were classified into different product categories of meat or dairy substitutes, based on product name i.e. "Naturli' Burgers" or "Plant-based sausage" or product description on the package or manufacture's website i.e. "Plant-based alternative to yoghurt", "Vegan paté", "Soy drink ", "Plant-based substitute for cheese", or "Meat-free alternative for cold cuts".

The main raw ingredient in the plant-based substitute products was defined as the ingredient with the highest contribution in percent, or if no such information was given, the first listed non-water ingredient on the nutritional content list. Information about raw ingredients were obtained from the manufacturer's website if available, or otherwise manually from online grocery stores.

Calculation of energy, total macronutrient- and salt intake

Intake of energy, macronutrients and salt was calculated using "FoodCalc" [44], a program that utilizes food composition tables to calculate per person nutrient intake based on recorded food intake (food code and amount in grams). In addition to total intake, intake from meat substitutes, and dairy substitutes were calculated separately.

Ethical approval

The study was approved by the Norwegian Centre for Research Data/NSD/101332 and the Regional Committees for Medical and Health Research Ethics, 2019/653/REC Southeast. Written and oral information about the study was provided and written consent was obtained prior to participation in the study.

Statistical tests

Statistical analysis was conducted in IBM SPSS version 27 and 28. (IBM Corp., Armonk, Ny, USA). The normality of the data was examined using Shapiro-Wilk`s test and visual examination of QQ-plots and histograms. Normally distributed data were presented as mean ± standard deviation (SD), and non-normally distributed data as median and Inter Quartile Range (IQR). The Chi-Square test with pairwise comparisons was used to compare differences between the diet groups using categorical variables (gender, marital status, educational level, work status, country of birth, smoking habits, supplement use (yes/no), reported use of meat and dairy substitutes). The Kruskal-Wallis test with post hoc test was used to examine differences in macronutrient and salt intake, and differences in contribution to macronutrient and salt intake from plant-based substitutes between the diet groups using non-parametric

continuous variables. A significance level of 0.05 was applied in all tests. Tables and figures were produced using Excel, Microsoft Office Home and Student 2016.

Results

Table 1 outlines the key characteristics of the participating vegans (n=83), vegetarians (n=43) and pescatarians (n=28). Our results showed a higher number of women among participants adhering to a pescatarian diet (93%) than those adhering to a vegetarian or a vegan diet (79% and 65%, respectively) ($p<0.05$ for both). No significant differences in age, educational level, work status, ethnicity, diet duration, use of supplements, smoking habits and body mass index (BMI) was found between participants according to adherence to different plant-based diets.

Table 1 Background characteristics of participating vegans (n=83), vegetarians n=47) and pescatarians (n=28)

Background		Total	Vegans	Vegetarians	Pescatarians	p - value[1]
		n (%)	n (%)	n (%)	n (%)	
Participants		158 (100)	83 (53)	47 (30)	28 (18)	
Gender	Women	117 (74)	54 (65) [a]	37 (79) [b]	26 (93) [ab]	0.010*
	Men	41 (26)	29 (35) [a]	10 (21) [b]	2 (7) [ab]	
Age, years[2]		30 ±9	31 ±9	31 ±10	29 ±9	0.266
BMI (kg/m2)[2]		23.1 ±3.5	22.8 ±2.8	23.8 ±4.7	23.1 ±3.0	0.789
Country of birth[3]	Norway	133 (84)	71 (86)	38 (81)	24 (86)	0.757
	Other[3]	25 (16)	12 (14)	9 (19)	4 (14)	
Marital status	Single	79 (50)	37 (45)	25 (53)	17 (61)	0.290
	Cohabitant/ Married	79 (50)	46 (55)	22 (47)	11 (39)	
Education level	≤12 years	28 (18)	15 (18)	9 (19)	4 (14)	0.860
	≥1-4 years higher education	130 (82)	68 (82)	38 (81)	24 (86)	
Work status	Unemployed	6 (4)	4 (5)	1 (2)	1 (4)	0.860
	Student	50 (32)	27 (33)	13 (28)	10 (36)	
	Employed	102 (65)	52 (63)	33 (70)	17 (61)	
Diet duration[2]		5 ±3	4 ±3	6 ±4	5 ±4	0.187
Supplements reported in 24h		109 (69)	62 (75)	29 (62)	18 (64)	0.257
Smoking habits[4]	Yes	14 (9)	7 (8)	6 (13)	1 (4)	0.391

[1] Test for differences between the diet groups using Chi-Square test (categorical data), and Kruskal-Wallis (continuous data); significance level used <0.05. marked as *

[ab] Diet groups with the same superscripts, have proportions that differed significantly in the post hoc test (p<0.05)

[2] Reported as mean ±SD

[3] Other includes: Colombia, Ethiopia, Germany, Great Britain, Iraq, Netherlands, Nicaragua, Poland, Portugal, Russia, Slovenia, Sweden, Ukraine, United States of America

[4] Smoking habits, includes daily and occasionally

Consumption of plant-based substitutes

In total 79.1% of the participants had consumed either meat or dairy substitutes **Table 2**. Consumption of substitute products differed between the diet groups (vegans 90.4%; vegetarians 68.1%; pescatarians 64.3%) p=0.001). A higher percentage of vegans (51.8%) than pescatarians (28.6%) reported consumption of meat substitutes (p<0.05 in post hoc test), but the percentage of vegetarians (38%) did not differ in pairwise comparison with either group (p>0.05). Vegans (80.7%) had a higher percentage of participants reporting consumption of dairy substitutes, than vegetarians (57.4 %) and pescatarians (50.0%) (both p<0.05 in post hoc tests).

Table 2 Percentage of participants (n= 158), reporting intake of meat substitutes and/or dairy substitutes

Total		**Vegans**		**Vegetarians**		**Pescatarians**		**P -value***
	n	**(%)**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**
Meat substitutes	69	43.7%	43^{a}	51.8%	18	38.3%	8^{a}	28.6%	0.068
Dairy substitutes	108	68.4%	67^{ab}	80.7%	27^{a}	57.4%	14^{b}	50.0%	0.002
Meat and dairy substitutes	52	32.9%	35^{a}	42.2%	13	27.7%	4^{a}	14.3%	0.017
Meat or dairy substitutes	125	79.1%	75^{ab}	90.4%	32^{b}	68.1%	18^{a}	64.3%	0.001
No substitutes	33	20.9%	8^{ab}	9.6%	15^{b}	31.9%	10^{a}	35.7%	0.001

[1] P-value for difference between different diet groups, Chi Square Test, significance level used: <0.05, marked as *

[ab] Diet groups with the same superscripts, have proportions that differ significantly in the post hoc test (p<0.05)

Raw ingredients

The main raw ingredient in the plant-based meat and dairy substitute products reported in the 24h, and the frequency of consumption for these products is presented in **Table 3**. Among the meat substitutes, soy-based products were consumed most frequently, both in total (55.4%), and within each category; sausages (44 %), burgers (56 %), mince and “meatballs” (54 %), nuggets and schnitzel (64 %), and other products (94%) **Figure 1 in supplements**. Peas was the main raw ingredient in 20.5% of all meat substitutes consumed and 50% of the cold cuts and spreads, 33% of the burgers and 15% of the mince and “meatballs” were based on peas.

Table 3 Frequency (%) of meat and dairy substitute products reported in the 24h according to main raw ingredient.

Meat substitutes		Dairy substitutes	
Raw ingredient	Frequency (%)	Raw ingredient	Frequency (%)
Soy	46 (55.4)	Oat	85 (35.0)
Peas	17 (20.5)	Soy	78 (32.1)
Legumes and vegetables	9 (10.8)	Modified Starch	39 (16.0)
Sunflower seeds	3 (3.6)	Coconut oil	8 (3.3)
Mycoprotein	2 (2.4)	Coconut milk	6 (2.5)
Other*	4 (4.8)	Almonds	7 (2.9)
Unspecified**	2 (2.4)	Cashew nuts	4 (1.6)
Rice	5 (2.1)		
Other*	4 (1.6)		
		Unspecified**	7 (2.9)
* Products with raw ingredients reported once			
** The specific product, and thereby the main ingredient, could not be identified			

Dairy substitutes most frequently consumed were based on either oat (35.0%) or soy (32.1%). Within the milk-substitute category, oat and soy accounted for 47% and 42% of the products respectively. While the yoghurts were mostly soy-based (61 %), most creams and crème fraiche (67 %) were based on oat. Modified starch was the main raw ingredient in 16% of all the dairy substitutes consumed **Table 3** and accounted for 80% of the cheese substitutes reported **Figure 2 in supplements**.

There were no differences between groups in percentage of participants reporting intake of meat substitutes in the different product categories. Consumption of dairy substitutes differed between diet groups in three product categories. A higher percentage of vegans (69.9%) than both vegetarians (44.7%) and pescatarians (42.9%) ($p<0.05$ for both in post hoc tests) had consumed milk substitutes. In addition, vegans (32.5%) had a higher percentage of participants reporting consumption of cheese substitutes than pescatarians (3.6%) ($p<0.05$ in post hoc test).

Intake of energy, macronutrients, and salt

Table 4 presents the median (IQR) intake of macronutrients in energy percentage (E%) according to adherence to different plant-based diets. Overall, the participants had a median energy intake of 2052 kcal (IQR 1546-2516). Vegans had lower intake of saturated fatty acids (SFA) (5.8 E%, IQR 4.5-8.7) than both vegetarians (9.7 E%, IQR (6.5-14.8) ($p<0.001$) and pescatarians (9.6 E%, IQR 5.4-14.1) ($p=0.002$). Furthermore, vegans reported higher median intake of polyunsaturated fatty acids (PUFA) (8 E%, IQR= 6-10), than vegetarians (6%, IQR 5-8) ($p=0.011$), though neither group differed from pescatarians in relative PUFA intake. Intake of n-3 fatty acids was within recommendations of ≥1 E% only in pescatarians (1.2 E%, IQR= 0.7-1.8), which reported higher relative intake than both vegetarians (0.5 E%, IQR= 0.4-1.0) ($p<0.001$) and vegans (0.7 E%, IQR= 0.5-1.2) ($p=0.010$). Pescatarians also had higher relative protein intake (15 E%, IQR 13-17) than both vegans (13 E%, IQR 11-15) ($p=0.029$) and vegetarians (13 E%, IQR 10-15) ($p=0.018$). Although, the median intake of added sugar was well below the recommendations of <10

E% in all groups, it was significantly higher in vegetarians (4 E%, IQR 1-8) than in both vegans (2 E%, IQR 0-5) ($p=0.014$) and pescatarians (2 E%, IQR 1-5) ($p=0.046$). Intake of dietary fiber was higher in vegans (5.2 g/MJ, IQR 4.1-6.0) compared with both vegetarians (3.8 g/MJ, IQR 2.8-4.7) ($p<0.001$) and pescatarians (4.2 g/MJ, IQR 2.7-5.1) ($p=0.005$). Although, no significant differences were found in salt intake between the diet groups, only vegans and vegetarians reported median salt intake within the recommendations of ≤6 g. No differences in total energy intake, intake of carbohydrates and monounsaturated fatty acids (MUFA) were observed between the groups. With the exception of n-3 fatty acids and salt, all diet groups had median intake of macronutrients complying with the Nordic Nutrition Recommendations (NNR) [45].

Table 4 Median (IQR) total dietary intake of macronutrients (E%) in vegans, vegetarians and pescatarians

	Total (n=158)		Vegans (n= 83)		Vegetarians (n= 47)		Pescatarians (n=28)		P-value[1]	RI[2]
	median	(IQR)	median	(IQR)	median	(IQR)	median	(IQR)	RI E%	
Kilocalories	2052	(1546-2516)	2076	(1521-2683)	2056	(1588-2467)	1910	(1490-2389)	0.763	-
Fat (E%)	33	(26-39)	31.3	(25.1-37.9)	34.7	(26.7-40.1)	33.3	(26.3-43.6)	0.295	25-40
SFA (E%)[3]	8	(5-11)	5.8[ab]	(4.5-8.7)	9.7[a]	(6.5-14.8)	9.6[a]	(5.4-14.1)	0.010*	<10
TFA (E%)[3]	0	(0-0)	0.0[ab]	(0.0-0.0)	0.1[a]	(0.0-0.3)	0.2[b]	(0.0-0.3)	0.010*	**
MUFA (E%)[3]	11	(8-15)	11.1	(7.8-15.0)	11.6	(8.6-14.2)	12.2	(9.1-16.1)	0.341	10-20
PUFA (E%)[3]	7	(5-10)	7.8[a]	(6.2-10.3)	5.8[a]	(4.7-8.0)	6.7	(5.1-9.4)	0.030*	5-10
n-3 (E%)	0.7	(0.5-1.2)	0.7[b]	(0.5-1.2)	0.5[a]	(0.4-1.0)	1.2[ab]	(0.7-1.8)	0.010*	≥1
Protein (E%)	14	(11-15)	13.3[b]	(11.5-15.1)	13.2[a]	(10.3-15.2)	14.9[ab]	(13.0-16.9)	0.045*	10-20
Carbohydrate (E%)	50	(43-55)	50.5	(44.5-56.2)	49.9	(41.3-55.7)	46.9	(38.5-51.2)	0.129	45-60
Added sugar (E%)	2	(1-6)	2.0[a]	(0.3-4.9)	4.1[ab]	(1.1-8.4)	1.8[b]	(0.8-4.6)	0.032*	<10
Dietary fiber (g/MJ)[4]	4.4	(3.5-5.7)	5.2[ab]	(4.1-6.0)	3.8[a]	(2.8-4.7)	4.2[b]	(2.7-5.1)	0.010*	>3
Salt (g)	5.8	(3.5-8.7)	6.0	(3.6-9.9)	5.2	(3.4-8.1)	7.0	(3.4-8.4)	0.509	≤6

[1] Test for difference between different the diet groups, Kruskal Wallis Test, significance level used: <0.05, marked as*

[2] Recommended intakes from Nordic Nutrition Recommendations

[3] SFA – saturated fatty acids; TFA- trans fatty acids; MUFA – monosaturated fatty acids; PUFA – polyunsaturated fatty acids; n-3 – polyunsaturated n-3 fatty acids

[ab] Diet groups with the same superscripts differed significantly in the post hoc test (p<0.05)

** As low as possible

Contribution from meat and dairy substitutes to the total intake of energy, macronutrients and salt

The contribution from meat and dairy substitutes to the total intake of energy, macronutrients and salt in participants reporting use of plant-based substitute products (n=125) is presented in **Table 5**. The overall median contribution to the total energy intake was 12.1% (IQR 6.9-19.4), and there were no differences between the groups. However, the percentage of total fat from substitutes was higher for vegans (19%, IQR 8.4-30.4) compared to pescatarians (10%, IQR 4.3-22.7) (p= 0.010), but not compared to vegetarians (13.7%, IQR 7.1-23.2). With a median intake of SFA from substitutes equaling 26.7% (IQR 10.3-54.9) vegans also had substantially higher percentage of SFA intake from substitutes, than both vegetarians (9.7%, IQR 2.2-44.6, p=0.020) and pescatarians (7.6%, IQR 1.9-19.7, p=0.002). The groups did not differ in contribution from substitutes to the total intake of TFA, MUFA or PUFA. Furthermore, there were no differences in the contribution to carbohydrates, added sugar or dietary fibers from substitutes between the groups. However, vegans had a significantly higher contribution to the total protein intake from substitutes (19.1%, IQR 6.2-36.9) than pescatarians (6.9, IQR 1.8-17.1) (p=0.03). The contribution from substitute products to total intake of salt did not differ across groups but ranged from 7.1% in pescatarians to 17.7% in vegans.

Table 5 Contribution (%) from meat and dairy substitutes to total intake of energy (kcal), macronutrients (g) and salt (g) (n=125)

	Total (n=125)		Vegans (n=75)		Vegetarians (n=32)		Pescatarians (n=18)		P-value[1]
	median	(IQR)	median	(IQR)	median	(IQR)	median	(IQR)	
Kcal %	12.2	(6.9-19.4)	13.8	(8.1-22.1)	10.3	(6.7-16.5)	10.2	(2.3-15.0)	0.061
Fat %	16.5	(8.4-30.4)	19.0[a]	(10.4-35.5)	13.7	(7.1-23.2)	10.0[a]	(4.3-22.7)	0.022*
SFA % [2]	15.5	(5.5-45.7)	26.7[ab]	(10.3-54.9)	9.7[b]	(2.2-44.6)	7.6[a]	(1.9-19.7)	0.002*
TFA % [2]	0.0	(0.0-0.0)	0.0	(0.0-0.0)	0.0	(0.0-0.0)	0.0	(0.0-0.0)	0.438
MUFA % [2]	9.2	(4.2-15.1)	9.5	(3.7-16.0)	9.2	(5.3-13.4)	7.6	(3.2-15.9)	0.860
PUFA % [2]	15.5	(5.2-28.0)	14.7	(4.5-27.9)	17.9	(8.2-32.3)	13.8	(4.7-26.4)	0.514
Protein%	14.2	(5.3-31.4)	19.1[a]	(6.2-36.9)	13.0	(6.1-27.4)	6.9[a]	(1.8-17.1)	0.011*
Carbohydrate %	7.9	(3.3-12.8)	8.0	(3.2-12.4)	7.4	(4.0-16.4)	5.1	(1.6-10.9)	0.372
Added Sugar %	0.0	(0.0-5.6)	0.0	(0.0-5.9)	0.4	(0.0-21.3)	0.0	(0.0-0.4)	0.203
Dietary fiber %	9.9	(4.0-17.1)	10.2	(4.1-16.3)	7.1	(3.4-19.6)	9.0	(1.7-16.8)	0.671
Salt %	15.9	(5.1-34.3)	17.7	(5.4-41.2)	14.7	(6.0-33.9)	7.1	(1.9-21.7)	0.109

[1] Test for difference between different the diet groups, Kruskal Wallis Test, significance level used: <0.05, marked as*

[2] SFA – saturated fatty acids; TFA- trans fatty acids; MUFA – monosaturated fatty acids; PUFA – polyunsaturated atty acids

[ab] Diet groups with the same superscripts, have proportions that differ significantly in the post hoc test (p<0.05)

Discussion

To our knowledge, the present study is the first to assess total dietary intake in plant-based diets in Norway. This study provides a snapshot of the intake of meat and dairy substitutes among people adhering to different plant-based diets. In summary, most participants had consumed meat or dairy substitutes, and consumption was most frequent among vegans, followed by vegetarians and pescatarians. Vegans also had a higher contribution from the substitutes to total intake of total fat, saturated fatty acids, and protein. The participants had total macronutrient intake within NNR recommendations, presenting a favorable distribution of fatty acids in addition to high levels of dietary fiber.

While traditional plant-based diets have focused on whole foods, the modern adaptation of these diets may include highly processed alternatives for meat and dairy [46]. Little is known about the impact of plant-based substitutes on diet quality and health, but recent studies suggest meat and dairy substitutes to be associated with higher intake of ultra-processed foods and less healthy eating patterns in plant-based diets [46, 47]. However, an analysis found meat substitutes to contain less total fat, saturated fat and more dietary fiber than their meat counterparts, although several products contained more sodium [30]. Gibney raises the question of whether consumption of processed foods, such as meat and dairy substitutes matter, if the total nutrient intake remains within recommendations for optimal nutrient intake [48].

Consumption of plant-based meat and dairy substitutes

Plant-based meat and dairy substitutes are flooding the global market, and replacing regular meat or dairy with these products, rather than whole foods, have become increasingly common [29]. These trends were reflected in the results presented in our study, as most participants reported to consume either meat or dairy substitutes during the last 24 hours. Previous studies have suggested that consumption of substitute products increase with increased avoidance of animal-source foods [14, 47, 49, 50]. Supporting this hypothesis, and coherent with all groups avoiding meat, the present study found no differences between groups in consumption of each product category of meat substitutes. Furthermore, our results showed the most prominent differences in consumption pattern of dairy substitutes, in milk and cheese categories. While, cow's milk, and cheese, often consumed daily in the Norwegian diet, are included in vegetarian and pescatarian diets, vegans would need to replace these products with plant-based substitutes. Findings in this study suggest that plant-based substitutes for both meat and dairy may provide a convenient way of maintaining food habits, replacing the foods and beverages excluded in the different eating patterns.

Another potential explanation for the large proportion of vegans who reported use of substitutes, is that these products are considered good sources of protein (soy-based meat substitutes) or micronutrients (fortified dairy substitutes). As the main ingredient in the early meat substitutes, tofu and tempeh [1], soybeans have long been recognized as a source of high-quality protein in vegetarians diet [1, 50, 51]. In addition, soybeans have been recommended as a source of iron, potassium, zinc, and selenium in diets excluding meat [1, 50, 51]. More than 55% of the meat substitutes and 32% of the dairy substitutes reported in this study was based on soy, suggesting that soy-based products are frequently chosen. However, most dairy substitutes consumed were oat-based, probably due to the popularity and wide range of oat-based dairy substitute products by the Swedish brand "Oatly" [52], and the common use of oats in the Norwegian diet. Many variants of plant-based substitutes for milk on the Norwegian market have been fortified with calcium, vitamin B_{12} and vitamin D [52-55], and a recent report from the Norwegian National Nutrition Council, has recommended inclusion of calcium fortified plant-based substitutes for milk from soy as an alternative to cow's milk [25]. As most participants in the present study had followed their current diet for several years, they were likely well informed about how to compose a nutritionally adequate diet and may consequently have included substitute products to ensure intake of certain nutrients. Although, soy or oats were the preferred raw ingredients in most dairy substitute categories, 80% of the plant-based cheese substitutes were based on modified starches. Consistent with this observation, a recent study on nutritional composition and quality of plant-based cheese found most products to be based on a combination of refined coconut oil and starches with refined coconut nut oil being the main ingredient [56].

Macronutrients

All groups reported total macronutrient intake within Nordic Nutrition Recommendations 2012 [45], and contrasts in macronutrient intake were usually strongest between vegans and pescatarians, with the exception of dietary fibers and added sugar. Similar to or results, other studies have found that vegans have a more favorable distribution of macronutrients, with a lower contribution of SFA [57, 58] and a higher contribution of PUFA [13, 57] to total energy intake, compared to vegetarians and pescatarians. These findings were as expected, since SFA are mostly found in animal-based foods, such as whole fat dairy products. Vegans therefore have few natural sources of SFA in their diets. Moreover, vegan diets may include ample amounts of plant-based oils, nuts, seeds, and whole grains, which are good sources of PUFA [10, 14]. Replacing SFA for PUFA is associated with reduced risk of cardio vascular disease (CVD) [59, 60], and improved blood lipid profile [61], which may in part explain the proposed cardio-protective effect of plant-based diets [62]. Pescatarians was the only group to meet the requirements of ≥1 E% n-3 fatty acids in the present study [45], which may most likely be explained by a regular consumption of fatty fish. However, low intake of n-3 fatty acids in vegans (0.7 E%) and vegetarians (0.5 E%) may most likely indicate that they do not include adequate amount of n-3 rich plant-based food sources (i.e., flax seeds and flax seed oil, chia seeds and walnuts) or supplements to meet their requirements.

An analysis of protein intake in the European Prospective Investigation into Cancer and Nutrition-Oxford study (EPIC-Oxford study), showed a rising gradient with lowest intakes in vegans, followed by vegetarians and highest in pescatarians [13]. A similar gradient was also observed in the French NutriNet-Santé study, though, this study did not distinguish between vegetarians and pescatarians [14]. Although, the median intake of protein in vegans (13 E%) and pescatarians (15 E%) in the present study was almost equal to findings in the EPIC-Oxford study, vegetarians in the present study reported protein intakes similar to the vegans, thereby deviating from the previously observed gradient [13].

Previous studies have found intake of dietary fiber to increase with dietary restriction, observing the highest levels in vegans compared to other diets [13, 14, 58, 63, 64]. Similarly, in the present study, vegans reported the highest intake of dietary fiber in g/MJ, whereas no difference was observed between vegetarians and pescatarians. However, the median intake of dietary fiber in all three groups (5.2 g/MJ, 3.8 g/MJ and 4.2 g/MJ) exceeded the estimated average intake in the general Norwegian population (2.3 g/MJ) [65]. The high intake of dietary fiber reported among all groups included in the present study was likely a result of high consumption of whole grains, legumes, vegetables, fruits, nuts, and seeds. These food groups represent main components in all healthy plant-based diets [10], and are often consumed in large amounts by vegans, vegetarians and pescatarians compared to omnivores [14, 49, 58, 63]. Consuming diets high in dietary fiber has also been associated with lower body weight, reduced CVD risk, and lower risk of colon cancer [66, 67]. Thus, the high content of dietary fibers in plant-based diets is suggested as one of the potential explanations for the lower relative risk of certain non-communicable diseases observed in vegetarian and vegan populations [66].

Although, vegetarians in the present study reported higher intake of added sugar than the other two groups, the intake in all groups was within the recommendations of <10 E%, and below the estimated average intake in the general Norwegian population (11 E%) [65]. A possible explanation for this low intake of added sugar, may be that the study participants are more conscious about their health and have more nutritional knowledge compared to the general population. However, underreporting attributed to social-desirability bias cannot be ruled out. Participants may have inadvertently or deliberately, neglected to mention intake of sugary foods in the 24h, or underestimated the amount eaten.

The salt intake reported in this study was considerably lower than the estimated average salt intake in the Norwegian population (10 g/day) [68]. However, only vegans (6.0 g) and vegetarians (5.2 g) met the recommendations in NNR

[45] of ≤6 g/day. Due to the adverse effect of sodium on blood pressure reduction in salt intake is one of the main national and global targets for the prevention of non-communicable diseases [69, 70]. The relatively low levels of salt intake reported in this study, concurs with several studies which have found vegans and vegetarians to consume lower levels of sodium than meat-eaters [14, 17, 63]. However, both the EPIC-Oxford study [13] and the Adventist Health study 2 [64] found no difference in sodium intakes between meat-eaters, pescatarians, vegetarians and vegans.

Contribution to macronutrient and salt intake from plant-based meat and dairy substitutes

Among participants who reported to consume plant-based substitutes in our study, vegans reported the highest contribution of total fat, SFA and protein from substitute products. As our results showed no differences in total energy intake (kcal) or total fat intake (E%) between the groups, the higher contribution from substitutes to total fat in vegans than pescatarians may simply be explained by a higher consumption of these products among vegans than pescatarians. However, the nutrient content in plant-based substitutes have been found to vary greatly [30, 32, 36, 56, 71], and although not assessed in this study, it is possible that products frequently consumed by the vegans contained more fat than the products consumed by the pescatarians. The prominent difference in consumption of dairy substitutes found between the diet groups, may be one possible explanation for differences in contribution from substitutes to SFA intake. However, with the exception of coconut-based milks, milk substitutes tend to have a lower SFA content than cow's milk [34, 71, 72]. Furthermore, few participants reported to have consumed milk substitutes based on coconut, making it unlikely that consumption of plant-based substitutes for milk could explain the difference in SFA intake between the diet groups. A more plausible explanation is that while vegetarians and pescatarians may include whole fat dairy containing significant amounts of SFA, vegans have few natural sources of SFA in their diets. Thus, SFA from substitutes was likely to account for a larger proportion of the total SFA intake in vegans than in vegetarians and pescatarians.

Similarly, the higher contribution to protein intake from substitutes in vegans (19%) than pescatarians (7%) may also be explained by the lower total protein intake observed in vegans compared to pescatarians in this study. However, Bradbury and coworkers (73) also found contribution from vegetarian protein alternatives (excluding legumes, nuts and seeds) and plant-based substitutes for milk to be higher in vegans than pescatarians, with intermediate values reported by vegetarians [73].

Although, intake of salt from substitutes did not differ between groups, the median contribution to the total salt intake was substantial in vegans (18%) and vegetarians (15%), and suggest a potential negative impact on salt intake from substitute products. This is further supported by the high 75th percentiles (41% and 34% respectively). Although, neither plant-based substitutes for milk or cheese have been found to contain high levels of sodium [56, 72], high sodium content is one of the main concerns regarding nutrient content of meat substitutes [30, 36].

Strengths And Limitations

To our knowledge, this was the first Norwegian study assessing total dietary intake in a group adhering to different plant-based diets. The major strength was the sample size which was relatively large in comparison with similar studies [16, 17]. Another strength of this study was that the 24h were conducted as personal interviews as opposed to i.e., online surveys, thus providing data with high levels of detail. Furthermore, since the participants were not

informed in advance that they would be asked to give a full recount of dietary intake, they were not able to adjust their diets, which increased the likelihood of recalled intake representing true normal intake.

The main limitation of this study was the use of single 24h dietary recall per person, as it does not provide information on habitual intake [74]. However, single 24h is commonly used to assess and monitor dietary intake in larger groups, and can help identify subgroups at risk of inadequate nutrient intake [75]. The method is also considered appropriate for comparison of nutrient intake between groups [74], which was the main aim of this study.

Using convenience sampling and snowball sampling methods may have introduced self-selection bias. Participants were mostly from urban areas of Norway, living near Oslo, the capital, and had higher education. Thus, the sample may not be representative to vegans, vegetarians and pescatarians living in other parts of the country, without higher education. However, plant-based diets in Norway are likely more common among people living in Oslo, [2], and higher education is positively associated with pant-based eating [76], strengthening the representativeness of the sample.

Because fortified plant-based substitutes, have been suggested to contribute substantially to intake of several micronutrients of concern in plant-based diets [64], a limitation of this study was that only macronutrient intake was assessed. Unfortunately, due to lack of information on nutrient content of meat and dairy substitute products not registered in the Norwegian food composition table, the data was insufficient to analyse the contribution from plant-based substitutes to total intake of micronutrients and n-3 fatty acids. Further research is needed to evaluate whether fortified plant-based substitutes can contribute to intake of micronutrients such as calcium, iodine, B_{12}, and vitamin D in Norwegian plant-based diets.

Conclusion

In summary, most participants consumed meat or dairy substitute products, suggesting that these products are regularly included in Norwegian plant-based diets. Vegans reported to consume plant-based substitutes most frequently, followed by vegetarians and pescatarians. All groups reported a total macronutrient intake within NNR recommendations, presenting a favorable intake of fatty acids dietary fiber according to the recommendations. Our results also showed a higher contribution from the substitute products to total intake of total fat, saturated fatty acids, and protein among vegans compared to the other groups. More studies are needed to gain knowledge about the diet and health effects of plant-based substitutes, and these studies should assess the contribution to both macro-and micronutrients. Further research is needed to ensure that policy related to marketing regulation and regulation of nutrient content, as well as development of dietary guidelines is based on knowledge of consumption and contribution of these substitute products to total dietary intake.

Abbreviations

BMI: Body mass index; CVD: Cardiovascular disease; EPIC-Oxford study: European Prospective Investigation into Cancer and Nutrition-Oxford study E%: Energy percentage; FCT: Norwegian Food Composition Table (FCT); IQR: Inter Quartile Range; MUFA: Monounsaturated fatty acids; NNR: Nordic Nutrition Recommendations; PUFA: Polyunsaturated fatty acids; RI: Recommended intake; SD: Standard deviation; SFA: Saturated fatty acids; TFA: Trans fatty acids; 24h: 24-hour dietary recall

Declarations

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Availability of data and materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by Regional Committee for Medical and Health Research Ethics (2019/653/REC Southeast) and by the Norwegian Centre for Research Data (NSD/101332). All participants gave their written informed consent.

Competing interests

The authors declare no conflict of interest.

Consent for publication

Not applicable

Authors' contributions

SH designed the study. LET and SGJ collected the data. LET performed the statistical analyses and drafted the original manuscript. SGJ, THS and SH revised the manuscript critically. SH supervised the project. All authors provided critical revision and read and approved the final manuscript.

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Figures

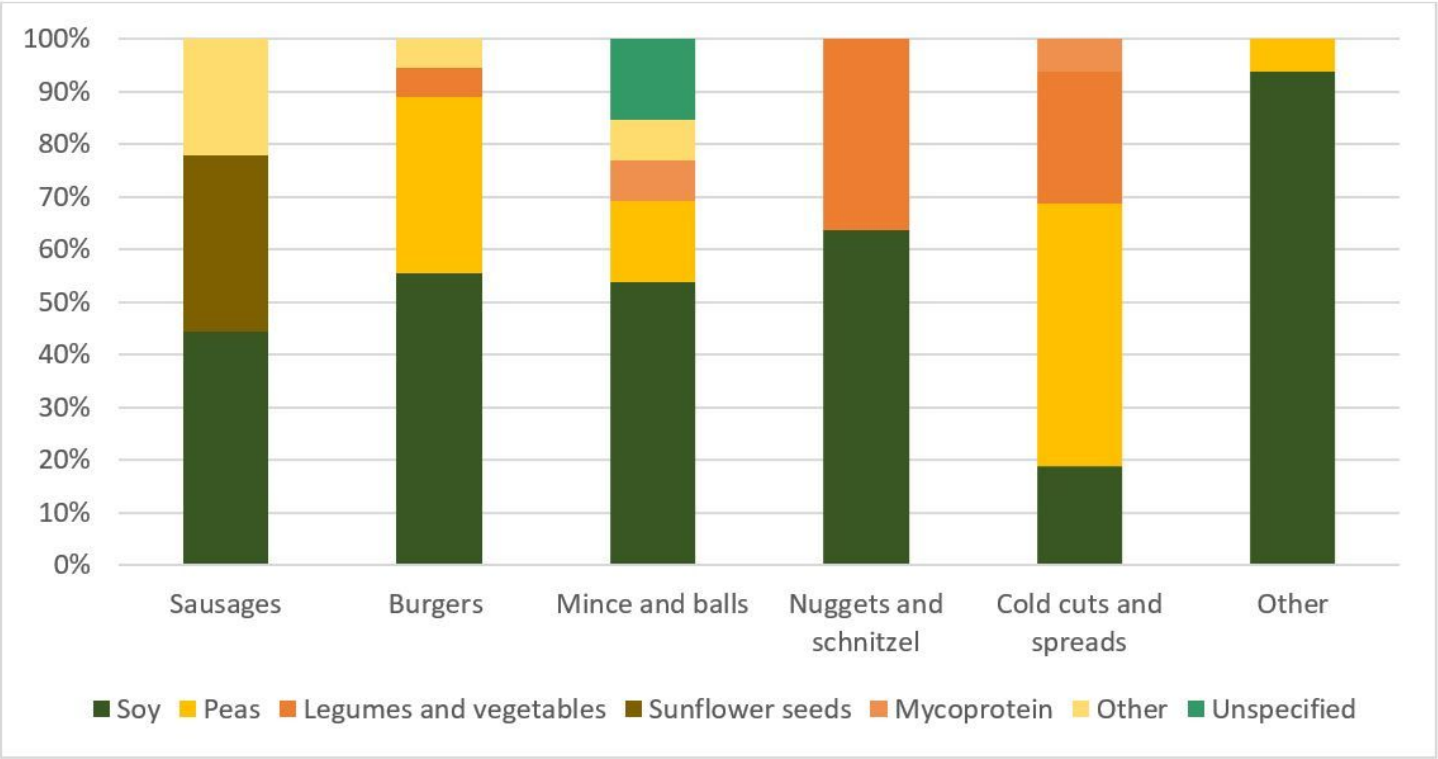

Figure 1

Proportions within each category of all meat substitute products reported in 24h by 125 participants, according to raw ingredients and frequency of intake. Other includes products based on raw ingredients reported only once. Unspecified includes unidentifiable products and raw ingredients.

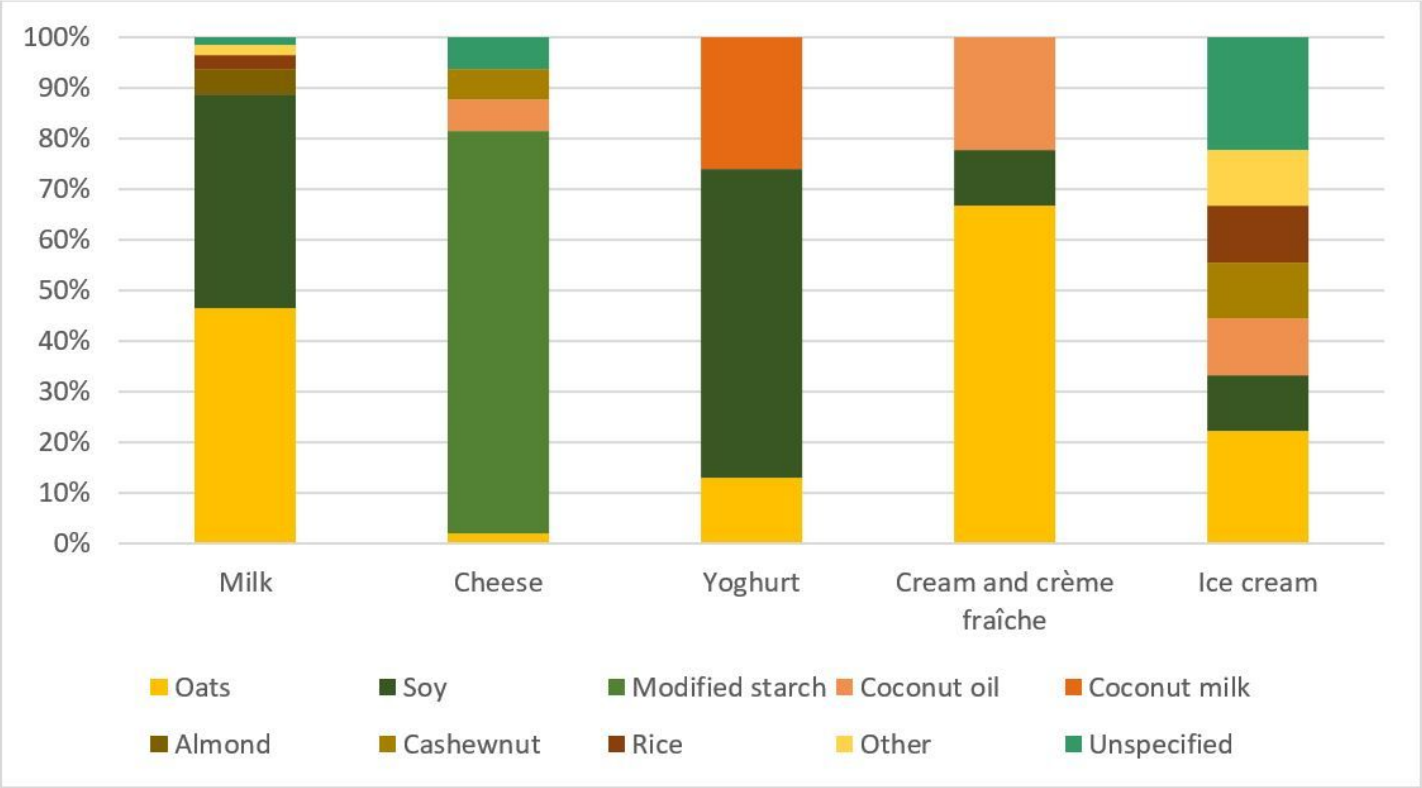

Figure 2

Proportions within each category of all dairy substitute products reported in 24h by 125 participants, according to raw ingredients and frequency of intake. The category ‘other’ includes products based on raw ingredients reported only once. The category ‘Unspecified’ includes unidentifiable products and raw ingredients.