



## Global perspectives on nutritional knowledge of bovine milk as a mineral source

Carmen L. Manuelian,<sup>1</sup> Marta Bonadonna,<sup>2</sup> Simona Censi,<sup>3</sup> Caterina Mian,<sup>3</sup> Maristela Rovai,<sup>4</sup> Eleni Tsiplakou,<sup>5</sup> Luciana da Costa,<sup>6</sup> Birgit Fuerst-Waltl,<sup>7</sup> Adriano G. Cruz,<sup>8</sup> Ramon Silva,<sup>8</sup> Donagh P. Berry,<sup>9</sup> Nicolas Lopez-Villalobos,<sup>10</sup> Antonio Masi,<sup>2</sup> Randeep Rakwal,<sup>11</sup> Garegin Hambardzumyan,<sup>12</sup> Francesc Borrissier-Pairó,<sup>13</sup> Lina Maria Trujillo Rojas,<sup>14</sup> Elena Albanell,<sup>1</sup> Santiago Guaman Rivera,<sup>15</sup> Sandra González-Luna,<sup>16</sup> Joel Berard,<sup>17</sup> Giovanni Niero,<sup>2\*</sup> and Massimo De Marchi<sup>2</sup>

<sup>1</sup>Ruminants Research Group (G2R), Department of Animal and Food Sciences, Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain

<sup>2</sup>Department of Agronomy, Food, Natural Resources, Animals and Environment, University of Padova, 35020 Legnaro, Italy

<sup>3</sup>Department of Medicine, University of Padova, 35121 Padova, Italy

<sup>4</sup>Department of Dairy and Food Science, South Dakota State University, Brookings, SD 57007

<sup>5</sup>Laboratory of Nutritional Physiology and Feeding, Department of Animal Science, School of Animal Biosciences, Agricultural University of Athens, 11855, Athens, Greece

<sup>6</sup>Department of Veterinary Preventive Medicine, The Ohio State University, Columbus, OH 43210

<sup>7</sup>Department of Sustainable Agricultural Systems, University of Natural Resources and Life Sciences, 1180 Vienna, Austria

<sup>8</sup>Food Department, Federal Institute of Education, Science, and Technology of Rio de Janeiro (IFRJ), 20270-021 Rio de Janeiro, Rio de Janeiro, Brazil

<sup>9</sup>Animal and Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, P61 C996, Ireland

<sup>10</sup>School of Agriculture and Environment, Massey University, Palmerston North 4442, New Zealand

<sup>11</sup>Institute of Health and Sport Sciences, University of Tsukuba, Tsukuba, Ibaraki 305-8574, Japan

<sup>12</sup>Veterinary Sanitary Examination, Food Safety and Hygiene Department, Armenian National Agrarian University, Yerevan 0009, Armenia

<sup>13</sup>Food Quality and Technology, IRTA, 17121 Monells, Spain

<sup>14</sup>Departamento de Ciencia Animal, Facultad de Ciencias Agropecuarias, Universidad Nacional de Colombia, sede Palmira, 763533, Colombia

<sup>15</sup>Escuela Superior Politécnica de Chimborazo (ESPOCH), sede Orellana, HX5X+JQ8, El Coca, Ecuador

<sup>16</sup>Departamento de Ciencias Pecuarias, Facultad de Estudios Superiores Cuautitlán, Universidad Nacional Autónoma de México, 54714 Cuautitlán Izcalli, Mexico

<sup>17</sup>Division Animal Production Systems and Animal Health, Agroscope, 1725 Posieux, Switzerland

### ABSTRACT

Reducing milk consumption has the potential to negatively affect dietary mineral intake, and it is important to understand people's knowledge of milk's nutritional contributions to help them make informed decisions. This international study assessed consumer knowledge of milk as a dietary source of energy, nutrients, and minerals (i.e., Ca, P, K, Mg, Fe, and I), and how that knowledge differed based on whether the survey respondents were milk consumers. A questionnaire was developed using a 7-point Likert scale, with questions assessing the respondents' perception of milk as a source of energy, nutrients, and minerals, as well as ancillary information on their sociodemographic data and milk consumption habits. Answers to the questionnaire were analyzed using a multiple regression fixed effects model, which included consumer class (i.e., consumers of milk versus nonconsumers of milk), geographical area, educational status,

gender, and age, as well as a series of 2-way interactions of these effects with milk consumption class. The sample, comprising both consumers (84.6%) and nonconsumers of milk (15.4%), consisted of 4,700 respondents from 16 countries recruited through convenience sampling. Sociodemographic characteristics were similar between milk consumers and nonconsumers; the sample was predominantly young (consumers, 55%; nonconsumers, 54%), female (consumers, 63%; nonconsumers, 70%), and university-educated (consumers, 61%; nonconsumers, 65%). Results revealed that milk consumers demonstrated slightly greater awareness of milk as an energy source compared with nonconsumers, though differences were modest. Respondents' knowledge of milk as a source of energy, nutrients, and minerals also differed by geographical region and educational status. Overall, respondents believed there was a strong association between calcium and milk, but awareness of the other minerals questioned (i.e., magnesium, potassium, phosphorus) was close to zero, indicating neutrality or possible uncertainty. In conclusion, this survey demonstrates that consumers of milk are more informed about milk as a source of energy; however, respondents' aware-

Received November 11, 2025.

Accepted February 16, 2026.

\*Corresponding author: [g.niero@unipd.it](mailto:g.niero@unipd.it)

The list of standard abbreviations for JDS is available at [adsa.org/jds-abbreviations-26](https://adsa.org/jds-abbreviations-26). Nonstandard abbreviations are available in the Notes.

ness of milk as a source of important minerals, other than calcium, is lacking. These results highlight a general gap in knowledge about critical health-related components in milk and underscore the need for targeted educational campaigns to promote milk as a mineral-rich dietary source that supports informed nutritional choices.

**Key words:** minerals, milk, preference, perception

## INTRODUCTION

The global growth in fluid milk output has slowed down in recent years (OECD-FAO, 2025), concurrent with a growing interest in plant-based beverages and milk-based functional products (Bus and Worsley, 2003). Milk is classified as a matrix effect food, meaning that the complex interaction among its macronutrients, micronutrients, and bioactive compounds produces beneficial effects for human health exceeding the benefits of each component when consumed independently (Thorning et al., 2017). Such a matrix effect improves the bioavailability of micronutrients (Shkembi and Huppertz, 2021), promotes synergistic interactions between them, and optimizes metabolic responses compared with the individual constituents, amplifying milk's overall nutritional impact on human health (Capuano and Janssen, 2021). Milk contains a wide array of mineral elements essential for supporting various physiological functions, particularly those related to the cardiovascular system (Chrysant and Chrysant, 2013) and bone metabolism (Cashman, 2006). Milk is a key source of calcium, with its absorption enhanced by lactose (Greupner et al., 2017), making dairy products crucial for bone health (Hodges et al., 2019). Phosphorus is highly bioavailable in milk, and it not only enhances bone health, but also supports cellular energy metabolism (Nilsson et al., 2021). Milk potassium is absorbed in the gastrointestinal tract through active transport (Castillo et al., 2015), contributing to a reduction in vascular stiffening (Stone et al., 2016). Milk contains highly bioavailable magnesium that is absorbed more efficiently than from some plant-based alternatives, supporting muscle function and bone health (Brink et al., 1992). Milk does not contain a high concentration of iron, and its absorption is limited owing to its competition with calcium (Giansanti et al., 2016). Milk is a good source of iodine, essential for thyroid hormones synthesis, which in turn regulates metabolism and neurological development, acting on multiple tissues and organs, particularly on the development of the central nervous system; the concentration of iodine in milk is dependent on both the diet of the animal and farming practices (Niero et al., 2023). Based on the daily mineral requirement for humans recommended by the Food and Drug Administration (FDA, 2021), 250

mL of milk (i.e., a cup of milk) provides approximately 25% calcium (Del Valle et al., 2011), 21% phosphorus (Visentin et al., 2018), 12% potassium (Visentin et al., 2018), 8% magnesium (Oh and Deeth, 2017), 1% to 3% iron (Lynch, 2000), and 40% to 50% iodine (Niero et al., 2023) of the daily requirements for those minerals for nonpregnant nonlactating healthy adults.

Previous studies have revealed that ethnicity is a primary reason for differences in milk choices, as specific population groups are more prone to lactose intolerance (Gulseven and Wohlgenant, 2017). Moreover, lactose-free milk consumers prefer products with extended shelf life and labels highlighting high protein or high calcium content (Rizzo et al., 2020). On the other hand, sociodemographic factors are not associated with milk type choices regarding milk fat and cholesterol (Elbon et al., 1996). However, consumers from both the United Kingdom and the United States tend to purchase whole milk, whereas Danish consumers prefer skim milk, as they consider fat an unhealthy component of milk (Vargas-Bello-Pérez et al., 2020).

Despite the global relevance of dairy consumption, no international study has yet investigated differences in the knowledge of milk's nutritional and mineral content between those that consume bovine milk versus those that do not consume milk. Understanding the factors likely associated with milk consumption may help in the development of effective dietary guidelines and in promoting informed nutritional choices. Therefore, this study aimed to examine how milk consumption status influences knowledge of milk as a source of energy, nutrients, and minerals across diverse global populations (i.e., geographical region, gender, age group, and educational status). Particular attention was given to the 6 minerals: calcium, phosphorus, potassium, magnesium, iron, and iodine.

## MATERIALS AND METHODS

### *Ethical Statement*

The survey was conducted through an online questionnaire. Before participation, all participants were required to acknowledge an informed consent statement. Participation was entirely voluntary, anonymous, and reserved for adults, in agreement with the 2013 version of the Declaration of Helsinki for research involving human subjects, as established by the World Medical Association (WMA, 2023). Data collection and processing complied with the General Data Protection Regulation 2016/679 (GDPR, 2016) and the Data Protection Act 2018 (DPA, 2018). Participants had the right to withdraw from the study at any time without providing any reason.

**Table 1.** Questionnaire sections, questions (Q), and responses (R)

| Questions                                                                                       | Responses                                                                                              |
|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| <b>Section A: Sociodemographic information</b>                                                  |                                                                                                        |
| Q <sub>A1</sub> : In which country do you live?                                                 | R <sub>A1</sub> : Close country list                                                                   |
| Q <sub>A2</sub> : Gender                                                                        | R <sub>A2</sub> : Male; female; other                                                                  |
| Q <sub>A3</sub> : Birth date                                                                    | R <sub>A3</sub> : Free answer                                                                          |
| Q <sub>A4</sub> : What is the highest level of education you have completed?                    | R <sub>A4</sub> : Doctorate degree; bachelor or master degree; secondary or lower education            |
| <b>Section B: Milk consumption</b>                                                              |                                                                                                        |
| Q <sub>B1</sub> : Do you consume milk?                                                          | R <sub>B1</sub> : Yes; no                                                                              |
| Q <sub>B2</sub> : What is the main reason you do not consume milk?                              | R <sub>B2</sub> : Close reasons list                                                                   |
| Q <sub>B3</sub> : How often do you consume milk?                                                | R <sub>B3</sub> : Never; 1 time/month; 2–3 times/month; 1–2 times/week; 3–6 times/week; every day      |
| Q <sub>B4</sub> : When you consume milk, how much milk do you drink per day?                    | R <sub>B4</sub> : Less than one glass; approximately one glass; more than one glass                    |
| Q <sub>B5</sub> : In respect to fat content, what type of milk do you consume more often?       | R <sub>B5</sub> : Whole milk; semi-skim milk; skim milk                                                |
| Q <sub>B6</sub> : In respect to thermal treatment, what type of milk do you consume more often? | R <sub>B6</sub> : Raw milk; pasteurized milk; UHT milk                                                 |
| <b>Section C: Knowledge on milk energy and nutrients</b>                                        |                                                                                                        |
| Q <sub>C1</sub> : How much do you associate energy with milk?                                   | R <sub>C1</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>C2</sub> : How much do you associate protein with milk?                                  | R <sub>C2</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>C3</sub> : How much do you associate fat with milk?                                      | R <sub>C3</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>C4</sub> : How much do you associate carbohydrates with milk?                            | R <sub>C4</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>C5</sub> : How much do you associate vitamins with milk?                                 | R <sub>C5</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>C6</sub> : How much do you associate minerals with milk?                                 | R <sub>C6</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| <b>Section D: Knowledge on milk minerals</b>                                                    |                                                                                                        |
| Q <sub>D1</sub> : How much do you associate calcium with milk?                                  | R <sub>D1</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>D2</sub> : How much do you associate phosphorus with milk?                               | R <sub>D2</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>D3</sub> : How much do you associate potassium with milk?                                | R <sub>D3</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>D4</sub> : How much do you associate magnesium with milk?                                | R <sub>D4</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>D5</sub> : How much do you associate iron with milk?                                     | R <sub>D5</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |
| Q <sub>D6</sub> : How much do you associate iodine with milk?                                   | R <sub>D6</sub> : 7-point Likert-type item (–3 is “not at all” and 3 is “very much”) or “I don’t know” |

### Questionnaire Design

The questionnaire consisted of 22 questions, divided into 4 sections (A, B, C, and D). Section A included 4 questions (Q<sub>A1</sub>, Q<sub>A2</sub>, Q<sub>A3</sub>, and Q<sub>A4</sub>) to capture participant sociodemographic information (i.e., home country, gender, birthdate, and educational status). Section B consisted of 6 questions (Q<sub>B1</sub>, Q<sub>B2</sub>, Q<sub>B3</sub>, Q<sub>B4</sub>, Q<sub>B5</sub>, and Q<sub>B6</sub>) related to bovine milk consumption habits (i.e., consume milk or not consume milk, reason for not consuming milk, consumption frequency, quantity consumed, and the specific fat content type of milk consumed [type of milk here refers to whole milk, semi-skimmed milk or skimmed milk]). Section C included 6 questions (Q<sub>C1</sub>, Q<sub>C2</sub>, Q<sub>C3</sub>, Q<sub>C4</sub>, Q<sub>C5</sub>, and Q<sub>C6</sub>) that explored respondents’ knowledge of milk energy and nutrient content (i.e., protein, fat, carbohydrates, vitamins, and minerals). Section D comprised 6 questions (Q<sub>D1</sub>, Q<sub>D2</sub>, Q<sub>D3</sub>, Q<sub>D4</sub>, Q<sub>D5</sub>, and

Q<sub>D6</sub>) related to respondents’ knowledge of milk mineral content (i.e., Ca, P, K, Mg, Fe, and I). For sections C and D, respondents could choose an answer expressed on a 7-point Likert-type scale ranging from –3 (meaning “not at all”) to +3 (meaning “very much”), or respond “I do not know.” It should be noted that responses near 0 may reflect either respondents’ uncertainty or true neutrality. Therefore, when interpreting the results, values close to 0 should be considered as potentially indicating a lack of knowledge or confidence, as well as a real balanced or neutral opinion. The full list of questions and response options is presented in Table 1.

The development of the questionnaire was described in detail by Niero et al. (2024), using the methodology proposed by Manuelian et al. (2023). Briefly, 2 researchers of different nationalities and countries drafted the questionnaire in English based on Dillman’s (2000) recommendations (first version). Subsequently, the ques-

tionnaire was reviewed by a team of 6 researchers of different nationalities and countries, who further refined the content and structure (second version). Lastly, the questionnaire was evaluated in a pilot test by 6 people from English-speaking countries, who completed the questionnaire and provided feedback. Based on their comments and suggestions, the questionnaire was amended, resulting in the final English version (third version). The final English version was translated into 13 languages (i.e., Arabic, Armenian, French, German, Greek, Hindi, Italian, Japanese, Nepalese, Portuguese, Russian, Spanish, and Tamil) by native speaker researchers, as suggested by the Brislin's method (Dufour et al., 2010). Once all questionnaires were ready in their respective languages, they were disseminated online through specific Google Form links.

### Questionnaire Dissemination

The questionnaires were disseminated by 2 or 3 representatives for each country over a 7-mo period through various channels (i.e., Facebook, Instagram, WhatsApp, university mailing lists, and paper leaflets and posters including a QR code in public notice boards). Survey respondents were not provided with any financial or material reward. The population of interest included adults residing in the selected countries worldwide. Upon accessing the questionnaire, participants were presented with an introductory description explaining the purpose of the study. This introduction informed participants that the survey involved over 20 countries worldwide and that their participation would contribute to advancing knowledge and guiding future dissemination actions. It also communicated that the estimated time to complete the survey was approximately 5 min, participation was voluntary, and respondents could withdraw at any time without providing a reason. Participants were assured that their responses would remain confidential and that only aggregated data would be reported.

### Data Editing and Statistical Analysis

From the 4,958 questionnaires collected from participants in 32 countries, records of underage or evidently incorrect reported ages ( $n = 63$ ), suspected duplicate records ( $n = 37$ ), and countries with fewer than 20 respondents ( $n = 108$ ) or unspecified territories ( $n = 46$ ) were discarded. An additional 4 records were deleted due to inconsistency in their responses between Q<sub>B1</sub> question ("Do you consume milk?") and Q<sub>B3</sub> question ("How often do you consume milk?"). Therefore, the final dataset consisted of survey responses from 4,700 participants living in 16 countries; the countries were Armenia ( $n = 320$ ), Austria ( $n = 641$ ), Brazil ( $n = 408$ ), Colombia ( $n = 406$ ), Ecuador ( $n = 192$ ),

France ( $n = 286$ ), Greece ( $n = 490$ ), India ( $n = 132$ ), Ireland ( $n = 64$ ), Italy ( $n = 500$ ), Japan ( $n = 76$ ), Mexico ( $n = 401$ ), New Zealand ( $n = 67$ ), Spain ( $n = 416$ ), Switzerland ( $n = 127$ ), and the United States of America ( $n = 174$ ). The 16 countries were grouped into 6 regions based on the United Nations geoscheme and as described by Niero et al. (2024): Southern Europe (including Spain, Italy, and Greece), Northern and Western Europe (including Ireland, France, Austria, and Switzerland), United States of America (treated alone), Latin America (including Mexico, Ecuador, Colombia, and Brazil), Asia (including Armenia, India, and Japan), and New Zealand (treated alone).

Descriptive statistics were obtained using the MEANS procedure of SAS v. 9.4 (SAS Institute Inc., Cary, NC). For relative frequencies, 95% CI were calculated with Microsoft Excel 2016 (Microsoft Office Professional Plus, Microsoft Corporation, Albuquerque, NM). Sources of variation for answers to the questions on knowledge of milk energy and nutrient content (section C) and on milk mineral content (section D) were investigated using a multiple regression fixed effects model implemented in the MIXED procedure of SAS v. 9.4 (SAS Institute Inc., Cary, NC). The model was as follows:

$$y_{ijklmn} = \mu + \text{Consumer}_i + \text{Region}_j + \text{Education}_k + \text{Gender}_l + \text{Age}_m + (\text{Consumer} \times \text{Region})_{ij} + (\text{Consumer} \times \text{Education})_{ik} + (\text{Consumer} \times \text{Gender})_{il} + (\text{Consumer} \times \text{Age})_{im} + e_{ijklmn},$$

where  $y_{ijklmn}$  is the dependent variable;  $\mu$  is the overall intercept of the model;  $\text{Consumer}_i$  is the fixed effect of the  $i$ th respondent profile in respect to milk consumption (2 classes: consumers defined as those who consume milk at least once per month, and nonconsumers defined as those who do not drink milk or consume it less than once per month);  $\text{Region}_j$  is the fixed effect of the  $j$ th geographical area (6 classes: Southern Europe, Northern and Western Europe, United States of America, Latin America, Asia, and New Zealand);  $\text{Education}_k$  is the fixed effect of the  $k$ th educational status of the respondents (3 classes: doctoral degree, bachelor's or master's degree, secondary or lower education);  $\text{Gender}_l$  is the fixed effect of the  $l$ th gender of the respondents (3 classes: male, female, or other);  $\text{Age}_m$  is the fixed effect of the  $m$ th age class of the respondents (3 classes: young,  $\leq 35$  yr old; adult, between 36 and 64 yr old; or senior,  $\geq 65$  yr old);  $(\text{Factor}_1 \times \text{Factor}_2)$  is the 2-way interaction between  $\text{Factor}_1$  and  $\text{Factor}_2$ ; and  $e_{ijklmn}$  is the random residual  $\sim N(0, \mathbf{I}\sigma_e^2)$ , where  $\sigma_e^2$  is the residual variance and  $\mathbf{I}$  is the identity matrix. For each question, differences between predicted marginal means were tested using the Bonferroni post hoc multiple comparison tests with significance established at  $P < 0.05$ .

**Table 2.** Frequencies and 95% CI for question related to milk consumption

| Question                                                  | Consumers (n = 3,975) |           | Nonconsumers (n = 725) |           |
|-----------------------------------------------------------|-----------------------|-----------|------------------------|-----------|
|                                                           | %                     | 95% CI    | %                      | 95% CI    |
| Frequency of consumption (Q <sub>B3</sub> )               |                       |           |                        |           |
| Every day                                                 | 38.6                  | 37.0–40.1 | —                      | —         |
| 1–2 times/week                                            | 21.5                  | 20.3–22.8 | —                      | —         |
| 3–6 times/week                                            | 19.8                  | 18.6–21.1 | —                      | —         |
| 2–3 times/month                                           | 14.9                  | 13.8–16.0 | 6.7                    | 4.9–8.6   |
| 1 time/month                                              | 5.2                   | 4.5–5.9   | 29.0                   | 25.7–32.3 |
| Never                                                     | —                     | —         | 64.3                   | 60.8–67.8 |
| Daily milk consumption (Q <sub>B4</sub> )                 |                       |           |                        |           |
| Approximately 1 glass (125 mL)                            | 49.7                  | 48.2–51.3 | —                      | —         |
| Less than 1 glass (less than 125 mL)                      | 26.6                  | 25.2–28.0 | —                      | —         |
| More than 1 glass (more than 125 mL)                      | 23.7                  | 22.3–25.0 | —                      | —         |
| Milk fat content consumed (Q <sub>B5</sub> )              |                       |           |                        |           |
| Whole milk (~3.5% fat)                                    | 57.3                  | 55.8–58.8 | —                      | —         |
| Semi-skim milk (~2% fat)                                  | 31.3                  | 30.0–32.7 | —                      | —         |
| Skim milk (~0.5% fat)                                     | 11.4                  | 10.4–12.4 | —                      | —         |
| Milk thermal treatment consumed (Q <sub>B6</sub> )        |                       |           |                        |           |
| Pasteurized milk                                          | 47.9                  | 46.9–48.9 | —                      | —         |
| UHT milk                                                  | 38.6                  | 37.5–39.5 | —                      | —         |
| Raw milk                                                  | 13.5                  | 12.5–14.5 | —                      | —         |
| Reason for not consuming milk (Q <sub>B2</sub> )          |                       |           |                        |           |
| I don't like milk                                         | —                     | —         | 40.8                   | 37.3–44.4 |
| Lactose intolerance                                       | —                     | —         | 20.7                   | 17.7–23.6 |
| Ethical concerns on animal welfare                        | —                     | —         | 9.9                    | 7.8–12.1  |
| Ethical concerns on the sustainability of milk production | —                     | —         | 4.3                    | 2.8–5.8   |
| Allergy                                                   | —                     | —         | 3.3                    | 2.0–4.6   |
| Concerns on antibiotic and toxic residues in milk         | —                     | —         | 2.4                    | 1.2–3.4   |
| High price                                                | —                     | —         | 0.7                    | 0.1–1.3   |
| Religious aspect                                          | —                     | —         | 0.1                    | 0.0–0.4   |
| Other health problems                                     | —                     | —         | 6.1                    | 4.3–7.8   |
| Other                                                     | —                     | —         | 11.7                   | 9.4–14.1  |

## RESULTS

### Respondent Characteristics

The majority of respondents were milk consumers (85%), with most reporting daily milk consumption (39%) or consumption once or twice a week (22%; Table 2). Regarding serving size, half of the consumers of milk stated that they drank approximately one glass of milk per day, whereas nearly one-quarter reported consuming more than one glass of milk per day (Table 2). The most consumed types were whole (57%) or semi-skimmed (31%) milk, with preferred processing methods being pasteurized (48%), UHT (39%), or raw milk (14%; Table 2). Conversely, nonconsumers comprised 15% of respondents, most of whom reported never consuming milk (64%), and remainder consuming milk infrequently (between once and 3 times a month; 36%; Table 2). The main reason stated for not consuming milk was a dislike for the taste (41%), followed by lactose intolerance (21%; Table 2). Other reasons stated included ethical concerns about animal welfare (10%), the perceived lack of sustainability in milk production (4%), allergies (3%), concerns about antibiotic or toxic residues (2%), and the high price of milk (1%; Table 2).

The geographical distribution of respondents was similar for those who consumed milk and those who did not (Table 3). The majority of respondents were from Latin America (representing 32% of all consumers and 20% of all nonconsumers), followed by Southern Europe (comprising 28% of all consumers and 39% of all nonconsumers), and then Northern and Western Europe (including 24% of all consumers and 24% of all nonconsumers). A lower proportion of respondents were from Asia (accounting for 11% all consumers and for 15% of all nonconsumers), the United States of America (representing 4% of all consumers and 3% of all nonconsumers), and New Zealand (with 2% of all consumers and 1% of all nonconsumers). Respondents were mainly young (representing 55% of all consumers and of all nonconsumers), female (representing 63% of all consumers and 69% of all nonconsumers), and had university qualifications (representing 61% of all consumers and 65% of all nonconsumers).

Regarding the awareness of consumers about milk's contribution to dietary nutrient intake, the number of respondents who selected "I do not know" varied by question, but it was similar between both milk consumers and nonconsumers (Table 4). The number of respondents who

**Table 3.** Frequencies and 95% CI for geographical area, gender, age class, and educational status stratified on whether consumers of milk or not

| Item                         | Consumers (n = 3,975) |           | Nonconsumers (n = 725) |           |
|------------------------------|-----------------------|-----------|------------------------|-----------|
|                              | %                     | 95% CI    | %                      | 95% CI    |
| Geographical area            |                       |           |                        |           |
| Southern Europe              | 28.3                  | 27.6–29.0 | 38.6                   | 37.2–40.0 |
| Northern and Western Europe  | 23.8                  | 23.1–24.5 | 23.6                   | 22.2–25.0 |
| United States of America     | 3.9                   | 3.2–4.6   | 2.6                    | 1.2–4.0   |
| Latin America                | 31.8                  | 31.1–32.5 | 20.0                   | 18.6–21.4 |
| Asia                         | 10.6                  | 9.9–11.2  | 14.5                   | 13.1–15.9 |
| New Zealand                  | 1.6                   | 0.9–2.3   | 0.7                    | 0.0–2.4   |
| Gender                       |                       |           |                        |           |
| Male                         | 36.0                  | 35.3–36.7 | 27.7                   | 26.3–29.1 |
| Female                       | 62.7                  | 62.0–63.4 | 69.4                   | 68.0–70.8 |
| Other                        | 1.3                   | 0.6–2.0   | 2.9                    | 1.5–4.3   |
| Age class                    |                       |           |                        |           |
| Young                        | 54.7                  | 54.0–55.4 | 55.3                   | 53.9–56.7 |
| Adult                        | 42.2                  | 41.5–42.9 | 43.2                   | 41.8–44.6 |
| Senior                       | 3.1                   | 2.4–3.8   | 1.5                    | 0.1–2.9   |
| Educational status           |                       |           |                        |           |
| Doctorate degree             | 16.5                  | 15.8–17.2 | 13.5                   | 12.1–14.9 |
| Bachelor or master degree    | 44.7                  | 44.0–45.4 | 51.6                   | 50.2–53.0 |
| Secondary or lower education | 38.8                  | 38.1–39.5 | 34.9                   | 33.5–36.3 |

selected “I do not know” was between 3% and 8% for the questions related to milk as a source of energy, nutrients, and calcium, whereas it was between 16% (iron) and 24% (iodine) for the question related to milk as a source of all other minerals.

### Sources of Variation in Knowledge of Milk Composition

All the main model effects, except gender, were associated ( $P < 0.05$ ) with questions on milk composition (Table 5). These associations were consistent regardless of whether the respondent consumed milk (i.e., no 2-way interactions).

#### Milk as a Source of Energy

Consumers of milk had a better knowledge of milk as an energy source than nonconsumers ( $Q_{C1}$ ;  $0.36 \pm 0.11$  and  $-0.33 \pm 0.27$ , respectively;  $P = 0.017$ ). Respondent knowledge differed across regions; respondents from Latin America ( $-0.30 \pm 0.15$ ) disagreed ( $P < 0.05$ ), whereas those both Southern Europe ( $0.11 \pm 0.14$ ) and Asia agreed ( $0.09 \pm 0.16$ ; Table 6) with milk being a source of energy. Additionally, respondents with a doctoral degree ( $0.17 \pm 0.17$ ) had better ( $P = 0.025$ ) knowledge of milk as an energy source than those with secondary or lower education ( $-0.15 \pm 0.16$ ; Table 7).

#### Milk as a Source of Protein

On average, respondents agreed that milk is a dietary source of protein ( $Q_{C2}$ ). However, respondents from

Northern and Western Europe had a greater ( $P < 0.05$ ) score ( $1.21 \pm 0.14$ ) than those from both Latin America ( $0.56 \pm 0.15$ ) and Southern Europe ( $0.80 \pm 0.14$ ; Table 6). Moreover, among all considered education statuses, respondents with a doctoral degree reported the highest score ( $1.29 \pm 0.17$ ;  $P < 0.05$ ; Table 7).

#### Milk as a Source of Fat

In general, respondents agreed that milk is a dietary source of fat ( $Q_{C3}$ ). Respondent opinions from both the United States of America ( $1.18 \pm 0.23$ ) and Northern and Western Europe ( $0.90 \pm 0.14$ ) differed ( $P < 0.05$ ) from Southern Europe ( $0.45 \pm 0.13$ ) and Asia ( $0.21 \pm 0.15$ ; Table 6). Moreover, those from Latin America ( $0.63 \pm 0.14$ ) also differed ( $P = 0.008$ ) from those from Asia (Table 6). Additionally, respondents with a doctoral degree ( $0.92 \pm 0.16$ ) had better ( $P = 0.030$ ) knowledge than those with secondary or lower education ( $0.62 \pm 0.15$ ; Table 7). Moreover, overall, young respondents assigned a higher ( $P = 0.022$ ) score than adults (young,  $1.02 \pm 0.11$ ; adult,  $0.47 \pm 0.32$ ).

#### Milk as a Source of Carbohydrates

On average, respondents disagreed with milk being a dietary source of carbohydrates ( $Q_{C4}$ ), with Southern Europe respondents ( $-0.84 \pm 0.14$ ) showing a stronger disagreement ( $P < 0.05$ ) than those from all of Asia ( $-0.21 \pm 0.16$ ), Latin America ( $-0.28 \pm 0.15$ ), and Northern and Western Europe ( $-0.54 \pm 0.14$ ; Table 6). Additionally, respondents with a doctoral degree had

**Table 4.** Number of respondents answering the 7-point Likert-type scale and percentage of respondents who selected “I do not know” (%Nk) for questions on milk energy and nutrients (section C) and minerals (section D)

| Question                                          | Consumers (n = 3,975) |      | Nonconsumers (n = 725) |      |
|---------------------------------------------------|-----------------------|------|------------------------|------|
|                                                   | Responses retained    | %Nk  | Responses retained     | %Nk  |
| Section C: Knowledge on milk energy and nutrients |                       |      |                        |      |
| Energy (Q <sub>C1</sub> )                         | 3,761                 | 5.4  | 685                    | 5.5  |
| Protein (Q <sub>C2</sub> )                        | 3,805                 | 4.3  | 692                    | 4.6  |
| Fat (Q <sub>C3</sub> )                            | 3,843                 | 3.3  | 699                    | 3.6  |
| Carbohydrates (Q <sub>C4</sub> )                  | 3,690                 | 7.2  | 669                    | 7.7  |
| Vitamins (Q <sub>C5</sub> )                       | 3,758                 | 4.5  | 686                    | 5.4  |
| Minerals (Q <sub>C6</sub> )                       | 3,824                 | 3.8  | 691                    | 4.7  |
| Section D: Knowledge on milk minerals             |                       |      |                        |      |
| Calcium (Q <sub>D1</sub> )                        | 3,853                 | 3.1  | 695                    | 4.1  |
| Phosphorus (Q <sub>D2</sub> )                     | 3,160                 | 20.5 | 566                    | 21.9 |
| Potassium (Q <sub>D3</sub> )                      | 3,212                 | 19.2 | 578                    | 20.3 |
| Magnesium (Q <sub>D4</sub> )                      | 3,248                 | 18.3 | 588                    | 18.9 |
| Iron (Q <sub>D5</sub> )                           | 3,314                 | 16.6 | 607                    | 16.3 |
| Iodine (Q <sub>D6</sub> )                         | 3,021                 | 24.0 | 555                    | 23.5 |

better knowledge ( $-0.21 \pm 0.17$ ) of the contribution of milk to carbohydrate intake than those with secondary or lower education ( $-0.55 \pm 0.16$ ;  $P = 0.017$ ; Table 7).

### Milk as a Source of Vitamins

Respondents agreed that milk is a dietary source of vitamins (Q<sub>C5</sub>). Respondents from United States of America ( $1.69 \pm 0.24$ ) showed a stronger ( $P < 0.001$ ) agreement than those from Northern and Western Europe ( $0.28 \pm 0.14$ ; Table 6).

### Milk as a Source of Minerals

On average, respondents agreed that milk is a dietary source of minerals in general (Q<sub>C6</sub>). Respondents from Asia ( $0.75 \pm 0.16$ ) and Latin America ( $0.70 \pm 0.14$ ) both had the lowest ( $P < 0.05$ ) score when compared against those from both United States of America ( $2.13 \pm 0.24$ ) and New Zealand ( $2.04 \pm 0.42$ ; Table 6). Additionally, respondents with a doctoral degree ( $1.55 \pm 0.17$ ) had better ( $P = 0.016$ ) knowledge than those with bachelor's or master's university qualifications ( $1.33 \pm 0.16$ ; Table 7).

### Milk as a Source of Calcium

Respondents strongly agreed that milk is a dietary source of calcium (Q<sub>D1</sub>). Respondents from Asia ( $1.16 \pm 0.15$ ) and Latin America ( $1.26 \pm 0.14$ ) both had the lowest ( $P < 0.05$ ) score when compared against both the United States of America ( $2.41 \pm 0.22$ ) and New Zealand ( $2.52 \pm 0.39$ ; Table 6). Additionally, respondents with a doctoral degree ( $2.06 \pm 0.15$ ) had better ( $P = 0.024$ ) knowledge than those with bachelor's or master's university qualifications ( $1.76 \pm 0.14$ ; Table 7).

### Milk as a Source of Phosphorus

Respondents from Southern Europe ( $0.44 \pm 0.16$ ) slightly agreed ( $P < 0.05$ ) on milk as a dietary source of phosphorus (Q<sub>D2</sub>) compared with those from Asia ( $-0.02 \pm 0.19$ ), Northern and Western Europe ( $-0.19 \pm 0.16$ ), and Latin America ( $0.10 \pm 0.17$ ), who had a more neutral or uncertain opinion (Table 6). Moreover, respondents with a doctoral degree ( $0.60 \pm 0.20$ ) had better knowledge than those with secondary or lower education ( $0.14 \pm 0.19$ ;  $P = 0.003$ ; Table 7).

### Milk as a Source of Potassium and Magnesium

Respondents had a neutral or uncertain opinion on milk as a dietary source of potassium (Q<sub>D3</sub>) and magnesium (Q<sub>D4</sub>). However, respondents from Northern and Western Europe had better knowledge of milk as a source of dietary magnesium ( $0.29 \pm 0.16$ ;  $P = 0.037$ ) than those from Asia ( $-0.10 \pm 0.18$ ; Table 6). For both minerals, young respondents assigned a higher score than adults (Potassium: young,  $0.19 \pm 0.14$ ; adult,  $-0.06 \pm 0.14$ ;  $P = 0.011$ ; Magnesium: young,  $0.21 \pm 0.14$ ; adult,  $-0.01 \pm 0.14$ ;  $P = 0.033$ ).

### Milk as a Source of Iron

Respondents from Northern and Western Europe ( $-0.78 \pm 0.16$ ) disagreed on milk as a dietary source of iron (Q<sub>D5</sub>), whereas those from Asia ( $-0.05 \pm 0.18$ ), Latin America ( $0.12 \pm 0.17$ ), and United States of America ( $0.25 \pm 0.29$ ;  $P < 0.05$ ) had a more neutral or uncertain opinion (Table 6). Moreover, respondents from Latin America ( $0.12 \pm 0.17$ ) slightly agreed ( $P < 0.001$ ) compared with Southern Europe respondents, who slightly disagreed ( $-0.38 \pm 0.16$ ;

**Table 5.** F-statistics and significance of fixed effects for questions on milk energy and nutrients (section C) and minerals (section D)

| Question                                          | Consumer (C) | Region (R) | Education (E) | Gender (G) | Age (A) | C × R | C × E | C × G | C × A |
|---------------------------------------------------|--------------|------------|---------------|------------|---------|-------|-------|-------|-------|
| Section C: Knowledge on milk energy and nutrients |              |            |               |            |         |       |       |       |       |
| Energy (Q <sub>C1</sub> )                         | 5.67*        | 3.85**     | 3.90*         | 1.33       | 0.20    | 1.81  | 0.24  | 1.92  | 0.46  |
| Protein (Q <sub>C2</sub> )                        | 1.61         | 8.36***    | 5.41**        | 0.89       | 1.22    | 0.74  | 0.11  | 2.19  | 0.83  |
| Fat (Q <sub>C3</sub> )                            | 0.02         | 10.73***   | 3.51*         | 2.61       | 4.56**  | 0.31  | 0.05  | 0.84  | 0.23  |
| Carbohydrates (Q <sub>C4</sub> )                  | 1.38         | 9.35***    | 3.83*         | 0.29       | 0.67    | 1.16  | 0.06  | 1.25  | 0.15  |
| Vitamins (Q <sub>C5</sub> )                       | 2.64         | 8.39***    | 0.68          | 0.44       | 2.04    | 1.28  | 0.26  | 3.47  | 2.28  |
| Minerals (Q <sub>C6</sub> )                       | 1.32         | 18.71***   | 3.91*         | 1.09       | 0.99    | 0.51  | 0.64  | 2.61  | 1.09  |
| Section D: Knowledge on milk minerals             |              |            |               |            |         |       |       |       |       |
| Calcium (Q <sub>D1</sub> )                        | 2.95         | 21.38***   | 3.56*         | 0.68       | 1.66    | 0.52  | 0.74  | 0.99  | 0.35  |
| Phosphorus (Q <sub>D2</sub> )                     | 0.31         | 8.65***    | 5.55**        | 0.19       | 1.29    | 1.84  | 1.42  | 0.05  | 1.10  |
| Potassium (Q <sub>D3</sub> )                      | 0.37         | 1.61       | 0.48          | 0.14       | 4.19*   | 1.73  | 1.02  | 0.18  | 0.22  |
| Magnesium (Q <sub>D4</sub> )                      | 0.00         | 2.07       | 0.52          | 0.29       | 3.22*   | 0.38  | 0.60  | 0.35  | 0.74  |
| Iron (Q <sub>D5</sub> )                           | 0.09         | 13.14***   | 1.69          | 1.73       | 3.88*   | 0.40  | 0.51  | 0.57  | 1.10  |
| Iodine (Q <sub>D6</sub> )                         | 0.09         | 9.80***    | 0.02          | 0.63       | 1.15    | 0.38  | 2.90  | 0.12  | 0.68  |

\* $P < 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ .

Table 6). In addition, young respondents ( $0.00 \pm 0.38$ ) had better knowledge than adults ( $-0.41 \pm 0.14$ ;  $P = 0.028$ ).

### Milk as a Source of Iodine

Respondents disagreed with milk as a dietary source of iodine (Q<sub>D6</sub>). However, respondents from Northern and Western Europe ( $-1.24 \pm 0.16$ ) indicated a stronger disagreement ( $P < 0.05$ ) than those from the United States of America ( $-0.39 \pm 0.30$ ), Asia ( $-0.56 \pm 0.19$ ), Latin America ( $-0.58 \pm 0.18$ ), and Southern Europe ( $-0.60 \pm 0.17$ ; Table 6).

## DISCUSSION

The survey involved 4,700 respondents from 16 countries, which were classified into 6 geographical areas. Of these, 85% of the respondents were regular milk consumers, and the remaining 15% either never consumed milk or consumed milk occasionally. Milk consumption was associated only with the respondents' opinion on milk as a source of energy (i.e., not with their opinions on other milk nutrients or milk minerals). In contrast, geographical region and educational status generally played a more substantial role in shaping responses to the questionnaire. The limitations of the study are those already reported by Niero et al. (2024), including that the sample may not fully reflect the demographics of the selected countries. As is common in voluntary surveys, distribution primarily through academic channels likely increased participation among younger, highly educated individuals while underrepresenting other groups.

The lower level of uncertainty for energy, protein, vitamins, and calcium, measured as fewer "I don't know" answers compared with other minerals, agreed with Bus and Worsley (2003), who surveyed 360 food shoppers

regarding milk in Melbourne, Australia. Bus and Worsley (2003) also reported that food shoppers have a better understanding of milk as a source of calcium, protein, and vitamins than as a source of iron.

### Effects of Consumption, Geographical Area, and Education on Consumers' Knowledge

Findings from the present study only partially align with existing literature reporting that food consumption of a key specific product plays a key role in shaping both perception and knowledge of that food product (Zandstra et al., 2000; Verbeke, 2006). Zandstra et al. (2000) indicated that individuals who frequently consume a given product are more likely to associate it with specific health benefits, often based on personal experience and repeated exposure. Verbeke (2006) stated that this relationship is often bidirectional, in a way that consumption improves knowledge, whereas existing beliefs (whether positive or negative) influence food choice.

Based on the results from the present study, consumers from different geographical locations perceive the same food item differently in terms of its nutritional content, likely due to diverse culturally embedded beliefs and dietary traditions, as well as different exposure to food items and education (Rozin, 2005; Ares and Gámbaro, 2007). These divergent perceptions are also likely influenced by national dietary guidelines, labeling, and public health campaigns (Rozin, 2005; Ares and Gámbaro, 2007). In essence, it can be assumed that food quality and nutritional value are only partially judged on their intrinsic characteristics, as they are also affected by cultural filters (Prescott, 1998). Moreover, in a cross-sectional study of Portuguese adults, Moreira and Padrão (2004) reported that a higher education status was associated with greater milk consumption.

**Table 6.** The 7-point Likert-type item (from –3 to +3) on milk energy, nutrients (section C), and minerals (section D) across different geographical area

| Question                              | LSM (SE)                    | Question                           | LSM (SE)                   |
|---------------------------------------|-----------------------------|------------------------------------|----------------------------|
| <b>Energy (Q<sub>C1</sub>)</b>        |                             | <b>Calcium (Q<sub>D1</sub>)</b>    |                            |
| Southern Europe                       | 0.11 (0.14) <sup>a</sup>    | Southern Europe                    | 1.74 (0.13) <sup>b</sup>   |
| Northern and Western Europe           | 0.06 (0.14) <sup>a</sup>    | Northern and Western Europe        | 2.00 (0.13) <sup>ab</sup>  |
| United States of America              | 0.08 (0.24) <sup>ab</sup>   | United States of America           | 2.41 (0.22) <sup>a</sup>   |
| Latin America                         | –0.30 (0.15) <sup>b</sup>   | Latin America                      | 1.26 (0.15) <sup>c</sup>   |
| Asia                                  | 0.09 (0.16) <sup>a</sup>    | Asia                               | 1.16 (0.15) <sup>c</sup>   |
| New Zealand                           | 0.06 (0.42) <sup>ab</sup>   | New Zealand                        | 2.52 (0.39) <sup>ab</sup>  |
| <b>Protein (Q<sub>C2</sub>)</b>       |                             | <b>Phosphorus (Q<sub>D2</sub>)</b> |                            |
| Southern Europe                       | 0.80 (0.14) <sup>bc</sup>   | Southern Europe                    | 0.44 (0.16) <sup>a</sup>   |
| Northern and Western Europe           | 1.21 (0.14) <sup>a</sup>    | Northern and Western Europe        | –0.19 (0.16) <sup>b</sup>  |
| United States of America              | 1.28 (0.24) <sup>ab</sup>   | United States of America           | 0.51 (0.30) <sup>ab</sup>  |
| Latin America                         | 0.56 (0.15) <sup>c</sup>    | Latin America                      | 0.10 (0.17) <sup>ab</sup>  |
| Asia                                  | 0.85 (0.16) <sup>b</sup>    | Asia                               | –0.02 (0.19) <sup>b</sup>  |
| New Zealand                           | 1.64 (0.42) <sup>abc</sup>  | New Zealand                        | 1.30 (0.55) <sup>ab</sup>  |
| <b>Fat (Q<sub>C3</sub>)</b>           |                             | <b>Potassium (Q<sub>D3</sub>)</b>  |                            |
| Southern Europe                       | 0.45 (0.13) <sup>b</sup>    | Southern Europe                    | –0.18 (0.17)               |
| Northern and Western Europe           | 0.90 (0.14) <sup>a</sup>    | Northern and Western Europe        | 0.01 (0.17)                |
| United States of America              | 1.18 (0.23) <sup>a</sup>    | United States of America           | 0.23 (0.30)                |
| Latin America                         | 0.63 (0.14) <sup>a</sup>    | Latin America                      | –0.21 (0.18)               |
| Asia                                  | 0.21 (0.15) <sup>b</sup>    | Asia                               | –0.02 (0.19)               |
| New Zealand                           | 1.25 (0.40) <sup>ab</sup>   | New Zealand                        | 0.54 (0.54)                |
| <b>Carbohydrates (Q<sub>C4</sub>)</b> |                             | <b>Magnesium (Q<sub>D4</sub>)</b>  |                            |
| Southern Europe                       | –0.84 (0.14) <sup>a</sup>   | Southern Europe                    | 0.15 (0.16) <sup>ab</sup>  |
| Northern and Western Europe           | –0.54 (0.14) <sup>ab</sup>  | Northern and Western Europe        | 0.29 (0.16) <sup>a</sup>   |
| United States of America              | –0.42 (0.25) <sup>ab</sup>  | United States of America           | 0.06 (0.29) <sup>ab</sup>  |
| Latin America                         | –0.28 (0.15) <sup>b</sup>   | Latin America                      | 0.04 (0.17) <sup>ab</sup>  |
| Asia                                  | –0.21 (0.16) <sup>b</sup>   | Asia                               | –0.10 (0.18) <sup>b</sup>  |
| New Zealand                           | –0.05 (0.43) <sup>ab</sup>  | New Zealand                        | 0.44 (0.17) <sup>ab</sup>  |
| <b>Vitamins (Q<sub>C5</sub>)</b>      |                             | <b>Iron (Q<sub>D5</sub>)</b>       |                            |
| Southern Europe                       | 0.60 (0.14) <sup>b</sup>    | Southern Europe                    | –0.38 (0.16) <sup>b</sup>  |
| Northern and Western Europe           | 0.28 (0.14) <sup>c</sup>    | Northern and Western Europe        | –0.78 (0.16) <sup>c</sup>  |
| United States of America              | 1.69 (0.24) <sup>a</sup>    | United States of America           | 0.25 (0.29) <sup>ab</sup>  |
| Latin America                         | 0.55 (0.15) <sup>bc</sup>   | Latin America                      | 0.12 (0.17) <sup>a</sup>   |
| Asia                                  | 0.62 (0.16) <sup>bc</sup>   | Asia                               | –0.05 (0.18) <sup>ab</sup> |
| New Zealand                           | 0.56 (0.43) <sup>abc</sup>  | New Zealand                        | –0.18 (0.45) <sup>ab</sup> |
| <b>Minerals (Q<sub>C6</sub>)</b>      |                             | <b>Iodine (Q<sub>D6</sub>)</b>     |                            |
| Southern Europe                       | 1.16 (0.14) <sup>c</sup>    | Southern Europe                    | –0.60 (0.17) <sup>a</sup>  |
| Northern and Western Europe           | 1.49 (0.14) <sup>b</sup>    | Northern and Western Europe        | –1.24 (0.17) <sup>b</sup>  |
| United States of America              | 2.13 (0.24) <sup>a</sup>    | United States of America           | –0.39 (0.30) <sup>a</sup>  |
| Latin America                         | 0.70 (0.15) <sup>d</sup>    | Latin America                      | –0.58 (0.18) <sup>a</sup>  |
| Asia                                  | 0.75 (0.16) <sup>d</sup>    | Asia                               | –0.56 (0.19) <sup>a</sup>  |
| New Zealand                           | 2.04 (0.42) <sup>abcd</sup> | New Zealand                        | –0.96 (0.54) <sup>ab</sup> |

<sup>a–d</sup>Within each question and column, different superscript indicates  $P < 0.05$  based on a Bonferroni post hoc test.

### **Milk as a Source of Dietary Energy, Protein, Fat, Carbohydrates, and Vitamins**

In line with the results of the present study, Bus and Worsley (2003) reported that individuals consuming milk considered it a product high in calories and fat compared with soymilk. Bus and Worsley (2003) also indicated that milk consumers considered milk as a good source of protein and vitamins. Such a general public perception is supported by scientific evidence showing that milk contributes substantially to both the quantity and quality of protein and vitamin nutrient supplies. Indeed, modeling of global food systems has demonstrated that milk ranks among the top contributors to the availability of protein and indispensable amino acids, as well as providing important supplies of vitamins such as vitamin A and vita-

min B (Smith et al., 2021). Likewise, global analyses of nutrient supplies indicate that milk consistently supplies over 10 % of consumable protein and multiple vitamins, underscoring its role as an important source of these nutrients in human diets (White and Gleason, 2023). As described by O’Neil et al. (2018) in the United States, milk is one of the top food sources of energy, fat, and vitamin D in children up to 18 years of age. In contrast, only flavored milk is listed among the carbohydrate-contributing foods in their diet, accounting for just 1 % of the daily carbohydrate intake (O’Neil et al., 2018). As observed by Lusk (2019), in the United States, consumers perceived high levels of added sugar in food products as unhealthy. However, above 60% of the respondents in Lusk (2019) considered milk a healthy food because it has a balanced carbohydrate and fat content. Moreover,

**Table 7.** The 7-point Likert-type item (from –3 to +3) on milk energy, nutrients (section C), and minerals (section D) across educational status

| Question                         | LSM (SE)                   | Question                      | LSM (SE)                  |
|----------------------------------|----------------------------|-------------------------------|---------------------------|
| Energy (Q <sub>C1</sub> )        |                            | Calcium (Q <sub>D1</sub> )    |                           |
| Doctoral degree                  | 0.17 (0.17) <sup>a</sup>   | Doctoral degree               | 2.06 (0.15) <sup>a</sup>  |
| Bachelor's or master's degree    | 0.03 (0.15) <sup>ab</sup>  | Bachelor's or master's degree | 1.76 (0.14) <sup>b</sup>  |
| Secondary or lower education     | –0.15 (0.16) <sup>b</sup>  | Secondary or lower education  | 1.76 (0.14) <sup>ab</sup> |
| Protein (Q <sub>C2</sub> )       |                            | Phosphorus (Q <sub>D2</sub> ) |                           |
| Doctoral degree                  | 1.29 (0.17) <sup>a</sup>   | Doctoral degree               | 0.60 (0.20) <sup>a</sup>  |
| Bachelor's or master's degree    | 0.99 (0.15) <sup>b</sup>   | Bachelor's or master's degree | 0.34 (0.19) <sup>ab</sup> |
| Secondary or lower education     | 0.88 (0.16) <sup>b</sup>   | Secondary or lower education  | 0.14 (0.19) <sup>b</sup>  |
| Fat (Q <sub>C3</sub> )           |                            | Potassium (Q <sub>D3</sub> )  |                           |
| Doctoral degree                  | 0.92 (0.16) <sup>a</sup>   | Doctoral degree               | 0.14 (0.21)               |
| Bachelor's or master's degree    | 0.77 (0.15) <sup>ab</sup>  | Bachelor's or master's degree | 0.04 (0.19)               |
| Secondary or lower education     | 0.62 (0.15) <sup>b</sup>   | Secondary or lower education  | 0.01 (0.20)               |
| Carbohydrates (Q <sub>C4</sub> ) |                            | Magnesium (Q <sub>D4</sub> )  |                           |
| Doctoral degree                  | –0.21 (0.17) <sup>a</sup>  | Doctoral degree               | 0.23 (0.20)               |
| Bachelor's or master's degree    | –0.41 (0.15) <sup>ab</sup> | Bachelor's or master's degree | 0.10 (0.18)               |
| Secondary or lower education     | –0.55 (0.16) <sup>b</sup>  | Secondary or lower education  | 0.12 (0.19)               |
| Vitamins (Q <sub>C5</sub> )      |                            | Iron (Q <sub>D5</sub> )       |                           |
| Doctoral degree                  | 0.79 (0.17)                | Doctoral degree               | –0.28 (0.19)              |
| Bachelor's or master's degree    | 0.71 (0.16)                | Bachelor's or master's degree | –0.18 (0.18)              |
| Secondary or lower education     | 0.65 (0.16)                | Secondary or lower education  | –0.05 (0.18)              |
| Minerals (Q <sub>C6</sub> )      |                            | Iodine (Q <sub>D6</sub> )     |                           |
| Doctoral degree                  | 1.55 (0.17) <sup>a</sup>   | Doctoral degree               | –0.71 (0.20)              |
| Bachelor's or master's degree    | 1.24 (0.15) <sup>b</sup>   | Bachelor's or master's degree | –0.72 (0.19)              |
| Secondary or lower education     | 1.33 (0.16) <sup>ab</sup>  | Secondary or lower education  | –0.74 (0.19)              |

<sup>a,b</sup>Within each question and column, a different lowercase superscript indicates  $P < 0.05$  based on a Bonferroni post hoc test.

Górska-Warsewicz et al. (2019) reported that milk and dairy products covered the average daily intake in the Polish diet by providing 9.1% of energy, 11.3% of fat, 18.1% of protein, 2.3% of carbohydrate, 13.5% of riboflavin, 10.3% of vitamin B<sub>12</sub>, and 4.4% of vitamin A.

### Milk as a Source of Dietary Calcium

Consistent with the findings of the present study, Bus and Worsley (2003) reported that nearly all whole milk consumers (96%) and the majority of reduced-fat milk (86%) and soymilk (78%) consumers in Melbourne, Australia considered milk as a good source of calcium. This widespread recognition may reflect the impact of nutrition education campaigns, which have been shown to improve knowledge and awareness of dietary calcium (Bronner et al., 2006; Naghashpour et al., 2014). Evidence also suggests that increased knowledge does not always translate into sustained changes in consumption or dietary behaviors. Indeed, although some interventions have successfully modified dietary habits to improve calcium intake (Bronner et al., 2006), other educational initiatives have shown limited effectiveness (Bohaty et al., 2008).

Milk was also the top food dietary source of calcium for 2- to 18-yr-old children in the United States (O'Neil et al., 2018) and accounted for 21.6% of calcium intake in the Polish diet (Górska-Warsewicz et al., 2019).

Accordingly, Smith et al. (2022) reported that milk is the main contributing food item for calcium, providing almost 50% of global nutrient availability, whereas Weaver et al. (2024) underscore the value of milk as a reference food for assessing calcium bioavailability, reflecting its established role in delivering absorbable calcium in typical diets. However, Geller et al. (2022) reported that only 3% of respondents of the Food and Drug Administration in the United States mentioned calcium when asked about their knowledge of milk in open-ended interviews. Moreover, of these, only one-third preferred dairy products over plant-based alternatives due to the high calcium content of the former (Geller et al., 2022). This low consumer awareness may contribute to the observation that global food system modeling still highlights calcium supply as insufficient in many contexts (Smith et al., 2021). In particular, Bailey et al. (2021) reported that due to low intakes, calcium remains a nutrient of public health concern in Americans aged  $\geq 1$  yr. It can be argued that underconsumption of milk and dairy products might be compensated for by higher intakes of nondairy foods. However, Cifelli et al. (2022) demonstrated that nondairy food combinations are not reasonable substitutes for dairy products: whether attempting to replace current intakes ( $\sim 1.8$  servings per day) or the recommended intakes ( $\sim 3$  servings per day), achieving equivalent nutrient intakes would require substantially larger amounts of other

foods, leading to increased calories and higher costs, which appear untenable.

### ***Milk as a Source of Dietary Phosphorus, Potassium, and Magnesium***

In agreement with the results from the present study, Wei and Wang (2023) stated that, based on an online survey, Chinese residents often overlook the association of phosphorus and milk because milk is strongly associated with calcium. Milk plays a notable role in dietary mineral intake. In the Polish diet, milk accounts for 9.4% of total phosphorus, 6.8% of total potassium, and 5.6% of total magnesium intake (Górska-Warsewicz et al., 2019). In the United States, milk was identified as the leading source of the dietary potassium among children up to 18 years of age (O'Neil et al., 2018). The contrasting knowledge on phosphorus content between milk and fish in the present study emphasized the impact of public education and food labeling on creating nutrient awareness.

### ***Milk as a Source of Dietary Iron and Iodine***

In agreement with Górska-Warsewicz et al. (2019), who demonstrated that milk contributes 1.2% to iron intake in the Polish diet, respondents of the present study did not recognize milk as a significant source of dietary iron. Surprisingly, a survey in Melbourne, Australia, found that over one-third of respondents believed milk is a good source of iron (Bus and Worsley, 2003).

The misconception that milk is not a dietary source of iodine may stem from the common association of iodine with seafood (Niero et al., 2024). Moreover, Niero et al. (2024) highlighted that consumers across different geographical areas are generally more conscious of the health benefits of iodine from fish and iodized salt than from dairy products. This aligns with other recent research, indicating that public understanding of dairy food composition and nutrition is often limited. Analyses of consumer comments submitted to the US Food and Drug Administration indicate that many consumers have an incomplete understanding of the calcium content and health implications of dairy products compared with plant-based alternatives, suggesting that even widely recognized dairy nutrients are not fully understood by the general public (Geller et al., 2022). Similarly, surveys conducted in Latin America have documented that the knowledge of fat components in dairy products is consistently low (Vargas-Bello-Pérez et al., 2025). Taken together, these findings reinforce the notion that consumer perceptions of dairy nutrition remain imperfect and that targeted education may be needed to improve understanding of dairy's nutrient contributions across populations.

## **CONCLUSIONS**

Results from this multicountry survey revealed that milk consumers demonstrated greater awareness of milk as a source of dietary energy compared with nonconsumers. Geographical region and educational status were also associated with knowledge of milk as a source of energy, nutrients, and minerals. Respondents correctly identified milk as a good source of calcium and accurately recognized its low iron content. However, misconceptions were evident regarding other minerals; many participants did not recognize milk as a source of iodine, potassium, phosphorus, and magnesium. The findings derived from this survey should be considered when designing nutritional educational campaigns to improve public understanding of milk's nutritional profile, promote balanced dietary choices, and address common misconceptions about bovine milk's nutritional profile.

## **NOTES**

Carmen L. Manuelian received funding from the Ramon y Cajal program of the Spanish Ministry of Science (Madrid, Spain; Grant Ref. RYC2023-042902-I). The authors acknowledge support from Bando 2022 PNRR Prot. P20228RP2Z, "The relevance of iodine in human nutrition: Filling the gap from the farm to the fork." The funders had no role in the study's design, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results. The data presented in this study are available free of charge for any user at the official data repository CORA RDR (<https://doi.org/10.34810/data3169>). Before participation, all participants were required to acknowledge an informed consent statement. Participation was entirely voluntary, anonymous, and reserved for adults, in agreement with the 2013 version of the Declaration of Helsinki for research involving human subjects, as established by the World Medical Association (WMA, 2023). Data collection and processing complied with the General Data Protection Regulation 2016/679 and the Data Protection Act 2018. Participants had the right to withdraw from the study at any time without providing any reason. The authors have not stated any conflicts of interest.

**Nonstandard abbreviations used:** %Nk = percentage of respondents who selected "I do not know."

## **REFERENCES**

- Ares, G., and A. Gámbaro. 2007. Influence of gender, age and motives underlying food choice on perceived healthiness and willingness to try functional foods. *Appetite* 49:148–158. <https://doi.org/10.1016/j.appet.2007.01.006>.

- Bailey, R. L., J. D. Ard, T. A. Davis, T. S. Naimi, B. O. Schneeman, J. S. Stang, K. G. Dewey, S. M. Donovan, R. Novotny, L. G. Snetselaar, J. de Jesus, K. O. Casavale, T. R. Pannucci, and E. E. Stookey. 2021. A proposed framework for identifying nutrients and food components of public health relevance in the Dietary Guidelines for Americans. *J. Nutr.* 151:1197–1204. <https://doi.org/10.1093/jn/nxaa459>.
- Bohaty, K., H. Rocolle, K. Wehling, and N. Waltman. 2008. Testing the effectiveness of an educational intervention to increase dietary intake of calcium and vitamin D in young adult women. *J. Am. Acad. Nurse Pract.* 20:93–99. <https://doi.org/10.1111/j.1745-7599.2007.00281.x>.
- Brink, E. J., P. R. Dekker, E. C. Van Beresteijn, and A. C. Beynen. 1992. Bioavailability of magnesium and calcium from cow's milk and soya-bean beverage in rats. *Br. J. Nutr.* 68:271–282. <https://doi.org/10.1079/BJN19920084>.
- Bronner, Y. I., A. S. Hawkins, M. L. Holt, M. B. Hossain, R. H. Rowel, K. L. Sydnor, and S. P. Divers. 2006. Models for nutrition education to increase consumption of calcium and dairy products among African Americans. *J. Nutr.* 136:1103–1106. <https://doi.org/10.1093/jn/136.4.1103>.
- Bus, A. E. M., and A. Worsley. 2003. Consumers' sensory and nutritional perceptions of three types of milk. *Public Health Nutr.* 6:201–208. <https://doi.org/10.1079/PHN2002417>.
- Capuano, E., and A. E. Janssen. 2021. Food matrix and macronutrient digestion. *Annu. Rev. Food Sci. Technol.* 12:193–212. <https://doi.org/10.1146/annurev-food-032519-051646>.
- Cashman, K. D. 2006. Milk minerals (including trace elements) and bone health. *Int. Dairy J.* 16:1389–1398. <https://doi.org/10.1016/j.idairyj.2006.06.017>.
- Castillo, J. P., H. Rui, D. Basilio, A. Das, B. Roux, R. Latorre, F. Bezanilla, and M. Holmgren. 2015. Mechanism of potassium ion uptake by the Na<sup>+</sup>/K<sup>+</sup>-ATPase. *Nat. Commun.* 6:7622. <https://doi.org/10.1038/ncomms8622>.
- Chrysant, S. G., and G. S. Chrysant. 2013. An update on the cardiovascular pleiotropic effects of milk and milk products. *J. Clin. Hypertens. (Greenwich)* 15:503–510. <https://doi.org/10.1111/jch.12110>.
- Cifelli, C. J., N. Auestad, and V. L. Fulgoni III. 2022. Replacing the nutrients in dairy foods with non-dairy foods will increase cost, energy intake and require large amounts of food: National Health and Nutrition Examination Survey 2011–2014. *Public Health Nutr.* 25:332–343. <https://doi.org/10.1017/S1368980020001937>.
- Del Valle, H. B., A. L. Yaktine, C. L. Taylor, and A. C. Ross. 2011. *Dietary Reference Intakes for Calcium and Vitamin D*. National Academies Press, Washington, DC.
- Dillman, D. A. 2000. *Mail and Internet surveys: The Tailored Design Method*. 2nd ed. John Wiley & Sons Inc.
- DPA. 2018. Data Protection Act. Accessed Apr. 3, 2026. <https://www.legislation.gov.uk/ukpga/2018/12/contents>.
- Dufour, S., H. W. Barkema, L. Des Côteaux, T. J. DeVries, I. R. Dohoo, K. Reyher, J. P. Roy, and D. T. Scholl. 2010. Development and validation of a bilingual questionnaire for measuring udder health related management practices on dairy farms. *Prev. Vet. Med.* 95:74–85. <https://doi.org/10.1016/j.prevetmed.2010.02.018>.
- Elbon, S. M., M. A. Johnson, and J. G. Fischer. 1996. Developing an instrument to measure the influence of knowledge, behaviors, and attitudes on milk consumption patterns in older participants of a community wellness group: a pilot study. *J. Nutr. Elder.* 15:21–37. [https://doi.org/10.1300/J052v15n04\\_03](https://doi.org/10.1300/J052v15n04_03).
- FDA (U.S. Food and Drug Administration). 2021. *Vitamins and Minerals Chart*. Accessed Jun. 3, 2025. <https://www.accessdata.fda.gov/scripts/InteractiveNutritionFactsLabel/factsheets.cfm>.
- GFPR. 2016. General Data Protection Regulation. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). Accessed Apr. 3, 2026. <http://data.europa.eu/eli/reg/2016/679/oj>.
- Geller, S. G., B. E. Clark, L. Pope, M. T. Niles, and E. H. Belarmino. 2022. Investigating knowledge on calcium and preferences for dairy vs. plant-based alternatives. *J. Healthy Eat. Act. Living.* 2:60–72. <https://doi.org/10.51250/jheal.v2i2.42>.
- Giansanti, F., G. Panella, L. Leboffe, and G. Antonini. 2016. Lactoferrin from milk: nutraceutical and pharmacological properties. *Pharmaceuticals (Basel)* 9:61. <https://doi.org/10.3390/ph9040061>.
- Górska-Warszewicz, H., K. Rejman, W. Laskowski, and M. Czacotko. 2019. Milk and dairy products and their nutritional contribution to the average polish diet. *Nutrients* 11:1771. <https://doi.org/10.3390/nu11081771>.
- Greupner, T., I. Schneider, and A. Hahn. 2017. Calcium bioavailability from mineral waters with different mineralization in comparison to milk and a supplement. *J. Am. Coll. Nutr.* 36:386–390. <https://doi.org/10.1080/07315724.2017.1299651>.
- Gulseven, O., and M. Wohlgenant. 2017. What are the factors affecting the consumers' milk choices? *Zemed. Ekon.* 63:271–282. <https://doi.org/10.17221/335/2015-AGRICECON>.
- Hodges, J. K., S. Cao, D. P. Cladis, and C. M. Weaver. 2019. Lactose intolerance and bone health: The challenge of ensuring adequate calcium intake. *Nutrients* 11:718. <https://doi.org/10.3390/nu11040718>.
- Lusk, J. L. 2019. Consumer beliefs about healthy foods and diets. *PLoS One* 14:e0223098. <https://doi.org/10.1371/journal.pone.0223098>.
- Lynch, S. R. 2000. The effect of calcium on iron absorption. *Nutr. Res. Rev.* 13:141–158. <https://doi.org/10.1079/095442200108729043>.
- Manuelian, C. L., S. Valleix, H. Bugaut, B. Fuerst-Waltl, L. da Costa, S. Burbi, U. Schmutz, A. Evans, N. Katsoulas, S. Faliagka, U. Aksoy, Ö. Çiçekli, D. Drózd, K. Malińska, L. Whistance, M. Johnson, L. Knebl, F. Righi, and M. De Marchi. 2023. Farmers concerns in relation to organic livestock production. *Ital. J. Anim. Sci.* 22:1268–1282. <https://doi.org/10.1080/1828051X.2023.2252005>.
- Moreira, P. A., and P. D. Padrão. 2004. Educational and economic determinants of food intake in Portuguese adults: A cross-sectional survey. *BMC Public Health* 4:58. <https://doi.org/10.1186/1471-2458-4-58>.
- Naghashpour, M., G. Shakerinejad, M. R. Lourizadeh, S. Hajinajaf, and F. Jarvandi. 2014. Nutrition education based on health belief model improves dietary calcium intake among female students of junior high schools. *J. Health Popul. Nutr.* 32:420–429.
- Niero, G., S. Censi, C. Mian, C. L. Manuelian, M. Rovai, E. Tsiplakou, L. da Costa, B. Fuerst-Waltl, A. G. Cruz, D. P. Berry, N. Lopez-Villalobos, A. Masi, R. Rakwal, G. Hambarzumyan, F. Borrisser-Pairó, M. Koczura, L. M. Trujillo Rojas, E. Albanell, S. Guaman Rivera, S. González-Luna, J. Berard, and M. De Marchi. 2024. Low public awareness opens up new opportunities for highlighting milk as an iodine dietary source. *J. Dairy Sci.* 107:10231–10243. <https://doi.org/10.3168/jds.2024-25030>.
- Niero, G., G. Visentin, S. Censi, F. Righi, C. L. Manuelian, A. Formigoni, C. Mian, J. Bérard, M. Cassandro, M. Penasa, S. Moore, A. Costa, and M. De Marchi. 2023. Invited review: Iodine level in dairy products—A feed-to-fork overview. *J. Dairy Sci.* 106:2213–2229. <https://doi.org/10.3168/jds.2022-22599>.
- Nilsson, Å., R. D. Duan, and L. Ohlsson. 2021. Digestion and absorption of milk phospholipids in newborns and adults. *Front. Nutr.* 8:724006. <https://doi.org/10.3389/fnut.2021.724006>.
- O'Neil, C. E., T. A. Nicklas, and V. L. Fulgoni III. 2018. Food sources of energy and nutrients of public health concern and nutrients to limit with a focus on milk and other dairy foods in children 2 to 18 years of age: National Health and Nutrition Examination Survey, 2011–2014. *Nutrients* 10:1050. <https://doi.org/10.3390/nu10081050>.
- OECD-FAO (Organisation for Economic Co-operation and Development and Food and Agriculture Organization of the United Nations). 2025. *OECD-FAO Agricultural Outlook 2025–2034*. Accessed Sep 17, 2025. <https://doi.org/https://doi.org/10.1787/601276cd-en>.
- Oh, H. E., and H. C. Deeth. 2017. Magnesium in milk. *Int. Dairy J.* 71:89–97. <https://doi.org/10.1016/j.idairyj.2017.03.009>.
- Prescott, J. 1998. Comparisons of taste perceptions and preferences of Japanese and Australian consumers: Overview and implications for cross-cultural sensory research. *Food Qual. Prefer.* 9:393–402. [https://doi.org/10.1016/S0950-3293\(98\)00021-4](https://doi.org/10.1016/S0950-3293(98)00021-4).
- Rizzo, P. V., W. S. Harwood, and M. A. Drake. 2020. Consumer desires and perceptions of lactose-free milk. *J. Dairy Sci.* 103:6950–6966. <https://doi.org/10.3168/jds.2019-17940>.

- Rozin, P. 2005. The meaning of food in our lives: A cross-cultural perspective on eating and well-being. *J. Nutr. Educ. Behav.* 37:S107–S112. [https://doi.org/10.1016/S1499-4046\(06\)60209-1](https://doi.org/10.1016/S1499-4046(06)60209-1).
- Shkempi, B., and T. Huppertz. 2021. Calcium absorption from food products: Food matrix effects. *Nutrients* 14:180. <https://doi.org/10.3390/nu14010180>.
- Smith, N. W., A. J. Fletcher, L. A. Dave, J. P. Hill, and W. C. McNabb. 2021. Use of the DELTA model to understand the food system and global nutrition. *J. Nutr.* 151:3253–3261. <https://doi.org/10.1093/jn/nxab199>.
- Smith, N. W., A. J. Fletcher, J. P. Hill, and W. C. McNabb. 2022. Modeling the contribution of milk to global nutrition. *Front. Nutr.* 8:716100. <https://doi.org/10.3389/fnut.2021.716100>.
- Stone, M. S., L. Martyn, and C. M. Weaver. 2016. Potassium intake, bioavailability, hypertension, and glucose control. *Nutrients* 8:444. <https://doi.org/10.3390/nu8070444>.
- Thorning, T. K., H. C. Bertram, J. P. Bonjour, L. de Groot, D. Dupont, E. Feeney, R. Ipsen, J. M. Lecerf, A. Mackie, M. C. McKinley, M.-C. Michalski, D. Rémond, U. Risérus, S. S. Soedamah-Muthu, T. Tholstrup, C. Weaver, A. Astrup, and I. Givens. 2017. Whole dairy matrix or single nutrients in assessment of health effects: Current evidence and knowledge gaps. *Am. J. Clin. Nutr.* 105:1033–1045. <https://doi.org/10.3945/ajcn.116.151548>.
- Vargas-Bello-Pérez, E., I. Faber, J. S. Osorio, and S. Stergiadis. 2020. Consumer knowledge and perceptions of milk fat in Denmark, the United Kingdom, and the United States. *J. Dairy Sci.* 103:4151–4163. <https://doi.org/10.3168/jds.2019-17549>.
- Vargas-Bello-Pérez, E., P. Toro-Mujica, A. Chávez Martínez, K. Tajonar, A. Ainslie, J. P. Keim, J. Baudracco, and N. Ghavipanje. 2025. Knowledge, attitudes, and perceptions toward dairy fat and consumption of dairy fat in Mexico, Chile, and Argentina. *J. Dairy Res.* 92:297–305. <https://doi.org/10.1017/S0022029925100927>.
- Verbeke, W. 2006. Functional foods: Consumer willingness to compromise on taste for health? *Food Qual. Prefer.* 17:126–131. <https://doi.org/10.1016/j.foodqual.2005.03.003>.
- Visentin, G., M. Penasa, G. Niero, M. Cassandro, and M. De Marchi. 2018. Phenotypic characterisation of major mineral composition predicted by mid-infrared spectroscopy in cow milk. *Ital. J. Anim. Sci.* 17:549–556. <https://doi.org/10.1080/1828051X.2017.1398055>.
- Weaver, C. M., M. Wastney, A. Fletcher, and K. Lividini. 2024. An algorithm to assess calcium bioavailability from foods. *J. Nutr.* 154:921–927. <https://doi.org/10.1016/j.tjnut.2023.12.005>.
- Wei, J., and J. Wang. 2023. Chinese residents' knowledge about and behavior towards dairy products: A cross-sectional study. *BMC Public Health* 23:374. <https://doi.org/10.1186/s12889-023-15254-1>.
- White, R. R., and C. B. Gleason. 2023. Global contributions of milk to nutrient supplies and greenhouse gas emissions. *J. Dairy Sci.* 106:3287–3300. <https://doi.org/10.3168/jds.2022-22508>.
- WMA (World Medical Association). 2023. Declaration of Helsinki. Accessed Dec. 20, 2024. <https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/>.
- Zandstra, E. H., C. de Graaf, and H. van Trijp. 2000. Effects of variety and repeated in-home consumption on product acceptance. *Appetite* 35:113–119. <https://doi.org/10.1006/appe.2000.0342>.

## ORCIDS

- Carmen L. Manuelian, <https://orcid.org/0000-0002-0090-0362>
- Caterina Mian, <https://orcid.org/0000-0003-2615-8001>
- Maristela Rovai, <https://orcid.org/0000-0001-9201-1505>
- Eleni Tsiplakou, <https://orcid.org/0000-0002-2544-8966>
- Luciana da Costa, <https://orcid.org/0000-0001-9514-4047>
- Birgit Fuerst-Waltl, <https://orcid.org/0000-0002-4336-5830>
- Adriano G. Cruz, <https://orcid.org/0000-0002-9285-9669>
- Donagh P. Berry, <https://orcid.org/0000-0003-4349-1447>
- Nicolas Lopez-Villalobos, <https://orcid.org/0000-0001-6611-907X>
- Antonio Masi, <https://orcid.org/0000-0003-0536-5984>
- Randeep Rakwal, <https://orcid.org/0000-0003-0559-8577>
- Garegin Hambardzumyan, <https://orcid.org/0000-0002-1942-7819>
- Francesc Borrissier-Pairó, <https://orcid.org/0000-0002-9196-394X>
- Lina Maria Trujillo Rojas, <https://orcid.org/0000-0003-0082-4109>
- Elena Albanell, <https://orcid.org/0000-0002-6158-7736>
- Sandra González-Luna, <https://orcid.org/0000-0001-8011-9463>
- Giovanni Niero, <https://orcid.org/0000-0002-6169-1162>
- Massimo De Marchi <https://orcid.org/0000-0001-7814-2525>