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Probiotic-fermented food consumption and dietary outcomes among children, adolescents, and young adults: a systematic review

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Systematic Review

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Abstract

This study aimed to conduct the first known systematic review concerning the evidence on probiotic-fermented food consumption among the young population across multiple countries and its dietary outcomes, including diet quality and nutrient intakes. Five databases were searched through December 8, 2025: Web of Science, Scopus, OVID Medline, EBSCO CINAHL, and ProQuest. English-language quantitative studies from 2004 to 2025 were included. Eligible studies reported probiotic-fermented food consumption patterns in youth aged 2–24 years and examined associations with dietary quality and nutrient intakes. Initial searches identified 11,844 records, of which twelve studies met the inclusion criteria. Included studies originated predominantly from high-income countries in North America and Europe, with limited representation from Africa and Asia. Consumption patterns varied widely, with both children and adolescents consuming probiotic-fermented foods at least once a week and having fewer daily servings, particularly for yogurt. Of the seven studies that examined dietary outcomes, six reported positive associations between consumption of probiotic-fermented foods and improved dietary quality scores, and six studies reported associations with higher nutrient intakes. The review underscored the need to increase the consumption of probiotic-fermented foods among the younger population to improve nutrient intake in the early stages. Further research is needed in under-represented regions, including Southeast Asia, Latin America, Africa, and the Middle East, where fermented food traditions are culturally significant but population-level consumption data among youth remain scarce.

Introduction

The gut microbiota balance in children and adolescents is vital for their optimal health. These microorganisms are majorly involved in nutrient absorption, building up immunity to defend against gastrointestinal and degenerative illnesses later in life.[1,2] Poor dietary habits at times of great growth and development may bring an imbalance of the digestive microorganisms that leads to dysbiosis, a condition recognised as a gateway for specific non-communicable diseases such as obesity, type 2 diabetes, and metabolic syndrome among the young population.[3–5] Considering that dietary patterns are formed during childhood and adolescence, encouraging the consumption of gut-supportive and nutritionally adequate foods is essential for achieving good health in the short and long term.

Probiotic-fermented foods deliver health in many ways. Fermentation increases the bioavailability of vitamins and minerals.[6,7] It enhances protein and carbohydrate digestion.[8–10] Other benefits include helping the immune system,[11,12] developing the brain,[13] and fighting infections.[11] Also, it has been found that fermentation decreases antinutrient factors, such as phytates, oxalates, tannins, and lectins, so that it may make those nutrients more available, which are very much required during fast growth among children and teenagers.[7,8,14] Probiotic-fermented foods are widely consumed globally and have been associated with a range of health benefits. Kimchi, a Korean vegetable-based fermented food, has demonstrated anti-obesity and antioxidative properties.[15,16] Tempeh, an Indonesian plant-based fermented protein, has been associated with cognitive function support and antidiabetic properties.[17,18] Natto, a Japanese fermented soybean product, contains bioactive compounds with reported anticancer and antibacterial activity.[19] Kefir, a fermented drink produced from kefir grains, generates bioactive compounds that enhance immune function.[20] Dairy-based fermented products, such as yogurt, have also been shown to contribute to bone health.[21,22] These benefits are consistent with evidence from observational studies and dietary surveys demonstrating that fermented food intake is positively associated with higher dietary quality and nutrient intake among adults,[23–25] suggesting that similar associations may exist among younger populations.

While a growing body of evidence supports the health benefits of probiotic-fermented foods, most of this evidence derives from clinical trials examining the effects of probiotic supplements[26–

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[28] rather than habitual dietary intake. As a result, there remains limited understanding of the types, amounts, and frequencies of probiotic-fermented food consumed as part of the everyday diet among children and adolescents. Furthermore, the extent to which regular probiotic-fermented food consumption is associated with dietary quality and nutrient intakes in the young population remains poorly characterised in the existing literature. This information is required to compare the present level of intake with that in studies where a health effect was demonstrated, and also whether any observed relationship between intake of probiotic-fermented food and diet quality extends to the younger population. Without such data, it is challenging to develop evidence-based dietary guidelines or effective nutrition interventions for children and adolescents.

This systematic review aimed to address the following research question: What are the consumption patterns of probiotic-fermented foods among individuals aged 2–24 years, and how are these patterns associated with dietary quality and nutrient intakes? Specifically, this review sought to determine: (1) what types are consumed more regularly or less frequently among different age populations; (2) in what quantities and how frequently; and (3) the relationship between fermented food intake, diet quality, and nutrient intake. Clinical research has demonstrated that probiotic-fermented food consumption offers a range of health benefits. However, it remains unclear whether these clinically established benefits are reflected in population-level dietary patterns, specifically whether habitual probiotic-fermented food consumption among children and adolescents is associated with improved diet quality and nutrient intakes. This review therefore aims to bridge this gap by synthesising evidence on consumption patterns and their dietary associations in younger populations. These findings advance culturally relevant dietary recommendation interventions that evaluate whether or not probiotic-fermented foods might advance as a nutrition-improving strategy among children and adolescents.

Method

This systematic review examines global dietary patterns of fermented probiotic foods and their association with diet quality, while adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.[29] This review was registered in the International Prospective Register of Systematic Reviews database (PROSPERO) under registration number CRD42024502476 on January 27, 2024. The protocol has also undergone substantial amendment during the study. Originally, this systematic review included all age populations and was conducted from January 2024 to May 2025. After the supervisor's review in September 2025, the population scope was narrowed to children, adolescents, and young adults aged 2–24 years to align with the doctoral research focus on adolescent populations. This update was applied in the October 2025 manuscript revision, and PROSPERO registration updating was done in December 2025. The final search took place on December 8, 2025, to make sure that the search would be up to date within three months of manuscript submission. The adjustment was based on doctoral research programme coherence, not on preliminary findings. Full protocol development is documented in PROSPERO. The review title was refined before submission to more precisely specify the population subgroup and primary outcomes; the research questions, eligibility criteria, and methodology remained unchanged. AI language tools were used to assist with language editing and manuscript formatting.

Search strategy and study screening

A comprehensive literature search was carried out in five electronic databases: Web of Science, Scopus, OVID Medline, ProQuest, and EBSCO Medline (CINAHL), covering publications up to May 9, 2025, and updated on 8 December 2025. Eligible studies were quantitative, published in English, and focused on:

1. Types of probiotic-fermented foods, as defined by the International Scientific Association for Probiotics and Prebiotics (ISAPP)[12] and listed in global probiotic food databases.[30]
2. Dietary patterns involving probiotic-fermented foods.
3. Associations between probiotic-fermented food consumption and diet quality.

The search strategy was purposely broad to ensure comprehensive identification of all relevant studies. We also included those with mixed-age populations that might report subgroup data for the target population. Search terms were combined involving concepts of: (1) Probiotic-fermented foods (e.g. 'probiotic*', 'fermented food*', 'yogurt', 'kefir', 'kimchi', 'tempeh', 'fermented milk'); (2) Consumption or intake patterns (e.g. 'consumption', 'intake', 'dietary pattern*', 'eating habit*', 'diet*'). No age-restriction terms were included in the search strategy to maximise sensitivity and avoid missing studies that might report relevant subgroup data. We limited the year from 2004–2025 as a starting point due to pivotal developments in probiotic research, including the FAO/WHO Expert Consultation (2001),[31] the Working Group on Guidelines for Probiotics (2002),[32] and the first ISAPP meeting,[33] which laid the foundation for standardised probiotic research. Complete search strategies for each database are provided in Appendix A. Screening was conducted using Covidence software and by email, with two reviewers (RN and HL) independently assessing each stage.

The eligibility criteria

Eligibility criteria were established a priori using the PICOS framework (Population, Exposure, Comparator, Outcome, and Study Design), which informed both the overarching research question of this review and the systematic guidance of study selection, as detailed below:

- Population: Studies involving healthy individuals aged 2–24 years, in line with WHO and the Indonesian National Population and Family Planning Board (BKKBN) classifications. Studies were included if they focused on children, adolescents, or young adults, or a broader population but presented a specific subgroup analysis with separate data for children and/or adolescents and/or young adults.
- Exposure: Included studies assessed consumption of probiotic-fermented foods, considering type, eating occasion, frequency, portion size, and diversity. Dietary intake was measured using validated tools such as 24-h dietary recalls, food records, or FFQs. Eligible food types were based on established probiotic food databases.[30]
- Outcome: Studies were included if they examined consumption patterns of probiotic-fermented foods, including types of foods, frequency, and portion/serving size. Where available, associations with nutrient intake, such as macronutrient and micronutrient intake, and diet quality were also assessed. Diet quality was defined through dimensions such

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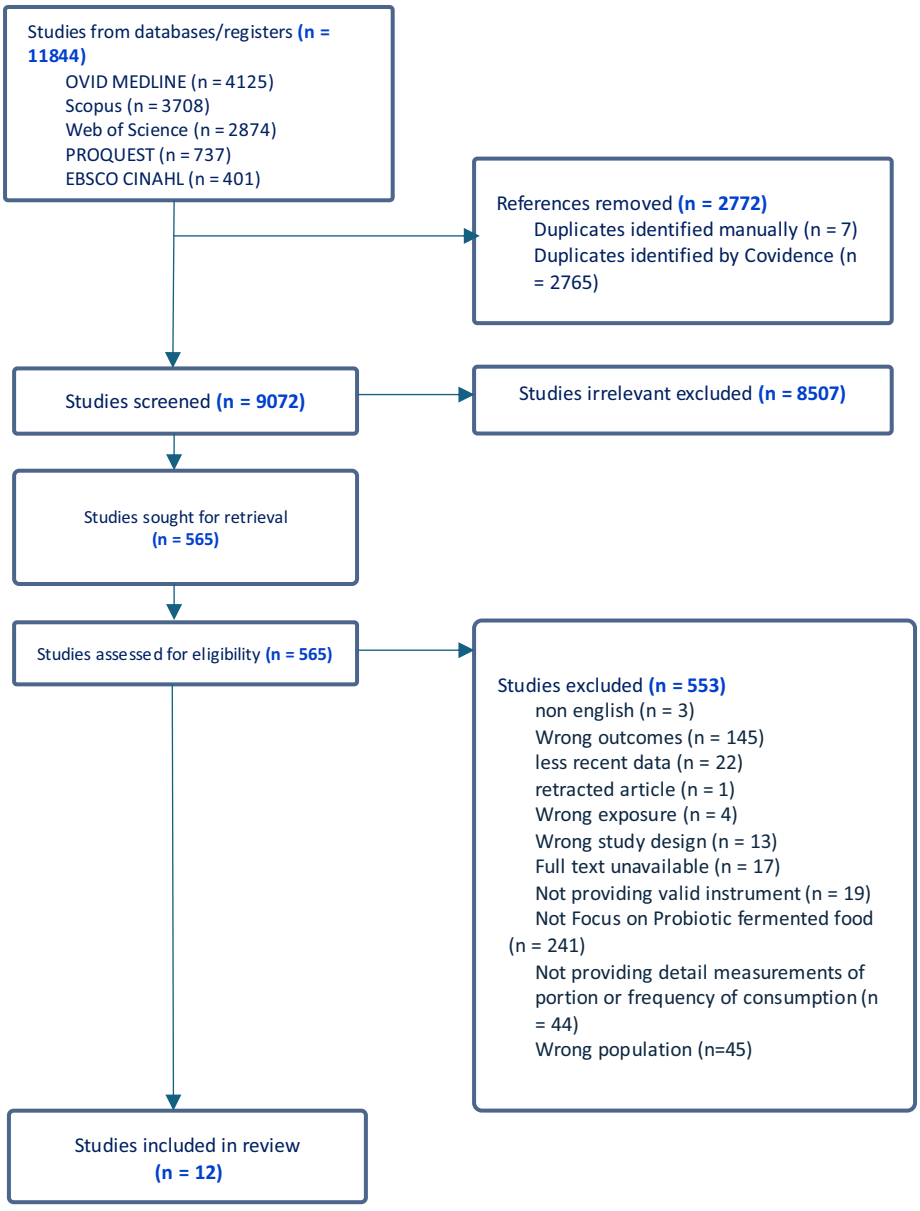


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of the screening process.

as diversity, adequacy, moderation, and balance, and measured using validated instruments such as the Healthy Eating Index (HEI), Diet Quality Indices (DQI), or inferred from detailed dietary intake data.[34,35]

- Study Design: Included studies were cross-sectional, prospective, or retrospective cohort designs, as these best reflect real-world dietary patterns. Experimental studies were excluded due to controlled conditions that do not represent habitual intake. Qualitative studies were also excluded due to limitations in quantifying portion sizes and frequency.

Exclusion criteria

Exclusion criteria were applied consistently across all screening stages. At the title and abstract screening stage, studies were excluded if they were deemed irrelevant to the research topic based on the predefined eligibility criteria. This screening was conducted using Covidence systematic review software. Excluded materials included experimental studies, reviews, letters, editorials, abstracts without full text, commentaries, magazine articles, and non-empirical studies. Studies focusing solely on probiotic supplements, non-fermented probiotic food products, or probiotic strains without a fermented food context were omitted. Non-English publications and studies published before 2004 were excluded. Reasons for exclusion at the full-text stage are documented in the PRISMA flow diagram (Figure 1) with aggregate counts by primary exclusion reason.

Data extraction

Two reviewers independently extracted data using a standardised data extraction form developed in Microsoft Excel by the authors. Extracted information included:

(i) Author and publication year, (ii) Country and participant characteristics (including sample size), (iii) Study design, (iv) Type of probiotic-fermented food, and (v) Findings related to consumption patterns and associations with diet quality. Data were compiled in Excel, and discrepancies were resolved by a third reviewer.

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Quality assessment

Study quality was independently assessed by two reviewers using the Joanna Briggs Institute (JBI) critical appraisal tool for cross-sectional studies,[36] and the Newcastle–Ottawa Scale (NOS) for cohort studies.[37] Cross-sectional studies scoring ≥5 'yes' responses and cohort studies with ≥6 'stars' were considered high quality. Detailed scores are provided in Appendix B.

Data synthesis

Included studies were synthesised using narrative methods and presented in summary tables (Tables 1 and 2) based on study characteristics, participant demographics, and outcomes. Study selection was documented via PRISMA flow diagram (Figure 1). Meta analysis was not appropriate due to substantial heterogeneity in study populations, type of probiotic-fermented food examined, dietary assessment methods, and outcome measures; therefore, narrative synthesis was employed. Findings are presented by type of probiotic-fermented food: dairy-based, soy-based, fruit-based, vegetable-based or other; then by participant category, for example, age group; finally, by consumption pattern information such as portion size and frequency, including mealtime. Consumption data were presented in the original units and formats reported by study authors (e.g. grams per day [g/day], servings per week [servings/week], percentage consuming, frequency categories), as measures varied substantially across studies and could not be meaningfully standardised. For papers that provided results for more than one age subgroup meeting our inclusion criterion, data were extracted and presented separately, thereby maintaining valuable detail on an age-specific basis. For dietary outcome measures, we extracted statistics as reported (correlation coefficients, regression coefficients, odds ratios, mean differences) without transformation. Formal publication bias assessment was not planned due to the narrative synthesis approach and anticipated limited number of studies. Missing data (e.g. SDs, CIs, specific subgroup data) were not imputed or calculated; we reported only statistics provided in original publications and noted data limitations where relevant. We did not contact study authors for additional data. Evidence linking fermented food consumption to diet quality was presented separately. Formal sensitivity analysis was not conducted; study quality was considered in the interpretation of findings.

Results

Study selection and characteristics of the included studies

This systematic review synthesised existing global evidence on consumption patterns of probiotic-fermented foods among young populations, including frequency of intake and portion sizes. Where reported, associations between probiotic-fermented food intake and overall diet quality.

From five databases, a total of 11,844 records published between 2004 and 2025 were identified. After removing duplicates, titles, and abstracts, 9,072 articles were screened, of which 8,507 were excluded as irrelevant. The remaining 565 full-text articles were assessed for eligibility, of which 12 studies met the inclusion criteria. The complete screening and selection process is presented in the PRISMA flow diagram (Figure 1).

Of the 12 included studies, 9 employed cross-sectional designs and three used prospective cohort designs, with sample sizes ranging from 280 to 65,799 participants (see Table 1). Eight studies were conducted in European countries: the UK,[38,39] Portugal,[40–42] Italy,[43] Spain,[44] and Poland[45]; three in North American countries: Canada[46] and the USA[47,48]; and one in an East Asian country: China.[49]

Quality assessment of the involved study

Quality appraisal revealed generally high methodological rigour across the included studies. For cross-sectional studies ($n = 9$), assessment using the JBI Critical Appraisal Checklist showed that all studies[38–41,43,46–49] met all eight quality criteria (score 8/8). Cohort studies ($n = 3$) were evaluated using the NOS, with all of the three studies[42,44,45] achieving the maximum score of 8 stars, demonstrating robust methodological quality in participant selection, comparability of cohorts, and outcome assessment (see Appendix B). We did not conduct a formal assessment of publication bias due to narrative synthesis and limited studies ($n = 12$).

Associations with diet quality

As shown in Table 2, six studies[38,39,43,46–48] have demonstrated positive relations between probiotic-fermented food consumption and diet quality. Additionally, six[38–40,46–48] of seven studies revealing the association with relevant nutrient intake have shown that higher intakes of probiotic foods were correlated with higher intakes of fruits and vegetables and better profiles of nutrients.

For example, Portuguese adolescents who consumed yogurt and cheese showed increased carbohydrate and fibre intake and reduced fat intake.[40] Consistently, in the USA, yogurt consumers had higher intakes of calcium, fibre, potassium, magnesium, and vitamin D.[47] Similarly, UK children who regularly consumed yogurt showed a higher intake of various vitamins and minerals.[38] Collectively, these findings indicate that individuals who regularly consume probiotic-fermented foods tend to have healthy overall dietary patterns.

Probiotic-fermented food consumption pattern

All 12 studies examined dairy-based probiotic-fermented foods, with yogurt being the most frequently examined product. Two studies included a broader range of fermented foods, such as milk and vegetable-based probiotic-fermented foods, such as pickled cucumber,[42,45] pickling juice, sauerkraut, fermented vegetables.[42]

Across studies, 30–50% of participants were classified as regular consumers (2–6 times per week), 20–45% as occasional consumers (<1–2 times per week), and 15–30% as daily consumers. Among yogurt consumers, daily intake varied considerably across studies and age groups, ranging from as low as 9.10 g/day in older Italian children[43] to 150 ± 3 g/day among children and adolescent consumers in the USA,[47] with the majority of children consuming below the estimated minimum of 100 g/day associated with meaningful probiotic benefit.[50,51]

Age-stratified consumption patterns

Early childhood (2–6 years)

A study conducted in Italy indicated that children aged 2–6 years consumed an average of 22.82 g/day of yogurt, with 0.55–4.5 g/day as mid-morning snacks and 3.7–15.4 g/day as afternoon snacks.[43] UK data indicated that among children aged 4–10 years, yogurt was consumed 14% at breakfast, 32% at lunch, and 18% at dinner.[38] Mean yogurt intake in this population ranged from 19 ± 8 g/day in the lowest tertile (T1) to 98 ± 36 g/day in the highest tertile (T3).[38] In comparison, Canadian children aged 2–5 years

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Table 1. Characteristics of the included studies

No	Author and year	Country	Participants	Study design	Type of probiotic-fermented food	Assessment method/ data collection tools	Consumption patterns		
							Serving (number, size)	Frequency	Mealtime
Dairy-based									
1	Lopez-Garcia, 2015[44]	Spain	4,445 individuals aged >15 years	Prospective Cohort	Dairy-based: Yogurt	Validated computerised diet history	34.8% never consume, 36.2% consume 1–3 servings/mo-6 serving/week, 28.9% consume ≥1 serving/day; >50% women consume1 serving/mo-≥/ day (1 serving ~ 125 g)	NR	NR
2	Tsai et al., 2022[49]	China	2,819 schoolchildren aged 11–12 years	Cross-sectional	Dairy-based: Yogurt and fermented probiotic drinks	SQ-FFQ-71 food item	Yogurt (52% rare/never consume, 48% consume 1 cup/day, 0.1% >=2 cups/ days; fermented probiotic drinks (37% rare/never consume, 63% consume 1–2 cups/day, 0.5% consume ≥3 cups/day)	NR	NR
3	Abreu et al., 2014[40]	Portugal	494 adolescents aged 15–18 years	Cross-sectional	Dairy-based: Milk, yogurt, cheese	SQ-FFQ	Median yogurt intake 55.57 g/day; cheese intake 12.86 g/day	NR	NR
4	Zhu et al., 2015[48]	USA	5,124 children aged 2–18 years	Cross-sectional	Dairy-based: Yogurt	Intake: FFQ diet quality: HEI-2005	NR	**Frequent consumers** 32% consume at least once per week): 2–11 years (65.6%) 12–18 years (34.4%) The median frequency: 2 times per week; **Infrequent consumers:** 68% consume <1 time per week) 2–11 years (42%) 12–18 years (58%) Frequency consumption: 1–6 times per year	NR

(*Continued*)

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Table 1. (*Continued*)

No	Author and year	Country	Participants	Study design	Type of probiotic-fermented food	Assessment method/ data collection tools	Consumption patterns		
							Serving (number, size)	Frequency	Mealtime
5	Cifelli et al., 2020[47]	USA	65,799 general population aged ≥2 years	Cross-sectional	Dairy-based: Yogurt	Intake:24-h diet recall; Diet quality: HEI-2015 scores	6.4% children (2–18 years) mean intake 150 ± 3 g/d and 5.5% adult consume yogurt mean intake 182 ± 3 g/d	NR	NR
6	Vatanparast et al., 2019[46]	Canada	20,487 general population	–	Dairy-based: Yogurt	Intake: 24-h dietary recall Diet quality: The Nutrient-Rich Foods (NRF) Index 9.3	Mean consumption: **2 years and over** (0.77 ± 0.02 serving/day), **Children (2–5 years**): 0.79 ± 0.03 serving/day, **6–12 years**: 0.84 ± 0.04 serving/day **13–18 years**: 0.75 ± 0.04 serving/day **Adults (19–54 years**: 0.75 ± 0.03 serving/day) **Older adults** (≥55 years: 0.76 ± 0.03 serving/day (1 serving size for yogurt ~ 175 g)	20% consume on any given day	**Yogurt consumers**: 37% ± 1.9% consume at a snack occasion, 32% ± 1.3% consume at breakfast, 25.5% ± 2.4% consume at lunch, 13.9 ± 0.8% consume at dinner
7	Sousa et al., 2022[41]	Portugal	311 University student	Cross-sectional	Dairy-based: Cheese, yogurt	FFQ of dairy product consumption	NR	Ripened cheeses: 58.6% consume 2–4 times/week; Drinking yogurt: 39.8% consume 2–4 times/week, 12.8% consume 1 serving/day; Set yogurt: 34.1%, consume 2–4 times per week, 8.4% consume 1 serving/day; Ripened cheeses: 15.2% consume 1 serving/day.	NR

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Table 1. (*Continued*)

8	Iglesia et al., 2020[43]	Italy	8807 children aged 2–9,9 years (T0); 5,085 aged 2–10 years (T1), 1991 aged <10-> = 10 years (T3)	Cross-sectional	Dairy-based: yogurt and cheese	24-h dietary recall, FFQ, and the DQI	Yogurt consumption T0: boys aged 2–6y consumed 22.82 g/day, T1 boys 2–6y consumed 31.75 g/d, T3 boys aged <10y consumed 11.15 g/day and >= 10y consumed 9.10 g/d Cheese consumption T0: boys aged 2–6y consumed 4.66 g/d, aged 6–10y consumed 5.19 g/d, T1: boys 2–6y consumed 6.11 g/d, T3: boys <10y consumed 3.52 g/d and >= 10y consumed 3.3 g/d Yogurt consumption T0: girls aged 2–6y consumed 20.49gr/day,T1 girls 2–6y consumed 24.79 g/d, T3 girls aged <10y consumed 12.73gr/day and >= 10y consumed 9.35 g/d Cheese consumption T0: Girls aged 2–6y consumed 4.89 g/d, aged 6–10y consumed 4.54 g/d, T1: boys 2–6y consumed 6.17 g/d, T3: boys <10y consumed 4.39 g/d and >= 10y consumed 3.27 g/d	NR	Children consumed yogurt 0.55–5.45 g/d as mid-morning snack, 3.73–15.45 g/d for mid afternoon snack and 3.0–11.05 g/d for after dinner snack
9	Hobbs et al., 2019[38]	UK	1687 children aged 4–10 and 11–18 years	Cross-sectional	Dairy-based:	Intake: 4-d diet diary Diet quality: HEI 2010	The mean (±standard deviation) consumption: **4–10-year-olds** T1: 19 ± 8 g yogurt/day in T3: 98 ± 36 g yogurt/day **11–18-year olds** T1: 20 ± 8 g yogurt/d T3: 105 ± 36 g yogurt/day	NR	C**hildren aged 4–10**: 32% consume at lunch 18% at dinner 14% at breakfast 13% at evening snack, 12% at afternoon snack 11% at morning snack **Children aged 11–18**: 26% consume at lunch 18% at dinner, 18% at evening snack 14% at morning snack 13% at breakfast 11% at afternoon snack
10	Zhu et al., 2021[39]	UK	1,912 children and 2,064 adults	Cross-sectional	Dairy-based: Yogurt	4-d food diaries	**Regular eaters (>4d):** Children: 343.4 g and Adult: 488.6 g **Occasional eaters**: Children: 143.5 g Adult: 173.7 g	Children: 52% yogurt consumers: 36% are occasional eaters, 16% are regular eaters. Adults: 25% are occasional eaters, 14% are regular eaters	NR

(*Continued*)

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Table 1. (*Continued*)

No	Author and year	Country	Participants	Study design	Type of probiotic-fermented food	Assessment method/ data collection tools	Consumption patterns		
							Serving (number, size)	Frequency	Mealtime
11	Karbownik et al., 2022[45]	Poland	372 medical students	Prospective Cohort	Dairy-based: Yogurt, kefir, kvass, cheese, soured milk, Fruit/Vegetable-based: pickled cucumber, pickling juice, sauerkraut, fermented vegetables, unpasteurised beer	7-d dietary record	Mean consumption of cheese 173 g/ week; yogurt, kefir, soured milk 425.9 g/ week; kvass and unpasteurised beer 52.4 g/week; pickled cucumber and pickling juice 72.8 g/week, sauerkraut 33 g/week; fermented vegetables 7.6 g/ week	NR	NR
12	Dobielska et al., 2025[42]	Poland	280 medical students	Prospective Cohort	Dairy-based: yogurts, kefir,sour milk and sour cream, Vegetable-based: pickled vegetables,		The mean daily intake of fermented food was 102.48 g. Group of yogurts, kefir,sour milk and sour cream were consumed: 220.03 g/ day (mean) Group of pickled vegetables: 6.94 g/day (mean)		

NR: Not Reported.

consumed yogurt at a mean of 0.79 servings/day, equivalent to 138.25 g/day.[46]

School age (7–12 years)

In China, 52% of children aged 11–12 never consumed yogurt, while 48% consumed probiotic drinks regularly.[49] Italian boys aged 6–10 years consumed 11.15 g/day, and girls consumed 12.73 g/day, representing lower yogurt consumption compared to the younger age group. This declining trend continued, with even lower consumption observed in children older than 10 years.[43] Meanwhile, Canadian children (6–12 years) consumed 0.84 ± 0.01 servings/day (~147 g/day), with significant variation by age subgroups.[46]

Early adolescence (13–15 years)

UK adolescents aged 11–18 years consumed 20 ± 8 g/day (T1) to 105 ± 36 g/day (T3), showing increased intake compared to younger children aged 4–10 years.[38] This pattern was contrary to findings in Italian children, where yogurt and cheese consumption decreased with increasing age.[43]

Late adolescence (16–18 years)

Portuguese adolescents had a median yogurt intake of 55.57 g/ day.[40] While Canadian adolescents (13–18 years) consumed 0.75 servings/day (131.25 g/day).[46] Spanish data revealed that 34.8% of adolescents never consumed yogurt, with only 28.9% consuming ≥1 serving daily.[44] In the USA, infrequent consumers (68%, <1 time per week) were more likely to be adolescents aged 12–18 years (58%) compared to the younger group (2–11 years), suggesting declining consumption with age.[48]

Young adulthood (>18–24 years)

A Polish study reported diverse fermented food consumption, including mean weekly consumption of cheese (173 g), soured milk (425.9 g), kvass and unpasteurised beer (52.4 g), pickled cucumber and pickling juice (72.8 g), sauerkraut (33 g), and fermented vegetables (7.6 g), alongside yogurt and kefir consumption.[45] Among Portuguese university students, 58.6% consumed ripened cheeses 2–4 times/week, with 15.2% consuming them daily, while yogurt was consumed by 39.8% of students 2–4 times/week and 13.8% daily. Similarly, set yogurt was consumed by 34.1% of students 2–4 times/week and 8.4% daily.[41] Polish medical students reported a mean intake of 220.03 g/day of dairy-based fermented foods, including yogurt, kefir, sour milk, and sour cream.[42]

Consumption adequacy relative to recommendations

Current guidelines recommend a daily probiotic intake of 10^7–10^9 colony-forming units (CFU) to confer health benefits,[12,50] a threshold estimated to be achievable through consumption of at least 100–200 g/day of yogurt,[51–53] consistent with national food-based dietary guidelines across multiple countries, including the USA,[54] Canada,[55] Australia,[56] and European nations,[57] which specify standard yogurt serving sizes ranging from 125 to 200 g/ day. Based on these recommendations, the review identified the following patterns:

Children: adequate portion sizes but low prevalence

The USA children aged 2–18 years reported a mean intake of 150 ± 3 g/day, exceeding recommended levels among consumers.[47] Similarly, Canadian children reported adequate mean intakes, with

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Table 2. Summary of research studies on probiotic fermented foods and their impact on nutrient intake and diet quality

No	Author and year	Data collection tools	Findings	
			Food/Nutrient intake outcome	Link with diet quality (+/−)
1	Abreu et al., 2014	SQ-FFQ	Yogurt consumers had higher carb and fibre intake, while cheese eaters consumed more fat and fewer carbs.	NSM
2	Zhu et al., 2015	Intake: FFQ Diet quality: HEI-2005	Frequent yogurt users had higher total fruit, whole fruit, whole grain, and milk.	(+) Higher diet quality (HEI-2005) ($P = 0.04$) among yogurt consumer
3	Cifelli et al., 2020	Intake: 24-h diet recall Diet quality: HEI-2015	Yogurt consumers consume more calcium, fibre, potassium, magnesium, and vitamin D.	(+) Higher diet quality (HEI-2015) scores among yogurt consumer
4	Vatanparast et al., 2019	Intake: 24-h dietary recall: Diet quality: The NRF Index 9.3	Yogurt consumers had higher fibre, carbohydrate, vitamin, and mineral intakes.	(+) Higher nutritional density of the diet among yogurt consumer
5	Iglesia et al., 2020	Intake: 24-h dietary recall, FFQ, Diet quality: DQI.	NSM	(+) Higher scores of DQI.among yogurt consumer ($p < 0.001$), or cheese consumer ($p < 0.001$)
6	Hobbs et al., 2019	Intake: diet diary Diet quality: HEI 2010	4–10-year-old yogurt eaters had higher nutrient intakes but lower fat and sodium intake. 11–18-year-old yogurt consumers showed increased intake of various vitamins and minerals.	(+)
7	Zhu et al., 2021	4-d food diaries	The consumption of yogurt was found to have a positive correlation with thiamine, riboflavin, vitamin C, potassium, calcium, magnesium, phosphorus, and iodine, in both children and adults (all $P < 0.0018$).	(+) The frequency of yogurt consumption in children ($p = 0.045$) and adults ($p < 0.001$) was correlated with diet quality.

NSM: Not Specifically Measured.

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those aged 2–5 years consuming 138 g/day and those aged 6–12 years consuming 147 g/day.[46] These quantities surpass the estimated 100 g/day probiotic threshold.[51–53] However, these adequate portion sizes were limited by the low population-level prevalence of yogurt consumption. In the USA, only 6.4% of children regularly consumed yogurt.[47] In Canada, prevalence varied considerably by age group, with 46.9% of children aged 2–5 years and 29.5% of those aged 6–12 years consuming yogurt on any given day.[46]

Adolescents: mixed adequacy and low prevalence

Among Canadian adolescents aged 13–18 years, average yogurt intake was 131 g/day, approaching recommended levels, though only 14% reported consumption.[46] In contrast, Portuguese adolescents had a median intake of 55.57 g/day, representing just 30% of the minimum recommended amount.[40] UK adolescents demonstrated variable portion sizes ranging from 20 ± 8 g/day to 105 ± 36 g/day across different consumption groups, with only the higher consumption group approaching adequate levels.[38]

Young adults: adequate portion sizes and moderate prevalence

The Polish medical students' average daily intake of 220.03 g of dairy-based fermented foods[42] exceeded the recommendation,[12,53] suggesting adequate probiotic exposure among this population. This study also found lower consumption of pickled vegetables other than cucumbers and cabbage, averaging only 6.94 g per day.[42] This pattern was similar with findings from the broader Polish population study, which also demonstrated relatively low consumption of fermented vegetables (7.6 g/week or approximately 1.1 g daily), sauerkraut (33 g/week or 4.7 g daily), and pickled cucumber (72.8 g/week or 10.4 g daily), while showing higher soured milk consumption averaging approximately 60.8 g per day (425.9 g weekly) alongside other fermented foods.[45] Both Polish studies thus revealed a consistent trend of higher dairy-based fermented food consumption compared to vegetable-based fermented products among young adults. Regarding the frequencies, the Portuguese university students demonstrated that the majority consumed fermented dairy products 2–4 times weekly rather than daily, and only a minority reported daily intake (13.8–15.2% across different products), suggesting that most participants likely did not meet the recommended daily probiotic intake consistently.[41]

Nutrient intake and diet quality associations

Seven studies examined the relationship between probiotic-fermented food consumption and nutritional outcomes, consistently revealing positive associations:

- ***Macronutrient Intake***

Consumers of probiotic yogurt demonstrated higher intakes of energy, protein, and fibre across multiple studies.[40,46] Portuguese adolescents who consumed yogurt and cheese had elevated carbohydrate and fibre intake, alongside reduced fat consumption, compared to non-consumers.[40]

- ***Micronutrient Intake***

In the USA, yogurt consumption was associated with significantly higher intakes of calcium, fibre, potassium, magnesium, and vitamin D.[47] UK children and adolescents who consumed yogurt also had higher levels of essential vitamins and minerals.[38] Additional findings from the UK indicated increased intake of thiamine, riboflavin, vitamin C, and minerals such as potassium, calcium, magnesium, phosphorus, and iodine among yogurt consumers.[39] Canadian yogurt consumers similarly showed improved intake of fibre, vitamins, and minerals.[46]

- ***Diet Quality***

Six studies were conducted in which the standardised indices were used to assess overall diet quality. Significantly higher HEI scores among frequent yogurt consumers than non-consumers in American youth were reported ($p = 0.04$).[48] Another US study indicated increased HEI scores for yogurt consumers.[47] A higher DQI score among Italian children and adolescents who are regular consumers of either yogurt or cheese has been found, with a $p < 0.001$ for both groups.[43] A positive correlation between the frequency of consumption of yogurt and quality of diet has been found in two UK studies, one among children and another equivalent study on adults, with $p = 0.001$, $p < 0.001$, respectively.[39] Canadian yogurt consumers showed higher nutritional density of their overall diet.[46]

Discussion

To our knowledge, the present study is the first systematic review of existing global evidence on probiotic-fermented food consumption patterns among young people and examining its association with nutrient intakes and diet quality. Existing evidence syntheses in this field have predominantly focused on adult populations and examined health outcomes such as mortality risk,[58] or gastrointestinal wellbeing.[59] Individual cross-sectional studies have examined yogurt consumption and nutrient intake in specific countries,[38,46] but no systematic review has comprehensively addressed consumption patterns and their dietary association across this age group at a global scale. Across the included studies, yogurt emerged as the most consistently studied probiotic-fermented food, with consumption patterns varying considerably across countries and age groups, reflecting differences in food culture, dietary traditions, and food availability and accessibility. The included studies were predominantly from European nations, which should be considered when interpreting the generalisability of these findings to another global context.

Age-related consumption patterns and developmental considerations

The consumption patterns across the included studies consistently revealed a gap between actual probiotic-fermented food intake and the quantities estimated to confer meaningful health benefits. While no specific intake recommendation exists for probiotic-fermented food, international criteria classify foods as probiotics if they contain a minimum of 10^7 CFU per gram or millilitre.[50] The Codex Alimentarius (CODEX STAN 243-2003), an international food standard established by the FAO and WHO, stipulates a minimum of 10^7 CFU per gram for yogurt starter cultures.[60] Yogurt intake of 125–250 g/day is estimated to provide 10^7–10^9 CFU, consistent with the national dietary guideline benchmarks from multiple countries,[54–57] suggesting that achieving recommended probiotic intake through diet is feasible when yogurt is habitually consumed at adequate portion sizes.[50,51]

In this review, consumption among the young population falls below the recommended levels. Eating a variety of probiotic-fermented foods daily might be a better way to reach the recommended levels. However, based on the most popular probiotic

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foods, like yogurt, the intake was considerably low. Italian children aged 2–6 years consumed only 22.82–31.75 g/day of yogurt,[43] which is insufficient to deliver the necessary beneficial bacteria.[61] In the UK,[38,39] children eat yogurt every day, between ¼ and ¾ cup (19–98 g) per day. These numbers are lower than those for children in the USA.[47] Considering that regular probiotic intake has been linked to better digestive health, stronger immune systems, and improved nutrient absorption in young people,[62,63] these low consumption rates showed that many children would potentially be missing out on the benefits that could improve their health.

Beyond childhood, data from the adolescent population across multiple countries included in this review revealed a decline in probiotic-fermented food consumption with increasing age. This age-related decline is consistent with evidence from dietary surveys documenting a general deterioration in diet quality during the transition from childhood to adolescence.[64] This condition is characterised by reduced consumption of nutrient-dense food and increased intake of energy-dense, nutrient-poor alternatives.[65] The consistent decline observed across various countries in this review indicates that developmental factors may be influencing adolescent food choices away from probiotic foods. As teenagers grow up, their food choices change from being guided by their parents to being influenced by their friends.[66] Their taste preferences also change to favour energy-dense, highly palatable foods.[67] This change happens at the same time as the feeling of being healthy and invulnerable that comes with being a teenager. This makes foods that are marketed as healthy less appealing.[68,69]

This review found that overall consumption patterns remain concerning. While yogurt consumers among Canadian children aged 2–12 years reported adequate mean intakes of 138–147 g/day, the overall prevalence of consumption remained low across all child age groups, ranging from 29.5% to 46.9%.[46] Similarly, in Portugal,[40] over 60% of adolescents consume yogurt below the median, which is still below the recommended daily intake. This low consumption is about 1/3–1/2 of a serving size, which is slightly less than the recommended amount of at least 1 serving per day or a minimum of 100 g per day. This is particularly concerning given that adolescence is a critical period for establishing lifelong dietary habits. It is important to acknowledge that while individual probiotic-fermented food items showed low consumption, total probiotic intake may be higher when multiple sources are consumed collectively throughout the day. However, none of the included studies assessed cumulative probiotic intake from diverse food sources, limiting our understanding of overall probiotic food consumption patterns among youth. Insufficient intake of probiotic foods during this stage may contribute to suboptimal nutrient intake, particularly for nutrients such as vitamin B, calcium, iron, and potassium, which are often lacking in adolescent diets.[70,71]

A Polish study has shown that people eat a variety of fermented foods such as cheese (173 g per week), soured milk (425.9 g), kvass, unpasteurised beer, pickled vegetables, and fermented drinks like yogurt and kefir.[45] A separate study among Polish medical students revealed higher dairy-based fermented food consumption, averaging 220.03 g per day across yogurt, kefir, sour milk, and sour cream, though pickled vegetables other than cucumbers and cabbage remained low at only 6.94 g per day.[42] This suggests that while medical students consumed substantial amounts of dairy-based fermented foods, the pattern of lower vegetable-based fermented food intake was consistent with the broader Polish population. Meanwhile, Portuguese university students demonstrated limited intake. There were 58.6% of students who consumed ripened cheeses 2–4 times weekly, while drinking yogurt was consumed by only 39.8% and set yogurt was consumed by 34.1%. The daily consumption for these foods is only 13.8% and 8.4%, respectively.[41] However, taking probiotic foods frequently does not ensure adequate intake of probiotics, as clinical trials demonstrating the health benefits typically employ daily doses of 10^9–10^{11} CFU.[72] It means that adequate intake of probiotics requires consistent consumption of substantial portions, generally 100–150 g daily of a probiotic product containing at least 10^6 CFU/ml. The Portuguese pattern of predominantly 2–4 times weekly consumption is particularly problematic because research on colonisation indicates that beneficial bacteria do not permanently establish in the gut; rather, continuous intake is necessary to maintain elevated levels.[41,73]

Irregular consumption may not sustain the gut microbiota alterations associated with health outcomes documented in the intervention study. Without daily consumption of specific probiotic-rich foods in adequate quantities, the health benefits observed in control trials, including reduced gastrointestinal infections, improved immune response, and better metabolic outcomes[74–76] are unlikely to be achieved in everyday life outside of clinical settings. Furthermore, considering most yogurt consumption among young people is below the recommended daily intake, diverse routine consumption of probiotic-fermented foods may contribute significantly towards meeting overall dietary recommendations or meeting the minimum number of live bacteria that people should consume.

Probiotic foods and nutritional outcomes: association with nutrient intake and diet quality improvements

Six of the seven studies demonstrated the association between probiotic-fermented foods and improved diet quality scores.[38,39,43,46–48] Six studies[38–40,46–48] showed associations with higher nutrient intakes. This pattern suggests that probiotic-fermented foods may serve as a marker of overall dietary patterns rather than only providing beneficial bacteria to consumers. Studies from Canada, the USA, Italy, and the UK all reported that consumers of probiotic yogurt and fermented foods had higher intakes of key nutrients compared to non-consumers. A study involving American adolescents who regularly consumed demonstrated higher total fruit, whole fruit, whole grain, and milk consumption, reflected in better HEI scores.[48] A similar pattern was revealed from the US population, which showed that yogurt consumers had a higher intake of fibre, calcium, magnesium, potassium, and vitamin D.[47] Furthermore, a greater proportion of yogurt consumers achieved the recommended intake levels than those who did not consume yogurt.[47] Those are aligned with Canadian yogurt consumers demonstrating higher fibre, carbohydrate, vitamin, and mineral intakes according to the Nutrient-Rich Foods (NRF) Index 9.3.[46] The UK data also showed a similar finding, showing that 4–10-year-old yogurt consumers had higher nutrient intakes and lower fat and sodium consumption. In addition, 11–18-year-old yogurt consumers showed increased intake of various vitamins and minerals but not necessarily reduced intake of less healthful nutrients.[38]

Mechanisms underlying the associations

The relationship between probiotic-fermented food consumption and diet quality appears to be multifactorial. Several mechanisms may explain such associations:

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1. Substitution effect: Fermented foods substitute for a less nutritious option it replaces. For example, yogurt replaces energy-dense snacks like chips or confectionery since it is a meal consumed in some countries; this improves dietary quality[77,78]
2. Satiety and Macronutrient Composition: Fermented dairy products often contain higher levels of protein and fat, which may enhance satiety and reduce the likelihood of consuming less healthy foods.[79]
3. Health-Conscious Behavior: Individuals who consume probiotic-fermented foods may exhibit greater nutrition awareness and motivation to maintain a healthy lifestyle, predisposing them to broader dietary choices.[80] Evidence from a population-based study specifically examining fermented dairy consumption supports this notion, finding that higher intakes of fermented dairy products were positively associated with greater health consciousness, better diet quality scores, and clustering of other positive dietary behaviours.[25]

Beyond these behavioural mechanisms, the nutritional composition of fermented foods itself may independently contribute to improving dietary quality. Probiotic-fermented foods from dairy products provide not only viable probiotic microorganisms, but also are rich in bioavailable micronutrients, including vitamins A, B1, B2, B3, B5, B6, B9, B12, and D, as well as calcium, phosphorus, potassium, magnesium, and zinc.[81–83] Acidity and fermentation change the amount of vitamins, while lactic acid is very important for calcium absorption, stopping harmful bacteria from growing, and intestinal secretion.[21] It is also known that fermented probiotic foods made from plants have free amino acids, vitamins, soluble dietary fibre, and bioactive compounds.[84]

The positive association between probiotic-fermented food consumption and higher nutrient intake observed across the included studies was predominantly driven by dairy-based probiotic foods, particularly yogurt. This finding is supported by an Australian study of children aged 8–10 years who consumed more than two servings of dairy had higher intakes of multiple nutrients and were more likely to meet recommendations.[85] Similarly, the South East Asian Nutrition Surveys (SEANUTS) II, involving 10,299 children aged 2–12 years, found that higher dairy consumption was associated with higher nutrient intake, particularly for vitamin A, B2, B12, D and calcium.[86]

The association observed in this review may also be explained through gut-mediated biological mechanisms. Probiotic microorganisms delivered through fermented foods modulate gut microbiota composition, promoting the production of SCFAs, including acetate, propionate, and butyrate, through bacterial fermentation of dietary fibre.[87] SCFAs stimulate the release of satiety hormones, particularly glucagon-like peptide-1 (GLP-1) and peptide YY (PYY), which regulate appetite and energy intake.[88] These hormonal signals may therefore contribute to more favourable dietary behaviours and food choice among habitual consumers of probiotic-fermented foods. Furthermore, the partial hydrolysis of lactose during yogurt fermentation improves its tolerability for individuals with lactase deficiency,[89] a condition prevalent among children and adolescents in Asian and African populations,[90] thereby facilitating greater dairy intake and enhancing the bioavailability of key nutrients including calcium, vitamin D, and vitamin B12[10] in populations where dairy consumption has traditionally been limited.

The public health implications are massive if fermented foods cluster with the consumption of other healthy dietary intakes. Promoting the intake of these foods can be an easy way to promote general dietary improvement. Studies in children have indicated that early introduction of such foods will assist in the accretion of better dietary habits.[43] Carrying this benefit into teenage and young adult years would also require a specific intervention since these age groups attain more autonomy in their food choices, thereby disrupting previously inculcated healthy patterns.

Limitation and strength

This review has several important limitations. First, restricting inclusion to studies published after 2004 may have excluded earlier relevant research. However, this cutoff was intentionally selected to align with the emergence of standardised probiotic definitions and guidelines, ensuring consistency in the studies reviewed. Second, the narrow diversity of probiotic foods examined represents a major limitation. Most studies focused exclusively on dairy-based products (primarily yogurt and cheese), limiting the capture of global probiotic-fermented food consumption, particularly traditional non-dairy fermented foods prevalent in Asian, African, and Latin American contexts. Furthermore, studies assessed individual probiotic food sources rather than cumulative daily intake, which may underestimate total probiotic exposure. Third, geographic bias is evident, with all included studies originating from high-income countries in North America and Europe; only two studies examined other regions, and neither captured traditional non-dairy fermented food consumption. The absence of data from Southeast Asia, Latin America, and other regions with rich fermented food traditions limits generalisability. Fourth, included studies lacked specificity regarding probiotic strains, yogurt subtypes, and cheese varieties, and microbial composition was not assessed as a factor that may influence the associations observed.

Regarding review methodology, the population scope was refined to 2–24 years following doctoral supervision guidance and was transparently documented in PROSPERO. One included study[44] involved participants aged 15 years and older with no subgroup data specific to young adults. This study was retained for its unique contribution of yogurt consumption pattern data from Spain, and findings should be interpreted with caution. The search was restricted to English-language publications, and substantial heterogeneity across studies precluded meta-analysis synthesis. Although inclusion was not restricted to any specific dietary quality index, eligible studies predominantly employed the HEI, DQI, and NRF, as few studies using other validated indices assessed probiotic-fermented food consumption, limiting the breadth of dietary quality assessments in this review. Publication bias remains a potential limitation.

Future research should address several key gaps identified in this review. Studies examining traditional non-dairy fermented foods in culturally diverse populations, particularly in Southeast Asia, Latin America, and sub-Saharan Africa, are needed to improve the generalisability of findings. Longitudinal and interventional designs are essential to establish the directionality of the observed associations. Comprehensive dietary assessment capturing cumulative probiotic intake from multiple food sources, alongside the use of diverse and culturally validated dietary quality indices, would provide a more accurate picture of probiotic exposure and its dietary associations in younger populations. Finally, mechanistic studies examining gut microbiome changes

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and SCFA production in response to habitual probiotic-fermented food consumption would advance understanding of the biological pathways underlying these associations.

Despite these limitations, this is the first systematic review focusing specifically on probiotic-fermented food consumption among youth ages 2–24 years, employing rigorous PRISMA methodology.

Conclusion

A systematic review of 12 studies was conducted to provide a broad overview of the consumption pattern for probiotic-fermented foods among children, adolescents, and young adults. Some clear patterns were observed about the type of foods being consumed and demographic trends in intake. Yogurt happens to be the main probiotic-fermented food that has been brought under study. There is an absence of traditional non-dairy fermented foods from Asia, Africa, and Latin America in the literature.

The consistent association between probiotic consumption and improved nutrient intake across diverse populations suggests a robust relationship. Consumption frequency was similarly inadequate, with most populations consuming probiotic-fermented foods occasionally, typically a few times per week, rather than daily. Across all countries observed, adolescents consistently demonstrated lower consumption levels than younger children, with the most marked decline observed among older adolescents aged 12–18 years. This age-related decline is particularly concerning given that adolescence represents a critical period for the consolidation of dietary habits that tend to track into adulthood. Insufficient probiotic-fermented food consumption during this formative stage may therefore have lasting implications for long-term dietary quality, nutrient adequacy, and gut health outcomes.

Several critical gaps limit understanding of global consumption patterns. The exclusive focus on dairy-based probiotics means consumption of traditional non-dairy fermented foods remains undocumented, despite their importance in many cultures. Future research should broaden its scope to include non-dairy fermented foods, incorporate populations from underrepresented regions such as Southeast Asia, Africa, and Latin America, and develop standardised tools for cross-cultural dietary assessment. Longitudinal studies are also needed to track consumption trends over time and identify effective, culturally appropriate interventions to support probiotic food intake during adolescence. Furthermore, most included studies employed cross-sectional designs, limiting causal inference. Although three prospective cohort studies provided some evidence of temporal associations, longitudinal interventional studies are needed to definitively establish the directionality of the observed associations between probiotic-fermented food consumption and dietary quality outcomes.

Data availability statement. The data presented in this study are available upon request from the corresponding author.

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Appendices

Appendix A. Search strategy tables

Step	Syntax	Result
1. Web of science (8 December 2025)		
#1	TS=(probiotic)	61,530
#2	TS=(probiotic* OR ferment* near/3 food*)	68,781
#3	TS=(probiotic* OR ferment* near/3 drink*)	61,968
#4	TS=(probiotic* OR ferment* near/3 beverage*)	63,714
#5	TS=(probiotic* OR ferment* near/3 product*)	92,462
#6	TI=(kimch* or yogurt or yoghurt or tempe or tempeh or koumiss or natto or kefir or pickle* or cheese or sauerkraut or kisk)	32,995
#7	TI=(consumption or “consumption pattern*” or “consumption behavior*” or “consumption practice*” or “consumption habit*”)	145,221
#8	TI=(“food habit*” or “food behavior” or “food pattern*” or “food intake” or “food portion” or “food frequency”)	16,698
#9	TI=(diet or “diet* pattern*” or “diet* behavior*” or “diet* practice*” or “diet* habit*” or “diet* quality” or “dietary assessment” or “dietary requirement” or “ diet* diversity”)	197,950
#10	TI=(eating or “eating pattern*” or “eating behavior*” or “eating practice*” or “eating habit*” or “eating portion” or “eating frequency”)	59,402
#11	TI=(intake or “daily intake” or “regular intake” or “habitual intake of nutrient* intake”)	100,600
#12	#1 OR #2 OR #3 OR #4 OR #5 OR #6	128,063
#13	#7 OR #8 OR #9 OR #10 OR #11	493,332
#14	#12 AND #13	4,406
#17	EXCLUDE by doc type (review article or meeting abstract or proceeding paper or early access or editorial material or letter or book chapters or correction or news item or bool review or reprint or note or retracted publication or expression of concern or publication with expression or concern) AND LIMIT by LANGUAGE (ENGLISH) AND LIMIT BY WEB OF SCIENCE CATEGORIES (nutrition dietetics or agriculture dairy animal science or food science or biotechnology applied microbiology or biochemistry or multidisclipinary sciences or chemistry applied or immunology or endocrinology metabolism or pharmacology pharmacy or public environmental occupational health or medicine general internal or medicine research experimental or environmental sciences or chemistry multidisclipinary **or** Oncology **or** Dentistry Oral Surgery Medicine **or** Neurosciences **or** Chemistry Medicinal **or** Infectious diseases **or** Pediatrics **or** Biology **or** Physiology **or** Psychiatry **or** Integrative Complementary Medicine **or** Cardiac Cardiovascular Systems **or** Behavioral Sciences **or** Geriatrics Gerontology **or** Agricultural Economics Policy **or** Plant Sciences **or** Entomology **or** Sport Sciences **or** Allergy **or** Clinical Neurology **or** Green Sustainable Science Technology **or** Agricultural Engineering **or** Economics **or** Obstetrics Gynecology **or** Biochemical Research Methods **or** Biophysics **or** Peripheral Vascular Disease **or** Materials Science Multidisciplinary **or** Urology Nephrology **or** Dermatology **or** Health Care Sciences Services **or** Chemistry Analytical **or** Medicine Legal **or** Anthropology **or** Chemistry Physical **or** Developmental Biology **or** Ecology **or** Environmental Studies **or** Psychology Biological **or** Social Sciences Biomedical **or** Business **or** Business Finance **or** Emergency Medicine **or** Geography **or** Orthopedics **or** Primary Health Care **or**orPsychology Multidisciplinary **or** Reproductive Biology **or** Tropical Medicine **or** Communication **or** Computer Science Theory Methods **or** Engineering Biomedical **or** Ethics **or** Hematology **or** History **or** Literature **or** Management **or** Medical Ethics **or** Medical Informatics **or** Medical Laboratory Technology **or** Nursing **or** Parasitology **or** Pathology **or** Physics Multidisciplinary **or** Rheumatology **or** Social Issues **or** Sociology AND LIMIT BY PUBLICATION YEAR (2004-2025)	**2,874**
2. OVID medline DATABASE (8 December 2025)		
#1	Exp probiotics	25,263
#2	Exp fermented foods/exp fermented beverages	34,176
#3	((probiotic* or ferment*) adj3 food*).ti,ab.	4,475
#4	((probiotic* or ferment*) adj3 drink*).ti,ab.	320
#5	((probiotic* or ferment*) adj3 beverage*).ti,ab.	927
#6	((probiotic* or ferment*) adj3 product*).ti,ab.	12,388
#7	(Kombucha or kefir or yogurt or yoghurt or tempe or tempeh or tapai or tape or kecap or sauerkraut or kimch* or cheese or pickle* or miso or natto or koumiss or kisk or anchovy or doenjang).ti,ab.	35,636
#8	(consumption or “consumption pattern*” or “consumption behavior*” or “consumption practice*” or “consumption habit*”).m_titl.	53,244
#9	(“eating or eating pattern*” or “eating behavior*” or “eating practice*” or “eating habit*” or “eating portion” or “eating frequency”).m_titl	3,381
#10	(food or “food habit*” or “food behavior” or “food pattern*” or “food intake” or “food portion” or “food frequency”).m_titl.	110,868

(*Continued*)

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Appendix A. (*Continued*)

Step	Syntax	Result
#11	(intake or “daily intake” or “regular intake” or “habitual intake” or “nutrient* intake”).m_titl.	55,292
#12	(diet or “diet* pattern*” or “diet* behavior*” or “diet* practice*” or “diet* habit*” or “diet* quality” or “dietary assessment” or “dietary requirement” or “ diet* diversity”).m_titl.	86,680
#13	#1 or #2 or #3 or #4 or #5 or #6 or #7	94,268
#14	#8 or #9 or #10 or #11 or #12	288,398
#15	**#13 AND #14**	8,097
#16	limit 15 to (english language and humans)	5,014
#17	limit 16 to (adaptive clinical trial or case reports or classical article or clinical study or clinical trial, all or clinical trial or comparative study or controlled clinical trial or government publication or journal article or meta analysis or observational study or randomized controlled trial or “systematic review”)	4,901
#18	limit 17 to yr=“2004 – current”	**4,125**
3. SCOPUS (8 December 2025)		
#1	TITLE-ABS-KEY (probiotic*)	81,613
#2	TITLE-ABS-KEY (probiotic* OR ferment* W/3 food*)	14,803
#3	TITLE-ABS-KEY (probiotic* OR ferment* W/3 drink*)	1,388
#4	TITLE-ABS-KEY (probiotic* OR ferment* W/3 beverage*)	4,543
#5	TITLE-ABS-KEY (probiotic* OR ferment* W/3 product*)	48,514
#6	TITLE-ABS-KEY (kombucha OR kefir OR yogurt OR yoghurt OR tempe OR tempeh OR tapai OR tape OR kecap OR sauerkraut OR kimch* OR cheese OR pickle* OR miso OR natto OR koumiss OR kisk OR anchovy OR doenjang)	178,292
#7	TITLE (consumption OR “consumption pattern*” OR “consumption behavior*” OR “consumption practice*” OR “consumption habit*”)	161,597
#8	TITLE (eating OR “eating pattern*” OR “eating behavior*” OR “eating practice*” OR “eating habit*” OR “eating portion” OR “eating frequency”)	48,060
#9	TITLE (food OR “food habit*” OR “food behavior” OR “food pattern*” OR “food intake” OR “food portion” OR “food frequency”)	349,513
#10	TITLE (intake OR “daily intake” OR “regular intake” OR “habitual intake” OR “nutrient* intake”)	91,259
#11	TITLE (diet OR “diet* pattern*” OR “diet* behavior*” OR “diet* practice*” OR “diet* habit*” OR “diet* quality” OR “dietary assessment” OR “dietary requirement” OR “ diet* diversity”)	179,627
#12	#1 OR #2 OR #3 OR #4 OR #5 OR #6	297,133
#13	**#7 OR #8 OR #9 OR #10 OR #11**	785,522
14	**#12 AND #13**	20,926
#15	ALL (animal AND study OR animal AND experiment OR non AND human AND study OR non AND human AND experiment)	2,172,164
#16	#14 AND NOT #15	19,495
#17	Limit to PUBYEAR > 2003 AND PUBYEAR < 2025 AND (EXCLUDE (DOCTYPE, “re”) OR EXCLUDE (DOCTYPE, “ch”) OR EXCLUDE (DOCTYPE, “cp”) OR EXCLUDE (DOCTYPE, “ed”) OR EXCLUDE (DOCTYPE, “bk”) OR EXCLUDE (DOCTYPE, “no”) OR EXCLUDE (DOCTYPE, “er”) OR EXCLUDE (DOCTYPE, “le”) OR EXCLUDE (DOCTYPE, “sh”) OR EXCLUDE (DOCTYPE, “cr”) OR EXCLUDE (DOCTYPE, “tb”) OR EXCLUDE (DOCTYPE, “dp”) OR EXCLUDE (DOCTYPE, “rp”)) AND (LIMIT-TO (LANGUAGE, “english”)) AND (EXCLUDE (EXACTKEYWORD, “nonhuman”) OR EXCLUDE (EXACTKEYWORD, “food waste”) OR EXCLUDE (EXACTKEYWORD, “food control”) OR EXCLUDE (EXACTKEYWORD, “unclassified drug”) OR EXCLUDE (EXACTKEYWORD, “isolation and purification”) OR EXCLUDE (EXACTKEYWORD, “cattle”) OR EXCLUDE (EXACTKEYWORD, “animal food”) OR EXCLUDE (EXACTKEYWORD, “animalia”) OR EXCLUDE (EXACTKEYWORD, “food handling”) OR EXCLUDE (EXACTKEYWORD, “animal feed”) OR EXCLUDE (EXACTKEYWORD, “high performance liquid chromatography”) OR LIMIT-TO (EXACTKEYWORD, “human”))	3,687
#18	(TITLE-ABS-KEY (“diet quality” OR “nutrient* intake” OR “diet* pattern” OR “diet* behavior” OR “eating pattern” OR “food choice” OR “food habit” OR “food preference”) AND PUBYEAR > 2023) AND ((TITLE-ABS-KEY (probiotic* OR ferment* W/3 food) AND PUBYEAR > 2023) AND (TITLE-ABS-KEY (consum* OR eat* OR intake* OR nutri* OR diet) AND PUBYEAR > 2023)) AND (LIMIT-TO (SRCTYPE,“j”)) AND (EXCLUDE (EXACTKEYWORD,“Nonhuman”) OR EXCLUDE (EXACTKEYWORD,“Genetics”) OR EXCLUDE (EXACTKEYWORD,“Mouse”) OR EXCLUDE (EXACTKEYWORD,“Mice”) OR EXCLUDE (EXACTKEYWORD,“Antibiotic Resistance”) OR EXCLUDE (EXACTKEYWORD,“Metagenomics”) OR EXCLUDE (EXACTKEYWORD,“RNA, Ribosomal, 16S”) OR EXCLUDE (EXACTKEYWORD,“In Vitro Study”) OR EXCLUDE (EXACTKEYWORD,“DNA Extraction”) OR EXCLUDE (EXACTKEYWORD,“Gene Sequence”) OR EXCLUDE (EXACTKEYWORD,“Antibiotic Sensitivity”) OR EXCLUDE (EXACTKEYWORD,“Animal Model”) OR EXCLUDE (EXACTKEYWORD,“Genomics”) OR EXCLUDE (EXACTKEYWORD,“Mass Spectrometry”) OR EXCLUDE (EXACTKEYWORD,“Gas Chromatography”) OR EXCLUDE (EXACTKEYWORD,“Genomic DNA”) OR EXCLUDE (EXACTKEYWORD,“Genome”) OR EXCLUDE (EXACTKEYWORD,“Chloramphenicol”) OR EXCLUDE (EXACTKEYWORD,“Ampicillin”) OR EXCLUDE (EXACTKEYWORD,“Animal Tissue”) OR EXCLUDE (EXACTKEYWORD,“Animal Cell”) OR EXCLUDE (EXACTKEYWORD,“Depression”) OR EXCLUDE (EXACTKEYWORD,“Real	**3,707**

(*Continued*)

Appendix A. (*Continued*)

Step	Syntax	Result
	Time Polymerase Chain Reaction") OR EXCLUDE (EXACTKEYWORD,"Rat") OR EXCLUDE (EXACTKEYWORD,"C57BL Mouse") OR EXCLUDE (EXACTKEYWORD,"Mice, Inbred C57BL") OR EXCLUDE (EXACTKEYWORD,"High Performance Liquid Chromatography") OR EXCLUDE (EXACTKEYWORD,"Animals") OR EXCLUDE (EXACTKEYWORD,"Animal")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (LANGUAGE,"English"))	
4. EBSCO MEDLINE (CINAHL) (8 December 2025)		
S1	XB probiotics	46,558
S2	XB fermented foods	4,658
S3	XB fermented beverages	1,487
S4	XB fermented drink	325
S6	XB tempeh	208
S7	XB (yogurt or yoghurt)	6,775
S8	XB fermented milk	3,012
S9	XB fermented products	4,651
S10	XB (consumption or intake or eating) OR	984,255
S11	XB eating habits OR eating behavior OR eating patterns	81,278
S12	XB consumption behavior OR consumption pattern OR consumption culture	15,023
S13	XB dietary habits OR dietary intake OR dietary patterns	123,116
S14	XB helaty diet OR healthy eating OR healthy food	39,208
S15	XB kombucha	502
S16	XB mandai	27
S17	XB tempoyak	11
S18	Diet quality or nutritional quality	29,225
S19	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S OR S10 OR OR S16 OR S17 OR S18	61,046
S20	S11 OR S12 OR S13 OR S14 OR S15 Or S19	1,049,019
S21	S19 AND S20	9,519
S22	S21 limit by year (2004-2025)	8,910
S23	S22 limit by English language; Human study	**401**
5. Proquest (8 December 2025)		
S1	abstract(consumption pattern) OR abstract(eating pattern) OR abstract(dietary pattern)	30,764
S2	Abstract(consumption habits) OR abstract(eating habit) OR abstract(dietary habit)	17,510
S3	abstract(diet quality) OR abstract(diet diversity) OR abstract(dietary practices)	31,225
S4	abstract(fermented food) OR (abstract(fermented dairy products) OR abstract(fermented beverage) OR abstract(fermented drink) OR abstract(fermented soybean) OR abstract(fermented milk) OR abstract(fermented vegetable) OR(fermented fruit)	7,239
S5	Abstract(yoghurt OR yogurt) OR abstract(kimchi) OR abstract (kimchee) OR abstract(tempe) OR abstract(tempeh) OR abstract(mandai) OR abstract (kefir) OR abstract (kombucha)	5,573
S6	S1 OR S2 OR 23	72,239
S7	S4 OR S5	11,690
S8	S6 AND S7	**737**

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Appendix B. Quality of cross-sectional studies according to the JBI Critical Appraisal Checklist

No	Author and year	Country	Characteristics of participants including sample size	Study design	1. Were the criteria for inclusion in the sample clearly defined?	2. Were the study subjects and the setting described in detail?	3. Was the exposure measured in a valid and reliable way?	4. Were objective, standard criteria used for measurement of the condition?	5. Were confounding factors identified?	6. Were strategies to deal with confounding factors stated?	7. Were the outcomes measured in a valid and reliable way?	8. Was appropriate statistical analysis used?	Quality score
1	Tsai et al., 2022	China	2,819 schoolchildren aged 11–12 years	Cross-sectional	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
2	Cifelli et al., 2020	America	65,799 general population aged 2 years and over, using data from National Health and nutrition examination survey 2001–2016	Cross-sectional	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
3	Abreu et al., 2014	Portugal	494 adolescents aged 15–18 years	Cross-sectional study	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
4	Vatanparast et al., 2019	Canada	20,487 general populatin	Survey	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
5	Zhu et al., 2015	USA	5,124 children agen 2–18 years	Survey	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
6	Sousa et al., 2022	Portugal	311 University studetn (231 women and 80 men)	Cross-sectional	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
7	Iglesia et al., 2020	Italy	8807 children aged 2–9 years (T0); 5085 aged 2–10 years (T1), 1991 aged <10->=10 years (T3)	Cross-sectional	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8

(*Continued*)

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Appendix B. (*Continued*)

No	Author and year	Country	Characteristics of participants including sample size	Study design	1. Were the criteria for inclusion in the sample clearly defined?	2. Were the study subjects and the setting described in detail?	3. Was the exposure measured in a valid and reliable way?	4. Were objective, standard criteria used for measurement of the condition?	5. Were confounding factors identified?	6. Were strategies to deal with confounding factors stated?	7. Were the outcomes measured in a valid and reliable way?	8. Was appropriate statistical analysis used?	Quality score
8	Hobbs et al., 2019	UK	1687 children aged 4–10 and 11–18 years	Cross-sectional	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
9	Zhu et al., 2021	UK	1,912 children and 2,064 adults	Cross-sectional	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8

Quality of cohort studies according to the Newcastle–Ottawa Scale (NOS)

					Selection				Comparability	Outcome			
No	Author and year	Country	Characteristics of participants including sample size	Study design	Representativeness of the exposed cohort	Selection of the non exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow up long enough for outcomes to occur	Adequacy of follow up of cohorts	Quality score (Number of stars)
1	Lopez-Garcia, 2015	Spain	4,445 aged >15 years	Prospective Cohort	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
2	Karbownik et al., 2022	Poland	372 medical student	Prospective Cohort	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
3	Dobielska et al., 2025	Poland	280 medical student	Prospective Cohort	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8