The Journal of Nutrition 155 (2025) 2717–2728

THE JOURNAL OF NUTRITION

journal homepage: https://jn.nutrition.org/

Nutritional Epidemiology

Classification and Estimation of Dietary Live Microorganisms and Fermented Foods Intake in Swiss Adults

Eugenia Pertziger [1,2,*], Ueli von Ah [1], Murielle Bochud [2], Angeline Chatelan [3], John Haldemann [1], Elaine Hillesheim [1], Michel Kaiser [4], Guy Vergères [1], Kathryn J Burton-Pimentel [1]

[1] *Agroscope, Food Microbial Systems Research Division, Bern, Switzerland;* [2] *Department of Epidemiology and Health Systems, University of Lausanne, Center for Primary Care and Public Health (Unisanté), Lausanne, Switzerland;* [3] *Department of Nutrition and Dietetics, University of Applied Sciences and Arts Western Switzerland, Geneva School of Health Sciences, Geneva, Switzerland;* [4] *Bern University of Applied Sciences, School of Health Professions, Bern, Switzerland*

A B S T R A C T

Background: Dietary live microorganisms and fermented foods may benefit human health by modulating gut microbiota composition and function. However, their classification and intake are not well-defined in population-based studies assessing whole diets.

Objective: The objectives of this study were to classify and quantify the intake of foods with live microorganisms and fermented foods among Swiss adults.

Methods: We analyzed data from 2086 adults aged 18–75 y in the cross-sectional Swiss National Nutrition Survey menuCH (2014–2015). Food items were classified by live microorganism levels (low, $<10^4$ CFU/g; medium, 10^4–10^7 CFU/g; or high, $>10^7$ CFU/g) and fermented food descriptors, including fermented ingredients and core microbiota. Intake of these foods was determined at the population level by demographic subgroups, food categories, and nutrient contributions.

Results: Mean intake of medium or high live microorganism foods (MedHi) was 269.3 g/d (8.0% of total food intake), primarily from fruit, vegetables, and fermented dairy products. MedHi foods contributed 12.3% of daily energy intake and >20% of daily intake of several nutrients, including β-carotene, vitamins A, C, B12, folate, calcium, and saturated fat. Fermented foods accounted for 717.1 g/d (21.0% of total food intake), mainly from coffee, bread products, alcoholic beverages, and fermented dairy, contributing 27.0% of daily energy and >30% of daily calcium, phosphorus, sodium, zinc, vitamins A and B12, starch, and saturated fat. Significant differences in MedHi food intake were observed between sexes and age groups but not linguistic regions, whereas fermented food intake varied across all population subgroups. We identified 186 microorganisms across 6 taxonomic levels in fermented foods.

Conclusions: This study provides a comprehensive classification of live microorganism levels and fermented foods, highlighting their intake and nutrient contribution to the Swiss diet. These results set the stage for future research linking the dietary intake of these foods to health outcomes in population studies.

Keywords: dietary live microbes, fermented foods, food microbiota, Switzerland, 24-h dietary recalls, GloboDiet

Introduction

The gut microbiota has attracted significant attention for its role in human health, in particular through intricate connections with various physiological systems, including the immune system, the central nervous system, and metabolism [1]. Despite this recognized importance, defining what constitutes a healthy microbiota remains challenging due to the vast diversity and variability of resident microorganisms among individuals [2]. In this regard, diet is being investigated as a key modifiable factor influencing gut microbiota composition and function by providing fermentable substrates, modulating compounds, or acting as a source of live microbes [3]. Fermented foods, defined as "foods made through desired microbial growth and enzymatic conversions of food components" [4], and nonfermented foods containing live microorganisms, such as fresh fruit and vegetables, are of particular interest in this context. These foods can act as transient modulators of the gut microbiota composition and activity [5–8].

Abbreviations: Low, estimated to contain $<10^4$ CFU/g live microorganisms; Med, estimated to contain 10^4–10^7 CFU/g live microorganisms; Hi, estimated to contain $>10^7$ CFU/g live microorganisms; MedHi, estimated to contain $>10^4$ CFU/g live microorganisms; FCDB, Food Composition Database; GD, GloboDiet.

* Corresponding author. *E-mail address:* eugenia.pertziger@unil.ch (E. Pertziger).

https://doi.org/10.1016/j.tjnut.2025.05.042

Received 10 December 2024; Received in revised form 9 May 2025; Accepted 28 May 2025; Available online 31 May 2025

Recently, the intake of live dietary microorganisms was estimated for the United States population by classifying all foods recorded in the NHANES dataset into high, medium, or low levels of live microbes [9], with higher intake of live microorganisms associated with positive cardiometabolic health outcomes [10]. Furthermore, in the same dataset, higher intake of live microbes was associated with reduced symptoms of depression [11,12], lower risk of frailty [13] and sarcopenia [14], better cognitive function [15], and reduced risk of all-cause and cardiovascular disease mortality [16]. A recent review of the impact of live dietary microbes on human health made a first attempt to estimate the recommended daily intake of live microorganisms at 2×10^9 CFU/d [17].

Fermented foods are a diverse group of foods with an inherent heterogeneity stemming from various substrates and fermentation techniques, deeply rooted in a long history of consumption across different cultures. These foods have multiple qualities that could play a role in health promotion, including the ingestion of live microbes, microbial metabolites, and inactivated microbial cells [4]. The intake of individual fermented foods, such as yogurt, fermented milk, coffee, wine, and beer, has been investigated for its associations with health, particularly in relation to cardiometabolic outcomes [18–20]. However, estimates of the total fermented food intake and evidence of its health effects are still limited [10,19,21,22].

Although interest in fermented foods has grown in Western societies, driven by increased research into the human microbiome [19], industrialization and the shift toward higher intake of ultraprocessed foods have contributed to the progressive deterioration of the gut microbiota, marked by reduced diversity and abundance of microbial species [1]. Conversely, a significant gap remains in our understanding of foods' microbiota: unlike nutrients, the microbial composition of foods, including microbial species and their counts, is absent from food composition databases (FCDBs). Therefore, our study aimed to classify and describe food items consumed by the Swiss adult population according to live microorganism levels and fermentation, as well as to estimate their intakes and the core microbiota present in the fermented foods consumed. This classification represents an important step toward addressing the existing knowledge gap and enabling the subsequent assessment of associations with health outcomes.

Methods

Dataset

We used data from the cross-sectional Swiss National Nutrition Survey menuCH, which was conducted in 2014–2015 and investigated dietary habits among adults aged 18–75 y living in the German-, French-, and Italian-speaking regions of Switzerland [23]. This population-based survey included 2086 participants (54.65% female), selected through a stratified random sample provided by the Federal Statistical Office. The design included 35 strata, based on a combination of 7 administrative regions of Switzerland (Lake Geneva, Midlands, Northwest, Zurich, East, Central, and South), covering the 3 main linguistic regions and 5 predefined age groups. The 24-h dietary recalls were collected by trained dietitians using the validated GloboDiet software (GD, version CH-2016.4.10, International Agency for Research on Cancer) [24], and the dietary data were then linked to the Swiss FCDB using FoodCASE (Premotec GmbH) to estimate macro- and micronutrient intakes. The menuCH survey was approved by the corresponding regional ethics committees (Protocol 26/13 from 12 February 2013), with written informed consent obtained from all participants. The survey was registered on isrctn.com as ISRCTN16778734.

In this study, the menuCH dietary data were used to classify foods and beverages according to their levels of live microorganisms and fermented food descriptors and to estimate the intake of these foods in the Swiss adult population. Data from participants with at least 1 24-h dietary recall (n = 2085) were used for classification (V04_2017_09 version), whereas data from participants with 2 24-h dietary recalls (n = 2057) were used for analyses (V05_2022 version, with improved micronutrient estimates).

Dietary data

The menuCH survey recorded 124,190 dietary entries from 2085 participants with at least 1 24-h dietary recall. Each entry, recorded by a unique GD identifier, was categorized as a food, recipe, or ingredient. There were 1519 unique foods and ingredients, forming 3341 food-ingredient pairs (e.g., potato, chicken breast, or egg paired with cooking fat) and 2307 recipes from ingredients (e.g., salad, sandwich, or pizza). Some items recorded as foods were composite items with multiple ingredients (e.g., pasta with cheese filling), but their precise composition was not detailed in the dietary collection process. Furthermore, food items in the menuCH dietary data were categorized into 6 food groups based on the 2011 Swiss Food Pyramid [25] and 31 subgroups. In the present study, food items with live microorganisms and fermented food items were aggregated by 6 food groups and 35 subgroups. Supplemental Table 1 illustrates the classification of 82 representative food items developed for the analysis of live microorganisms and fermented food intake. The full classification of 1519 foods and ingredients from menuCH is not included due to contractual restrictions with the data provider on the disclosure of brand and product names. Further details and explanations about the methods are available in Supplemental Methods.

Live microorganism levels classification

MK and EP assigned a level of live microorganisms defined as low (Low, $<10^4$ CFU/g), medium (Med, 10^4–10^7 CFU/g), or high (Hi, $>10^7$ CFU/g) to 1519 foods and ingredients. These levels were adapted from the classification system of the NHANES data [9], taking into account the specific food processing techniques used in Switzerland. Briefly, the levels were chosen to reflect the approximate numbers of viable microorganisms expected to be found in pasteurized foods ($<10^4$ CFU/g), fresh vegetables and fruits consumed unpeeled (10^4–10^7 CFU/g), and unpasteurized fermented foods and probiotics ($>10^7$ CFU/g) [9]. For Swiss-specific foods absent in the NHANES classification, the levels were assigned based on a literature review, by consulting industry experts, or inferred from production methods, and similar foods (e.g., "spätzli" or "pizzocheri" were assigned a similar level as "cooked pasta").

Fermented food classification

The 1519 foods and ingredients were assigned a fermentation status, categorized as "fermented," "nonfermented," or "composite food item with fermented ingredients," based on the International Scientific Association for Probiotics and Prebiotics definition of "foods made through desired microbial growth and enzymatic conversions of food components" [4]. For fermented food items, the following descriptors were assigned: the presence of live microorganisms ("present" or "absent"), the method of inactivation or removal when live microorganisms were absent (e.g., "heat," "filtration," "filtration-heat," or "cell disruption methods"), and the core microbiota present or responsible for fermentation. Fermentation status and descriptors were defined by EP, based on production methods reported in the literature, determined by Swiss laws or established industry practices, and then reviewed with KJB, GV, and MB. The microbiota of fermented foods was classified by reviewing 5–10 publications reporting on microbiota for each fermented food type. JH provided feedback on the microbiota classification of fermented dairy products, whereas UvA conducted microbiological analyses for the butter classification and consulted on the microbiota taxonomy of fermented foods.

The core fermented food microbiota was determined at the lowest taxonomic level whenever possible, whereas higher levels were used when the dietary information was unspecific. For example, the microbiota of coffee fermentation varies depending on the country of origin and processing method [26]; however, menuCH, as a population-based survey, did not capture such high-resolution dietary data. Consequently, the coffee microbiota was assigned at the genus level. To further address the imprecision in dietary data, we introduced a conservative and broad classification for the microbiota of fermented foods. The conservative classification was defined as the microorganisms consistently identified in the literature for a specific food or across food types (e.g., common microorganisms found in all coffee types). In contrast, the broad classification included microorganisms reported in the literature that showed variability across studies or different types of the same food (e.g., common microorganisms found in various types of coffee).

For composite food items containing 1 or more fermented ingredients, the proportions of fermented ingredients were estimated by KJB and EP by consulting the Swiss FCDB, ingredient lists published by food producers, and typical Swiss cooking recipes published online [27–32]. On average, we consulted 3 recipe formulations if ingredients were consistently used and 5 recipe formulations if ingredients varied. In addition, when data reported were unspecific (e.g., chocolate not defined as dark, milk, or white), the proportion of fermented ingredients was averaged across market products. Fermented ingredients with a proportion <1% and ingredients such as whey powder, vanilla extract, yeast extract, cheese powder, and yogurt powder were excluded from classification and analyses. In the classification of composite food items with fermented ingredients, the presence or absence of live microorganisms was considered based on the live microorganisms in fermented ingredients and the final processing method of the composite food item.

Classification implementation in the menuCH data

The live microorganism levels and fermented food descriptors from 1519 unique foods and ingredients were linked by GD identifier to 124,190 dietary entries in the original menuCH dataset. Additionally, fermented food descriptors were assigned to 12,673 newly created fermented ingredient entries, for which the proportions within composite food items were estimated.

To determine the final levels of live microorganisms consumed, the cooking or processing status of the dietary entries was determined using food descriptors described in the menuCH study documentation [33]. When food descriptors were unavailable, the cooking or processing status was manually assigned by EP and KJB. In both cases, the levels of live microbes were set to Low for entries that underwent heat treatment, peeling, or drying. Similarly, the status of live microorganisms in fermented food entries was changed from "present" to "absent" if an entry underwent processing such as filtration or heat treatment.

In the aggregation by food groups and subgroups, fermented food items linked to recipes or food-ingredient pairs were analyzed as fermented ingredients from recipes within their respective food groups and subgroups. Likewise, fermented ingredients within composite food items were analyzed as fermented ingredients from composite foods and also categorized by their respective food groups and subgroups in data analyses. For example, "Cucumber, pickled" was recorded in menuCH under "Vegetables," whereas "Vinegar, n.s." estimated as an ingredient in pickled cucumber was categorized under "Condiments & Seasonings" in our analyses.

Statistical analysis and data visualization

All statistical analyses were performed using R (version 4.4.0) [34]. Weighted analyses were conducted with the "survey" R package (version 4.4-2) [35], incorporating the menuCH survey weights, strata, and population strata sizes to account for the sampling design and nonresponse, ensuring a better approximation of nationally representative results. The survey weights were also calibrated to account for weekday variations and seasonality [33].

Weighted estimates of intake in grams, proportions (relative to total gram intake of food and beverages, including water), and nutrient contributions of foods containing live microorganisms or fermented foods were obtained using the arithmetic mean of 2 24-h dietary recalls ($n = 2057$). Participants who reported consuming foods with live microorganisms or fermented foods in at least 1 recall were considered consumers. Intake estimates were calculated based on the combined data of consumers and nonconsumers, with the proportion of consumers reported. For the intake data, estimates were summarized using weighted mean and SD, accounting for the survey design. Additionally, weighted median and interquartile range (IQR, 25th and 75th percentiles) were reported to provide a robust description of the central tendency and spread of the intake distributions.

In the analysis of live microorganism level intake, a MedHi level category was created, aggregating food items with Med or Hi levels of live microorganisms ($>10^4$ CFU/g), similar to Marco et al. [9]. When estimating nutrient intake, we calculated the percentage of nonmissing values based on the availability of nutrient information in the Swiss FCDB. For fermented foods and ingredients, nutrient contributions were estimated solely using individual foods, food-ingredient pairs, and ingredients from recipes. Although we could estimate the amounts of fermented ingredients in composite items, nutrient information was unavailable for many of them. For example, the most common fermented ingredients in composite food items were cocoa products, combining cocoa butter, cocoa powder, and cocoa mass. However, the Swiss FCDB only provides information for cocoa powder. Finally, alcohol was excluded from nutrient contribution estimates because all alcohol is produced through fermentation.

Differences in the estimated weighted intakes of foods with live microorganisms or fermented foods across demographic subgroups were assessed with the svyranktest function from the R "survey" package. Specifically, a design-based Wilcoxon rank test was used to compare intakes by sex, and a design-based Kruskal-Wallis rank test was applied for age groups and linguistic regions with >2 subgroups. A custom pairwise comparison function, using the design-based Wilcoxon rank test, was implemented for individual pairwise comparisons of the intake by food subgroup and linguistic region, with *P* values adjusted by Holm's method to correct for multiple testing. All subgroup differences were tested when there were at least 10 consumers per subgroup. In cases where comparisons were based on 10–29 observations per subgroup, the potential reduction in statistical accuracy was noted in an annotation. The level of significance was set at a 2-sided *P* value of 0.05, including adjusted *P* values.

The core microbiota of fermented foods, using a conservative classification, was visually summarized using a balloon plot. After determining the main microorganisms present in the fermented foods, the updated bacterial taxonomy was extracted from the Bacterial Diversity Metadatabase using the "BacDive" R package (version 0.8.0) [36], whereas the updated fungal taxonomy was manually extracted from the National Center for Biotechnology Information Taxonomy Database [37]. The R packages "ggplot2" (version 3.5.2) [38] and "ggpubr" (version 0.6.0) [39] were then used to create the plot, with the final annotations made using Inkscape (version 1.0.2-2, Inkscape Project).

Results

Classification of unique foods and ingredients

Among 1519 foods and ingredients, 81 (5.3%) food items were assigned a Hi level of live microorganisms, whereas 160 (10.5%) and 1278 (84.1%) foods were classified as having Med and Low levels, respectively. Notably, 38.3% (*n* = 31) of the foods with Hi levels were in the food subgroup "Hard Cheese," 32.1% (*n* = 26) were in "Soft Cheese," and 19.8% (*n* = 16) were in "Yogurt & Fresh Cheese." Collectively, >90% (*n* = 73) of food items with Hi levels were primarily fermented dairy products. Foods with Med levels were mostly in the "Vegetables" (53.8%, *n* = 86) and "Fruit" (18.1%, *n* = 29) subgroups but also included smaller numbers of foods from "Condiments & Seasonings" (8.8%, *n* = 14), "Hard Cheese" (3.8%, *n* = 6), and "Processed Meat" (3.8%, *n* = 6). For food items with Low levels, 10.0% (*n* = 128) were in the "Cakes, Desserts & Ice Cream" subgroup, followed by "Other Cereal Products" (8.8%, *n* = 112) and "Bread Products" (6.9%, *n* = 88). Note that fermented foods, whose microbes were inactivated or removed by methods such as heating or filtration (e.g., coffee, chocolate, bread, wine, and beer), were classified as having a Low level.

Based on the fermented food classification, 264 foods or ingredients (17.4%) were classified as fermented foods and 341 (22.4%) as composite foods with fermented ingredients. Among the fermented food items, 18.6% (*n* = 49) were classified as "Bread Products," 15.2% (*n* = 40) as "Hard Cheese," 13.6% (*n* = 36) as "Fortified Wines, Liqueurs & Spirits," and 11.0% (*n* = 29) as "Soft Cheese." Other food subgroups for fermented foods included "Processed Meat," "Coffee," "Yoghurt & Fresh Cheese," "Condiments & Seasonings," "Wine," and "Beer & Cider." For the composite food items with fermented ingredients, 23.2% (*n* = 79) were classified as "Cakes, Desserts & Ice Cream," 18.5% (*n* = 63) as "Chocolate Products," and 10.0% (*n* = 34) as "Bread Products." Other food subgroups for fermented ingredients included "Cream, Fatty Sauces & Other Fats," "Salty Snacks," "Other Sweet Products," and "Condiments & Seasonings." Within the 341 composite foods with fermented ingredients, there were 423 instances of 44 unique fermented ingredients. The most common fermented ingredients were cocoa products (28.6%, *n* = 121 instances) and bread in composite bread products (19.9%, *n* = 84). Other key ingredients included vinegar (12.3%, n = 52), vanilla bean (5.2%, n = 22), various alcohols (wine and spirits), and fermented dairy products (cheese, sour cream, and yogurt).

Live microorganisms were present in 119 (19.7%) fermented foods and composite foods with fermented ingredients. In fermented foods, the primary methods of microorganism inactivation or removal included heat inactivation during baking (e.g., in bread products) or roasting (e.g., in coffee and cocoa), filtration (e.g., in alcoholic beverages), and both filtration and heat inactivation in condiments (e.g., in vinegar and soy sauce).

Intake of foods with live microorganisms and fermented foods

In the menuCH survey, the weighted mean intake of foods with MedHi live microorganism levels was 8.0% (269.3 g/d) of the total food intake by gram amount (3465.6 g/d) (Table 1). Females had a higher mean (8.5% compared with 7.4%) and greater variability in the intake, as observed by the differences in the IQRs, of MedHi foods than males. Older individuals had a higher mean and greater variability in intake than younger individuals. There were no significant differences in the intake of MedHi between linguistic regions.

Considering the combined intake of fermented foods and ingredients, the weighted mean intake was 21.0% (717.1 g/d) of the total food intake by gram amount (3465.6 g/d) (Table 2). Males had a higher mean (24.4% compared with 17.7%) and a greater variability of the intake of fermented foods than females. Older individuals consumed more fermented foods than younger individuals, although there was an inconsistent pattern in the intake variability. The Italian-speaking region had the lowest mean and variability of intake of fermented foods (17.5%) compared with the German- and French-speaking regions (21.6% and 20.3%, respectively).

Intake of foods with live microorganisms and fermented foods by food subgroup

The food subgroups with the highest weighted mean intake of MedHi live microorganism levels were "Fruit" (2.8% of total gram intake or 97.4 g/d), "Vegetables" (2.0% or 69.5 g/d), "Yogurt & Fresh Cheese" (2.0% or 64.4 g/d), "Hard Cheese" (0.5% or 18.0 g/d), and "Soft Cheese" (0.2% or 7.8 g/d) (Table 3). For fermented foods, the food subgroups with the

TABLE 1
Daily intake of foods by levels of live microorganisms.

Live microorganism intake	Participants	*N*	Mean (SD)	Median (P25, P75)	Consumers, %[1]	Difference (*P* value)[2]
Total food intake, g/d	All	2057	3465.6 (981.7)	3372.6 (2786.9, 3989.8)	100	
Low foods, g/d	All	2057	3196.3 (953.6)	3091.6 (2546.1, 3719.9)	100	
Med foods, g/d	All	2057	178.7 (167.9)	134.5 (55.6, 255.3)	96.5	
Hi foods, g/d	All	2057	90.7 (96.9)	62.5 (10.9, 140.5)	81.1	
MedHi foods, g/d	All	2057	269.3 (208.8)	230.5 (114.4, 375.1)	98.2	
Low foods, % daily[3]	All	2057	92.0 (5.9)	93.1 (88.9, 96.3)	100	
Med foods, % daily	All	2057	5.2 (4.7)	4.1 (1.7, 7.3)	96.5	
Hi foods, % daily	All	2057	2.7 (2.9)	1.9 (0.4, 4.3)	81.1	
MedHi foods, % daily	All	2057	8.0 (5.9)	6.9 (3.7, 11.1)	98.2	
MedHi foods, % daily	Female	1124	8.5 (5.8)	7.5 (4.4, 11.9)	99.0	<0.001
by sex	Male	933	7.4 (6.0)	6.2 (3.0, 10.3)	97.5	
MedHi foods, % daily	18–34 y	563	6.1 (5.3)	5.1 (2.3, 8.2)	96.1	<0.001
by age group	35–49 y	602	7.3 (4.9)	6.3 (3.5, 10.3)	98.3	
	50–64 y	554	9.6 (6.5)	8.5 (5.2, 12.6)	99.7	
	65–75 y	338	10.0 (6.5)	9.2 (4.5, 13.9)	99.5	
MedHi foods, % daily	German-speaking	1341	8.1 (6.1)	6.9 (3.7, 11.2)	98.2	0.19
by linguistic region[4]	French-speaking	502	7.8 (5.6)	6.8 (3.7, 10.4)	98.4	
	Italian-speaking	214	7.2 (5.5)	6.1 (3.7, 9.4)	98.0	

Live microorganism levels: Low, estimated to contain <10^4 CFU/g; Med, estimated to contain 10^4-10^7 CFU/g; Hi, estimated to contain >10^7 CFU/g; MedHi, estimated to contain >10^4 CFU/g.

1 Participants who reported consuming foods with live microorganisms in at least one of the 2 dietary recalls were considered consumers.

2 Differences between the population subgroups were assessed using design-based Wilcoxon rank test for sex and design-based Kruskal-Wallis rank test for age groups and linguistic regions. Tests for subgroup differences were performed when there were at least 10 consumers per population subgroup.

3 Proportions of foods with levels of live microorganisms were calculated relative to the total food intake by gram amount.

4 The German-speaking region included the cantons of Aargau, Basel-Land, Basel-Stadt, Bern, Lucerne, St. Gallen, Zurich; the French-speaking region: Geneva, Jura, Neuchatel, Vaud, and the Italian-speaking region: Ticino.

TABLE 2
Daily intake of fermented foods and ingredients.

Fermented food intake	Participants	*N*	Mean (SD)	Median (P25, P75)	Consumers, % [1]	Difference (*P* value) [2]
Total food intake, g/d	All	2057	3465.6 (981.7)	3372.6 (2786.9, 3989.8)	100	
Fermented foods, g/d	All	2057	621.5 (433.1)	547.4 (317.3, 810.6)	99.8	
Fermented ingredients (recipes), g/d	All	2057	36.4 (59.9)	8.3 (0.0, 50.2)	64.0	
Fermented ingredients (composite foods), g/d	All	2057	59.2 (62.3)	40.6 (14.8, 83.4)	97.5	
Total fermented foods & ingredients, g/d	All	2057	717.1 (447.8)	645.4 (403.7, 911.2)	100	
Fermented foods, % daily [3]	All	2057	18.1 (11.2)	16.4 (9.9, 24.3)	99.8	
Fermented ingredients (recipes), % daily	All	2057	1.1 (1.7)	0.2 (0.0, 1.5)	64.0	
Fermented ingredients (composite foods), % daily	All	2057	1.8 (1.9)	1.2 (0.4, 2.5)	97.5	
Total fermented foods & ingredients, % daily	All	2057	21.0 (11.6)	19.4 (12.5, 27.7)	100	
Total fermented foods & ingredients, % daily	Female	1124	17.7 (9.3)	16.5 (10.6, 23.4)	100	<0.001
by sex	Male	933	24.4 (12.6)	23.2 (15.0, 31.8)	100	
Total fermented foods & ingredients, % daily	18–34 y	563	16.4 (9.8)	14.1 (9.3, 21.1)	100	<0.001
by age group	35–49 y	602	20.6 (11.3)	19.0 (12.3, 27.6)	100	
	50–64 y	554	24.2 (11.4)	23.0 (15.9, 30.4)	100	
	65–75 y	338	25.1 (12.2)	23.4 (16.2, 31.5)	100	
Total fermented foods & ingredients, % daily	German-speaking	1341	21.6 (11.5)	20.5 (13.0, 28.3)	100	<0.001
by linguistic region [4]	French-speaking	502	20.3 (11.7)	17.7 (11.8, 26.7)	100	
	Italian-speaking	214	17.5 (11.0)	15.4 (9.7, 22.5)	100	

1 Participants who reported consuming fermented foods or ingredients in at least one of the 2 dietary recalls were considered consumers.

2 Differences between the population subgroups were assessed using design-based Wilcoxon rank test for sex and design-based Kruskal-Wallis rank test for age groups and linguistic regions. Tests for subgroup differences were performed when there were at least 10 consumers per population subgroup.

3 Proportions of fermented foods and ingredients were calculated relative to the total food intake by gram amount.

4 The German-speaking region included the cantons of Aargau, Basel-Land, Basel-Stadt, Bern, Lucerne, St. Gallen, Zurich; the French-speaking region: Geneva, Jura, Neuchatel, Vaud, and the Italian-speaking region: Ticino.

highest weighted mean intake were "Coffee" (7.5% of total gram intake or 251.9 g/d), "Bread Products" (3.5% or 114.1 g/d), "Beer & Cider" (2.6% or 103.3 g/d), "Wine" (2.5% or 84.9 g/d), and "Yogurt & Fresh Cheese" (2.2% or 71.9 g/d) (Table 4).

Comparison of the intake of live microorganisms and fermented foods by food subgroups across linguistic regions are presented in Supplemental Tables 2 and 3. Among the food subgroups contributing the most to MedHi food intake,

TABLE 3
Daily intake of MedHi foods by food subgroup [1].

Food subgroup [2]	Amount, g/d [3]		% daily [4]	Consumers, % [5]
	Mean (SD)	Median (P25, P75)	Mean (SD)	
Fruit	97.4 (132.9)	51.8 (0.0, 153.5)	2.8 (3.8)	57.9
Vegetables	69.5 (73.6)	50.0 (19.2, 100.0)	2.0 (2.1)	85.3
Yogurt & Fresh Cheese	64.4 (88.3)	15.4 (0.0, 100.0)	2.0 (2.7)	51.8
Hard Cheese	18.0 (29.3)	5.5 (0.0, 22.7)	0.5 (0.8)	56.4
Soft Cheese	7.8 (16.3)	0.0 (0.0, 10.0)	0.2 (0.5)	29.7
Butter	4.0 (8.1)	0.0 (0.0, 5.0)	0.1 (0.3)	34.2
Processed Meat	2.9 (10.8)	0.0 (0.0, 0.0)	0.1 (0.3)	14.0
Other Protein-based Products	1.6 (13.5)	0.0 (0.0, 0.0)	0.1 (0.4)	1.7
Nuts, Seeds & Olives	1.5 (6.1)	0.0 (0.0, 0.0)	0.0 (0.2)	11.4
Cream, Fatty Sauces & Other Fats	0.8 (5.2)	0.0 (0.0, 0.0)	0.0 (0.1)	3.8
Cakes, Desserts & Ice Cream	0.6 (6.7)	0.0 (0.0, 0.0)	0.0 (0.2)	1.2
Fish & Seafood	0.3 (3.7)	0.0 (0.0, 0.0)	0.0 (0.1)	1.4
100% Fruit & Vegetable Juices	0.3 (9.7)	0.0 (0.0, 0.0)	0.0 (0.4)	0.2
Condiments & Seasonings	0.2 (1.0)	0.0 (0.0, 0.0)	0.0 (0.0)	17.0
Red Meat	0.1 (1.7)	0.0 (0.0, 0.0)	0.0 (0.1)	0.4
Other Cereal Products	0.1 (2.4)	0.0 (0.0, 0.0)	0.0 (0.1)	0.1

[1] Live microorganism levels: MedHi, estimated to contain $>10^4$ CFU/g.
[2] Food subgroups are ordered by their mean gram contribution of MedHi foods in each food subgroup. Food subgroups with no MedHi foods or no consumers are not shown (Water; Tea; Coffee; Tuber Products; Bread Products; Pasta & Rice; Milk; Other Unprocessed Meat; Vegetable Oil; Added Sweeteners; Chocolate Products; Other Sweet Products; Salty Snacks; Soft Drinks; Beer & Cider; Wine; Other Alcohols; Fortified Wines, Liqueurs & Spirits; Artificial Sweeteners).
[3] Dietary intake was estimated for 2057 participants.
[4] Proportion of MedHi foods in each food subgroup was estimated relative to the total food intake (3465.6 g/d).
[5] Participants who reported consuming foods with live microorganisms in at least one of the 2 24-h dietary recalls by food subgroup were considered consumers.

TABLE 4
Daily intake of fermented foods and ingredients by food subgroup.

Food subgroup [1]	Amount, g/d [2]		% daily [3]	% live daily [4]	Consumers, % [5]
	Mean (SD)	Median (P25, P75)	Mean (SD)	Mean (SD)	
Coffee	251.9 (234.9)	214.0 (75.0, 367.5)	7.5 (6.7)	0.0 (0.0)	83.1
Bread Products	114.1 (87.2)	94.5 (52.1, 156.3)	3.5 (2.6)	0.0 (0.0)	95.1
Beer & Cider	103.3 (265.9)	0.0 (0.0, 74.9)	2.6 (6.2)	0.0 (0.0)	26.9
Wine	84.9 (140.7)	2.0 (0.0, 125.0)	2.5 (4.3)	0.4 (4.6)	55.2
Yogurt & Fresh Cheese	71.9 (94.5)	37.6 (0.0, 110.0)	2.2 (2.8)	37.1 (39.3)	60.9
Hard Cheese	28.4 (42.9)	13.0 (0.0, 38.1)	0.8 (1.2)	34.3 (35.0)	72.5
Soft Cheese	15.5 (25.3)	0.0 (0.0, 21.8)	0.5 (0.8)	16.9 (28.3)	46.5
Processed Meat	9.5 (20.4)	0.0 (0.0, 11.5)	0.3 (0.6)	18.9 (29.5)	38.1
Condiments & Seasonings	9.4 (10.4)	6.3 (2.0, 13.4)	0.3 (0.3)	0.8 (6.3)	90.5
Other Cereal Products	5.4 (18.6)	0.0 (0.0, 0.0)	0.2 (0.6)	0.0 (0.0)	12.7
Chocolate Products	4.5 (6.3)	2.0 (0.0, 6.8)	0.1 (0.2)	0.0 (0.0)	64.5
Butter	4.1 (8.2)	0.0 (0.0, 5.1)	0.1 (0.3)	22.7 (34.6)	34.5
Soft Drinks	4.0 (34.8)	0.0 (0.0, 0.0)	0.1 (1.0)	0.0 (0.0)	4.2
Fortified Wines, Liqueurs & Spirits	3.8 (14.2)	0.0 (0.0, 0.0)	0.1 (0.4)	0.0 (1.5)	20.2
Other Protein-based Products	1.6 (13.5)	0.0 (0.0, 0.0)	0.1 (0.4)	1.0 (8.2)	2.0
Nuts, Seeds & Olives	1.6 (6.2)	0.0 (0.0, 0.0)	0.0 (0.2)	6.4 (18.7)	14.3
Cream, Fatty Sauces & Other Fats	1.3 (5.8)	0.0 (0.0, 0.0)	0.0 (0.2)	1.2 (7.9)	12.8
Vegetables	0.8 (8.2)	0.0 (0.0, 0.0)	0.0 (0.3)	0.1 (1.7)	1.4
Salty Snacks	0.6 (4.6)	0.0 (0.0, 0.0)	0.0 (0.1)	0.0 (0.0)	3.7
Tea	0.5 (15.1)	0.0 (0.0, 0.0)	0.0 (0.5)	0.0 (0.0)	0.1

[1] Food subgroups are ordered by their mean gram contribution of total fermented foods and ingredients (from recipes and composite foods) in each food subgroup. Food subgroups with no fermented foods or ingredients or no consumers are not shown (Water; Fruit; 100% Fruit & Vegetable Juices, Tuber Products; Pasta & Rice; Milk; Red Meat; Other Unprocessed Meat; Fish & Seafood; Vegetable Oil; Added Sweeteners; Cakes, Desserts & Ice cream; Other Sweet Products; Other Alcohols; Artificial Sweeteners).
[2] Dietary intake was estimated for 2057 participants.
[3] Proportion of total fermented foods and ingredients (from recipes and composite foods) in each food subgroup was estimated relative to the total food intake (3465.6 g/d).
[4] Proportion of total fermented foods and ingredients (from recipes and composite foods) with live microorganisms was estimated relative to the fermented foods and ingredients intake (from recipes and composite foods) in each food subgroup.
[5] Participants who reported consuming fermented foods or ingredients in at least one of the 2 24-h dietary recalls by food subgroup were considered consumers.

"Vegetables" were consumed in higher amounts by individuals in the German-speaking region compared with the French-speaking region. Intake of "Yogurt & Fresh Cheese" was also greater in the German-speaking region than in the Italian-speaking region. For fermented foods, individuals in the German-speaking region consumed higher amounts of "Coffee" and "Bread Products" compared with both the French- and Italian-speaking regions.

Nutrient intake from foods with live microorganisms and fermented foods

We analyzed the intake of 36 nutrients derived from foods with live microorganisms (Table 5) and fermented foods and ingredients, excluding fermented ingredients from composite food items (Table 6). The MedHi foods provided 12.3% (265.2 kcal/d) of the total energy intake and contributed 36.1% of the β-carotene intake (1006.8 μg/d), 35.4% of β-carotene activity (1070.8 μg-BCE/d), 34.4% of vitamin A activity (231.8 μg-RE/d), 27.1% of all-trans retinol equivalents (115.9 μg-RE), 27.1% of calcium (300.5 mg/d), 26.1% of vitamin C (28.0 mg/d), 22.1% of folate (57.6 μg/d), 21.9% of SFAs (8.1 g/d), and 21.0% of vitamin B12 (0.8 μg/d). Fermented foods provided 27.0% (615.9 kcal/d) of the total energy intake and contributed 37.7% of the calcium intake (429.2 mg/d), 37.1% of all-trans retinol equivalents (162.7 μg-RE/d), 34.8% of chloride (1569.3 mg/d), 33.0% of sodium (1002.0 mg/d), 32.4% of phosphorus (457.2 mg/d), 32.3% of starch (39.3 g/d), 31.4% of vitamin B12 (1.0 μg/d), 31.2% of SFAs (11.8 g/d), and 30.3% of zinc (3.5 mg/d).

Microbiota of fermented foods by food subgroup

A total of 186 microorganisms were identified across 6 taxonomic levels in both the conservative and broad core microbiota classifications, highlighting the complexity of microbial communities present in fermented foods. These included 1 biovar, 6 strains, 7 subspecies, 108 species, 63 genera, and 1 order of microorganisms.

Under the conservative core microbiota classification, a total of 55 genera were identified in fermented foods consumed by the

TABLE 5
Energy and nutrient contribution of MedHi foods.

Nutrient	Amount [1]		% daily [2]	Nonmissing values, % [3]	
	Mean (SD)	Median (P25, P75)	Mean (SD)	MedHi foods	All foods
Energy, kJ/d	1107.0 (900.2)	931.7 (475.2, 1523.3)	12.2 (8.9)	100	100
Energy, kcal/d	265.2 (216.1)	222.4 (113.3, 364.3)	12.3 (8.9)	100	100
Fat, total, g/d	14.54 (14.99)	10.70 (4.14, 20.15)	15.8 (13.1)	100	100
Fatty acids, saturated, g/d	8.14 (8.51)	5.90 (2.15, 11.59)	21.9 (17.0)	100	99.0
Fatty acids, monounsaturated, g/d	3.74 (4.14)	2.74 (0.98, 5.13)	12.0 (11.4)	100	98.9
Fatty acids, polyunsaturated, g/d	0.99 (1.12)	0.72 (0.35, 1.29)	8.9 (7.9)	100	98.9
Cholesterol, mg/d	40.3 (43.7)	28.3 (10.0, 55.5)	15.3 (14.9)	99.4	99.3
Carbohydrates, g/d	20.42 (19.59)	16.42 (3.66, 30.03)	10.1 (10.2)	100	100
Sugars, total, g/d	19.54 (18.90)	15.56 (3.33, 28.85)	19.2 (17.4)	99.2	99.5
Starch, g/d	0.43 (1.88)	0.10 (0.00, 0.26)	0.6 (2.4)	99.7	98.5
Dietary fibers, g/d	3.60 (3.52)	2.58 (1.01, 5.19)	16.9 (13.5)	100	99.9
Protein, g/d	11.45 (10.90)	8.77 (3.93, 15.76)	14.3 (11.4)	100	100
Water, g/d	216.66 (174.08)	183.25 (87.02, 303.05)	7.4 (5.8)	100	99.8
Vitamin A activity, RE, μg-RE/d	231.8 (205.6)	179.5 (90.7, 322.7)	34.4 (20.8)	97.7	84.7
All-trans retinol equivalents, μg-RE/d	115.9 (127.5)	81.8 (26.1, 164.4)	27.1 (21.5)	98.1	89.9
Beta-carotene activity, μg-BCE/d	1070.8 (1475.3)	615.0 (243.8, 1298.1)	35.4 (23.9)	99.8	98.6
Beta-carotene, μg/d	1006.8 (1306.6)	607.2 (244.6, 1219.3)	36.1 (23.9)	99.8	98.0
Thiamine, mg/d	0.093 (0.088)	0.073 (0.037, 0.122)	9.2 (7.6)	100	98.6
Riboflavin, mg/d	0.279 (0.240)	0.229 (0.101, 0.395)	19.5 (13.9)	100	98.6
Pyridoxine, mg/d	0.184 (0.148)	0.155 (0.081, 0.249)	13.2 (9.7)	100	98.6
Vitamin B12, μg/d	0.779 (4.535)	0.477 (0.169, 0.880)	21.0 (18.8)	100	97.9
Niacin, mg/d	0.967 (1.016)	0.692 (0.320, 1.287)	7.6 (7.1)	99.9	98.0
Folate, μg/d	57.56 (47.30)	47.13 (25.09, 78.28)	22.1 (13.8)	99.9	98.3
Pantothenic acid, mg/d	0.656 (0.502)	0.556 (0.284, 0.900)	14.8 (10.5)	99.4	97.8
Vitamin C, mg/d	28.01 (35.13)	17.41 (7.25, 35.79)	26.1 (20.4)	100	98.7
Vitamin D, μg/d	0.32 (0.43)	0.22 (0.09, 0.43)	16.8 (16.9)	99.0	97.5
Vitamin E activity, mg-ATE/d	1.458 (1.514)	1.111 (0.569, 1.908)	11.4 (9.6)	100	98.3
Potassium, mg/d	458.1 (366.9)	384.6 (192.0, 635.7)	16.0 (10.9)	100	99.0
Sodium, mg/d	296.98 (350.05)	185.29 (65.35, 419.00)	10.1 (10.1)	100	99.0
Chloride, mg/d	424.5 (474.9)	276.9 (116.6, 596.9)	10.2 (9.6)	96.8	96.8
Calcium, mg/d	300.47 (304.48)	225.85 (93.99, 409.10)	27.1 (18.1)	99.8	98.7
Magnesium, mg/d	31.20 (24.14)	26.55 (13.87, 42.62)	10.3 (7.2)	99.3	98.5
Phosphorus, mg/d	241.5 (223.3)	189.7 (84.1, 329.7)	17.3 (12.4)	100	97.2
Iron, mg/d	0.87 (0.73)	0.70 (0.38, 1.16)	9.6 (7.3)	100	97.2
Iodide, μg/d	14.81 (14.27)	11.21 (5.29, 20.00)	16.9 (12.9)	96.8	96.0
Zinc, mg/d	1.53 (1.50)	1.15 (0.53, 2.07)	14.5 (11)	98.3	96.8

Abbreviations: ATE, alpha-tocopherol equivalent; BCE, beta-carotene equivalent; RE, retinol equivalent.
[1] Nutrient amounts from MedHi foods, containing $>10^4$ CFU/g, were estimated for 2057 participants (Consumers = 98.2%).
[2] Proportion of each nutrient from MedHi foods was estimated relative to the total nutrient intake from all foods.
[3] Proportion of nonmissing values for macro- and micronutrients, based on the availability of estimates in the Swiss Food Composition Database.

TABLE 6
Energy and nutrient contribution of fermented foods and ingredients from recipes.

Nutrient	Amount [1]		% daily [2]	Nonmissing values, % [3]	
	Mean (SD)	Median (P25, P75)	Mean (SD)	FFs	All foods
Energy, kJ/d	2572.9 (1648.0)	2302.8 (1395.5, 3388.7)	26.9 (12.9)	100	100
Energy, kcal/d	615.9 (394.1)	551.7 (334.4, 809.8)	27.0 (12.9)	100	100
Fat, total, g/d	22.46 (18.84)	18.06 (9.05, 30.81)	24.0 (15.2)	100	100
Fatty acids, saturated, g/d	11.83 (10.43)	9.24 (4.42, 16.31)	31.2 (18.4)	96.0	99.0
Fatty acids, monounsaturated, g/d	6.30 (5.66)	4.86 (2.37, 8.52)	19.4 (14.2)	95.9	98.9
Fatty acids, polyunsaturated, g/d	2.00 (1.61)	1.63 (0.90, 2.67)	17.8 (12.5)	95.9	98.9
Cholesterol, mg/d	58.4 (51.8)	46.4 (21.7, 80.8)	21.9 (16.9)	99.6	99.3
Carbohydrates, g/d	53.41 (41.02)	44.0 (25.6, 71.4)	23.2 (13.9)	100	100
Sugars, total, g/d	11.56 (11.80)	8.00 (2.54, 17.05)	11.7 (11.4)	99.3	99.5
Starch, g/d	39.30 (36.27)	30.82 (13.96, 54.41)	32.3 (21.8)	99.7	98.5
Dietary fibers, g/d	4.36 (3.65)	3.50 (1.76, 6.06)	21.5 (14.3)	100	99.9
Protein, g/d	24.03 (17.00)	20.38 (11.80, 31.57)	29.5 (15.7)	100	100
Water, g/d	537.47 (393.61)	464.78 (268.64, 702.12)	18.2 (12.1)	100	99.8
Vitamin A activity, RE, µg-RE/d	169.2 (161.8)	130.6 (52.9, 236.9)	25.4 (18.1)	86.4	84.7
All-trans retinol equivalents, µg-RE/d	162.7 (154.2)	126.0 (53.0, 226.3)	37.1 (22.5)	88.4	89.9
Beta-carotene activity, µg-BCE/d	81.6 (73.6)	64.5 (28.0, 113.7)	6.3 (7.9)	95.4	98.6
Beta-carotene, µg/d	87.2 (77.0)	69.8 (31.6, 120.0)	6.9 (8.3)	95.4	98.0
Thiamine, mg/d	0.241 (0.217)	0.189 (0.089, 0.325)	21.0 (14.1)	95.9	98.6
Riboflavin, mg/d	0.40 (0.28)	0.346 (0.197, 0.546)	27.7 (14.8)	95.9	98.6
Pyridoxine, mg/d	0.322 (0.254)	0.269 (0.150, 0.418)	21.4 (12.9)	95.9	98.6
Vitamin B12, µg/d	0.964 (0.834)	0.753 (0.368, 1.336)	31.4 (21.5)	95.8	97.9
Niacin, mg/d	3.160 (3.015)	2.352 (1.232, 4.037)	21.6 (14.0)	95.8	98.0
Folate, µg/d	43.02 (34.89)	35.40 (20.59, 56.40)	17.8 (11.6)	94.8	98.3
Pantothenic acid, mg/d	0.873 (0.567)	0.768 (0.464, 1.168)	19.7 (11.2)	95.8	97.8
Vitamin C, mg/d	2.89 (6.88)	0.93 (0.04, 3.09)	3.5 (6.6)	95.9	98.7
Vitamin D, µg/d	0.40 (0.37)	0.31 (0.14, 0.55)	21.9 (18.7)	94.3	97.5
Vitamin E activity, mg-ATE/d	1.408 (1.362)	1.007 (0.517, 1.893)	11.6 (9.8)	94.9	98.3
Potassium, mg/d	514.9 (342.0)	457.0 (287.4, 675.2)	18.6 (10.0)	95.9	99.0
Sodium, mg/d	1002.04 (743.20)	847.64 (484.72, 1321.33)	33.0 (17.4)	95.9	99.0
Chloride, mg/d	1569.3 (1145.0)	1341.3 (766.8, 2080.3)	34.8 (17.5)	94.3	96.8
Calcium, mg/d	429.18 (397.36)	322.63 (169.59, 560.08)	37.7 (18.8)	94.8	98.7
Magnesium, mg/d	81.82 (55.11)	71.01 (43.63, 105.49)	25.5 (12.7)	95.8	98.5
Phosphorus, mg/d	457.2 (324.9)	381.2 (237.0, 603.1)	32.4 (15.4)	95.9	97.2
Iron, mg/d	2.01 (1.62)	1.61 (0.86, 2.79)	20.2 (13.2)	95.8	97.2
Iodide, µg/d	22.14 (17.84)	17.73 (9.68, 30.49)	24.3 (15.0)	91.5	96.0
Zinc, mg/d	3.45 (3.47)	2.73 (1.48, 4.33)	30.3 (16.3)	94.7	96.8

Abbreviations: ATE, alpha-tocopherol equivalent; BCE, beta-carotene equivalent; FF, fermented food and ingredients (from recipes); RE, retinol equivalent.

[1] Nutrient amounts from fermented foods and ingredients (from recipes but not composite foods) were estimated for 2057 participants (consumers = 99.9%).

[2] Proportion of each nutrient from fermented foods and ingredients (from recipes) was estimated relative to the total nutrient intake from all foods.

[3] Proportion of nonmissing values for macro- and micronutrients, based on the availability of estimates in the Swiss Food Composition Database.

participants in the menuCH survey (Figure 1). Among the 35 food subgroups, 21 included fermented foods. The subgroup with the highest number of genera was "Condiments & Seasonings" ($n = 24$), followed by fermented dairy products, including "Yogurt & Fresh Cheese" ($n = 12$), "Soft Cheese" ($n = 16$), and "Hard Cheese" ($n = 11$). The lowest number of genera were identified in the subgroups "Other Cereal Products," "Salty Snacks," "Soft Drinks," and "Beer & Cider." Of the 55 genera, the majority (64%) belonged to the domain Bacteria, whereas the remaining genera (36%) belonged to the domain Eukaryota, kingdom Fungi. Within Fungi, 3 genera were classified as molds and 17 as yeasts. The most frequently identified genera across all fermented food items were *Saccharomyces* ($n = 11$), *Lactococcus* ($n = 7$), and *Leuconostoc* ($n = 7$). The broad classification also captures additional genera such as Weissella in "Vegetables" and "Nuts, Seeds & Olives," Torulaspora in "Bread Products" and "Coffee," and Rhizopus in "Coffee" (Supplemental Table 1).

Discussion

Our study presents a comprehensive diet classification that allowed for the first assessment of live microorganism levels and fermented foods consumed in Switzerland.

We observed a mean intake of foods containing Med or Hi levels of live microorganisms at 269.3 g/d, representing 8.0% of the total gram intake in this Swiss adult population. This intake is notably higher than that reported in a similar study conducted in the United States [9], where adults aged ≥19 y consumed 127 g/d of MedHi foods. However, the United States study did not report the total gram intake, making comparisons of relative intakes impossible. For fermented foods, our estimates indicated a total intake of 717.1 g/d, accounting for 21.0% of the total gram intake. This figure exceeds the proportions reported in the Dutch adult population [21], where the intake was 16%–18%, and in Japanese adults [22], where the intake was 438 g/d or

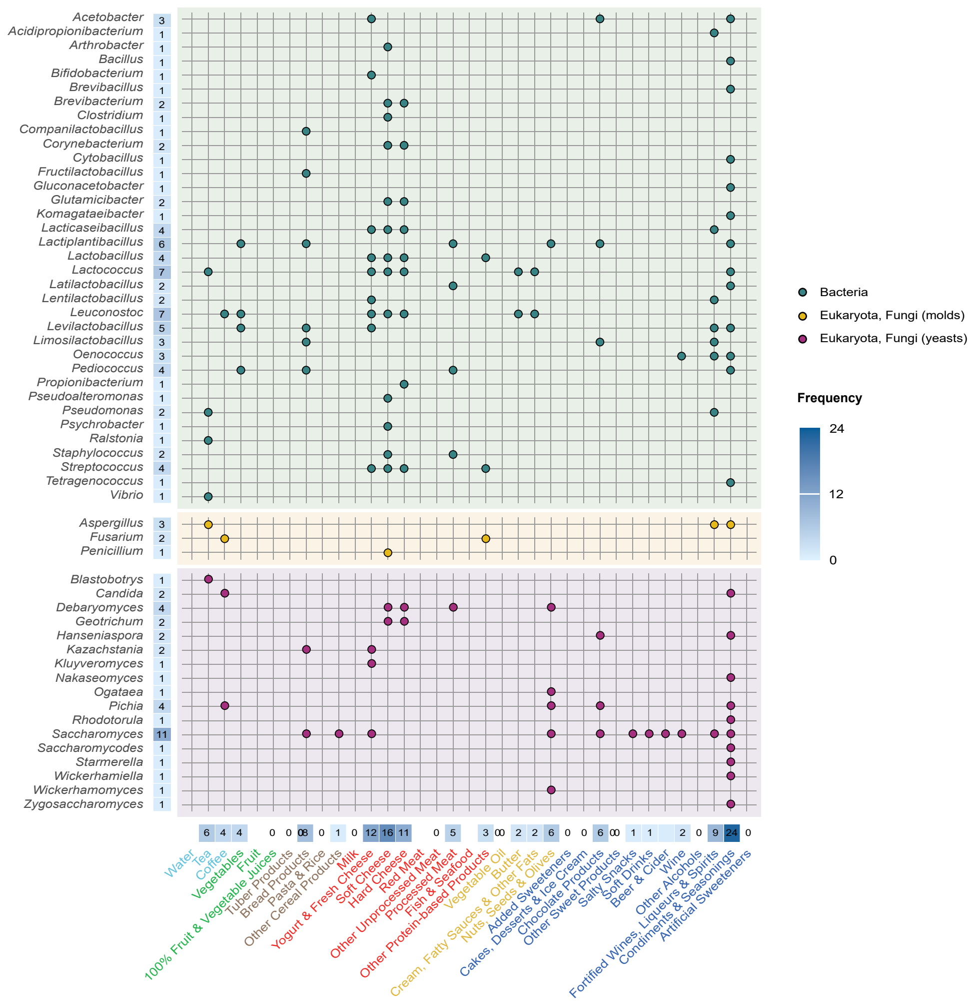

FIGURE 1. Diversity of microorganisms at the genus level in fermented foods and ingredients consumed by the participants in the menuCH survey, based on the conservative core microbiota classification. Each bubble indicates that the genus was identified in at least 1 food item within the respective food subgroup. The numbers on the x-axis indicate the number of genera identified in each food subgroup, whereas the numbers on the y-axis represent the number of food subgroups containing the genus. Food subgroups are adapted from the Swiss Food Pyramid, with colors representing the food groups in the Pyramid.

17% of the total gram intake. Nevertheless, it is important to note that the Dutch study did not assess the proportion of fermented ingredients in composite foods, likely resulting in an underestimation of the total intake of fermented foods and ingredients.

The main food subgroups contributing to MedHi intake in our study included fruit, vegetables, and fermented dairy products. Although MedHi foods accounted for only 12.3% of the total energy intake, they contributed to the intake of several nutrients, providing >20% of β-carotene, vitamins A, C, B12, and folate, as well as calcium and SFAs. On the other hand, the main subgroups contributing to fermented food intake were coffee, bread products, alcoholic beverages, and fermented dairy. Fermented foods accounted for 27.0% of the total energy intake while contributing >30% of daily calcium, sodium, vitamins A and B12, starch, SFAs, phosphorus, and zinc. Interestingly, despite potential cultural differences in food habits, the most consumed food subgroups of MedHi foods and fermented foods in our study were similar to those identified in studies conducted in the United States, the Netherlands, and Japan [9,21,22].

In our study, demographic and regional differences in the intake of live microorganisms and fermented foods are worth noting. For example, females had a higher intake of foods with live microorganisms but a lower intake of fermented foods than males and older individuals consumed more live microorganisms and fermented foods compared with younger individuals. These findings reflect the importance of how age, sex, and cultural factors shape dietary patterns and, ultimately, health outcomes. Notably, we observed regional differences in the types of foods consumed, for example, with individuals in the German-speaking region consuming more coffee and bread than in the French- or Italian-speaking regions. Understanding these regional and demographic variations can offer insights into how future public health strategies might be tailored to promote live microorganisms and fermented food consumption across different population groups.

The strengths of the present study include the comprehensive annotation and description of the Swiss diet, incorporating levels of live microbes and fermented food descriptors, including proportions of fermented ingredients and the core microbiota of fermented foods. Another strength is that we analyzed the data from a nationally representative sample of Swiss adults based on 2 detailed 24-h dietary recalls. To our knowledge, this is the first study to integrate the live microbe level categorization and fermented food descriptors and to classify the microbiota of fermented foods consumed within the context of a whole diet. We also provided the first estimate of the intake of these foods in the Swiss adult population.

However, there were challenges in classifying and analyzing the menuCH data due to the low dietary data resolution when it came to annotating foods with live microorganism levels and fermented food descriptors. Although menuCH was the only nationally representative, population-based dataset in Switzerland available for this study, it was not originally designed to capture the usual food intake at the individual level (only 2 recorded days per person) nor the specific details necessary for the classification of these foods. Consequently, for certain foods, we had to make assumptions based on average foods on the Swiss market when precise dietary information was lacking. Additionally, a large proportion of unique food items (22.4%) were captured in the menuCH dataset as composite foods containing fermented ingredients. Estimating the proportions of these ingredients—by evaluating FCDBs, ingredient lists, and published recipes—helped produce more accurate estimates of fermented food consumption and is important for future investigation of their health effects. However, relying on average formulations was often necessary. Although the menuCH survey remains the only comprehensive, nationally representative dietary dataset currently available for Switzerland, we acknowledge that dietary habits may have evolved since 2014–2015. A more recent survey would be valuable to confirm and extend these findings.

To classify the levels of live microorganisms in foods, we used categories (Low, Med, Hi, and MedHi) rather than assigning a CFU/g count to each food. Despite the broad categories, this approach has successfully identified associations between live microorganism intake and health outcomes [10–16]. Furthermore, we generally adopted a more conservative approach when assigning levels of live microorganisms, which may have underestimated the levels for some food items. For instance, we assigned a Low level to dried and peeled fruit and vegetables. Recent studies on apples, however, showed that the pulp and seeds harbor similar levels of microorganisms as the peel [40], and after processing, such as boiling or air drying, microbial counts are reduced, but a fraction of the microbiota survives [41].

Similarly, for the microbiota of fermented foods, we estimated the core microbiota based on an extensive literature review and consultations with industry experts, alongside known production methods. However, the actual microbiota present in foods might differ and should be confirmed in future studies, using advanced microbiological methods such as metagenomics and 16S rRNA sequencing to identify and quantify the specific microbial communities present in foods. For example, a recent Swedish study using sequencing techniques to classify the microbial composition of 47 fermented foods identified discrepancies between expected and actual microbial content, including the absence of *Lactobacillus delbrueckii* subsp. *bulgaricus*, a bacterium commonly used in yogurt [42].

Ultimately, further efforts should aim to refine FCDBs to capture the microbial profiles of foods, allowing to estimate whether populations consume adequate amounts of beneficial live microbes should a recommended daily intake be established [17,43]. This is particularly important in the context of Western diets, where the increased consumption of ultraprocessed foods has progressively reduced gut microbiota diversity [1]. Moreover, the variability in gut microbial composition among individuals suggests that dietary recommendations may need to be tailored to individual microbiomes [44–46].

In the future, integrating information on live microorganisms from both fermented and nonfermented foods into dietary assessment tools and FCDBs will be essential to evaluating their associations with health outcomes in both observational and intervention studies. This includes not only characterizing microbial load but also taxonomic composition—including species- and strain-level diversity—fermentation characteristics and the presence of bioactive metabolites. As evidence builds, dietary live microbes and fermented foods could be considered in national dietary guidelines, including in the context of personalized nutrition.

In conclusion, this study provides a first estimate of the intake of live microorganisms and fermented foods in Switzerland, which, given its multicultural setting, provides relevant information for neighboring countries, such as Germany, France, and Italy. Several observational studies support the idea that beneficial dietary live microbes likely contribute positively to human health [10–20]. Our findings, however, highlight the importance of these foods not only as sources of live microorganisms but also as major contributors to nutrient intake. Next, addressing the limitations of current FCDBs and further exploring the health impacts of live microorganisms and fermented foods will be essential to better understand their role in human health and disease prevention.

Author contributions

The authors' responsibilities were as follows – KJB, GV, MB, EP: designed the project and assigned fermented food descriptors to menuCH foods and ingredients; MK, EP: assigned live microbes levels to menuCH foods and ingredients; KJB, EP: prepared menuCH data for analysis, estimated proportions of fermented ingredients in composite food items among menuCH foods and ingredients, and assigned cooking status to menuCH recipes; EH, UvA: retrieved fermented food microbiota taxonomy; EH: developed the fermented food microbiota figure; JH, UvA: consulted on the microbiota of selected fermented food items; AC: consulted on the menuCH survey; EP: annotated the menuCH data with descriptors of live microbes and fermented foods, analyzed the data, prepared Supplemental Table 1, and wrote the manuscript; GV, MB, EH: revised the manuscript; EP: had primary responsibility for the final content; and all authors: read and approved the final manuscript.

Conflict of interest

The authors report no conflicts of interest.

Funding

Funding for this study was provided by Agroscope, the Federal Office for Agriculture (FOAG), the Federal Department of Economic Affairs, Education and Research (EAER) (Bern, Switzerland) for the Metabolic Nutrient Profiling Project.

Data availability

Availability of the data described in the manuscript is subject to application and approval. The data source is the Federal Food Safety and Veterinary Office (Bern, Switzerland): menuCH National Nutrition Survey 2014/15. The complete classification table of 1519 unique foods and beverages (with an extract illustrated in Supplemental Table 1), including descriptors of live microorganism levels and fermented foods, contains individual brand information that cannot be published for contractual reasons. Access to the full classification can be granted upon request under conditions that comply with the contractual agreement with the data supplier.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT (version 4) to assist in refining selected sections of the manuscript for readability. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tjnut.2025.05.042.

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