

## Investigating Knowledge on Calcium and Preferences for Dairy vs. Plant-Based Alternatives

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### Abstract

Calcium is a nutrient of public health concern and commonly associated with dairy foods. In recent years, plant-based alternatives to dairy products have grown in popularity. This study examines public understanding of dietary calcium in dairy products and plant-based alternatives and explores whether knowledge is associated with product preference. In 2018, the U.S. Food and Drug Administration (FDA) solicited comments on the labeling of plant-based dairy alternatives (FDA-2018-N-3522), including input on consumer understanding of the nutritional content of dairy foods and plant-based products. All 11,906 submissions were obtained and 8,052 were retained after duplicate and near-duplicate comments were removed. Comments were coded for major nutrition themes and those that mentioned calcium and were analyzed for three calcium-specific themes: knowledge and beliefs about calcium content, calcium bioavailability, and health outcomes associated with intake. Submissions were examined in relation to each commenter's preference for dairy products or plant-based alternatives. 244 unique submissions (3.0%) mentioned calcium. Over half (51.2%) of commenters who mentioned calcium preferred plant-based alternatives. Comments mentioning calcium often reflected preference. Most commenters had an accurate understanding of calcium content in dairy and plant-based products. However, several commenters—especially those who preferred plant-based alternatives—misunderstood calcium metabolism and health outcomes related to calcium. Given declining consumption of fluid dairy milk—a key source of dietary calcium—and increasing consumption of plant-based alternatives, addressing gaps in nutrition knowledge and misunderstanding related to dairy and calcium intake is critical and has implications for nutrition education and policy.

**Keywords:** calcium, milk, health, metabolism, plant-based nutrition, dairy products

The Dietary Guidelines for Americans (DGA) promote daily dairy intake on account of evidence that it supports bone health and contributes several key nutrients to the diet, including calcium, phosphorous, vitamin A, vitamin D (in products fortified with vitamin D), riboflavin, vitamin B12, and protein (U.S. Department of Agriculture & U.S. Department of Health and Human Services [USDA & USDHHS], 2020). However, intake of fluid milk has been declining since the 1970s due to lower intake among younger generations and a drop in milk intake at midday and evening meals (Stewart et al., 2013). Today, nine in ten Americans do not meet the dairy recommendation (Stewart et al., 2013; USDA & USDHHS, 2020). In recent years, plant-based alternatives to dairy have grown in popularity. In the past two years, dollar sales of plant-based products sold as ‘milk,’ such as soy, almond, rice, coconut, oat, and hemp ‘milks’ grew by 27% (Retail sales data: Plant-based meat, eggs, dairy, 2021). Of these products, only soy beverages and soy yogurt fortified with calcium, vitamin A, and vitamin D (commonly known as soy “milk”) are included in the dairy group in the DGA because they are considered similar to milk and yogurt in nutrient composition and use in meals (USDA & USDHHS, 2020).

One important nutrient that varies in content between dairy products and plant-based alternatives is calcium; plant-based alternatives may be fortified with calcium, while dairy contains naturally occurring calcium. Calcium is necessary for heart, muscle, and nerve function, and plays a role in blood clotting (Calcium, 2021). Additionally, calcium supports the structure and function of bones and teeth, and adequate calcium intake has been associated with lower rates of osteoporosis (Calcium, 2021). Yet, calcium is under-consumed by many Americans, making it a nutrient of public health concern (Calcium, 2021; USDA & USDHHS, 2020). Using data from the National Health and Nutrition Examination Survey (NHANES) from 2013-2014 and 2015-2016, a study funded by the National Dairy Council found that almost 60% of Americans over the age of two who did not meet dairy recommendations also failed to meet the Estimated Average Requirement (EAR) for calcium (Hess et al., 2020). A separate food pattern modeling analysis showed that calcium intake drops by 68-88% in all age and sex groups when no dairy is consumed (Dietary Guidelines Advisory Committee, 2015).

There is limited data on the bioavailability of calcium, i.e., the amount of calcium that is absorbed and utilized by a person’s body, in fortified plant-based beverages compared to dairy products (Singhal et al., 2017). The bioavailability of calcium from dairy products and calcium-fortified plant-based alternatives may differ based on various factors, including interactions with other nutrients and food components, the type of calcium supplement used in fortification, and the sedimentation of fortified calcium (Calcium, 2021; Chalupa-Krebsdak et al., 2018; Golden et al., 2014; Heaney et al., 2005; Mäkinen et al., 2016; Singhal et al., 2017; Zhao et al., 2005). One bioavailability study found an equivalent amount of calcium-fortified soy “milk” provided the same proportion of absorbable calcium

as cow’s milk when fortified with calcium citrate and a slightly lower proportion of absorbable calcium when fortified with tricalcium phosphate (Zhao et al., 2005).

The complexities of calcium nutrition in dairy and plant-based alternatives, as well as some discrepant research findings related to dairy intake and health outcomes (Bian et al., 2018; Bischoff-Ferrari et al., 2011; Feskanich et al., 2014; Matía-Martín et al., 2019; Vogel et al., 2017; Willett & Ludwig, 2020; Zhang et al., 2021), may impact consumer understanding of the calcium they receive from these foods. Yet there is limited research on consumer understanding of nutrition in dairy and plant-based alternatives. A 2002 study conducted with shoppers in Melbourne, Australia found the majority of respondents believed that both dairy milk and soy “milk” were good sources of calcium, which is in line with the DGA (Bus & Worsley, 2003; USDA & USDHHS, 2020). In the U.S., the National Dairy Council and Dairy Management Inc. recently commissioned a study of consumer perceptions of nutritional content of dairy milk and plant-based alternatives. According to the report, over 60% of consumers perceived plant-based “milk” alternatives—specifically those made from almond, soy, and coconut—as having the same or more key nutrients as dairy milk, which may (or may not) be accurate depending on fortification (Consumer perceptions: Dairy milk and plant-based milk alternatives, 2018). These beliefs could potentially influence demand.

With the growth of the market for plant-based dairy alternatives, some stakeholders have raised concern that the use of dairy terms including “milk,” “cheese,” and “yogurt,” on plant-based alternatives’ labels may mislead consumers who do not recognize that most are nutritionally different from dairy (Welch, Leahy introduce bipartisan bill to stop the labeling of non-dairy products as “milk”, 2019). With support from the dairy industry, a bill was introduced to Congress in 2017 that would prohibit products that do not come from a hooved animal from being labeled using dairy terms (DAIRY PRIDE Act, 2020). The bill, “Defending Against Imitations and Replacements of Yogurt, Milk, and Cheese to Promote Regular Intake of Dairy Everyday Act” or the DAIRY PRIDE Act, failed to pass initially and was reintroduced in 2019 and 2021. In part prompted by this, in 2018, the U.S. Food and Drug Administration (FDA)—the agency responsible for enforcing labeling guidelines—issued a request for public comments on this topic by establishing a docket in the Federal Register (No. FDA-2018-N-3522) (Use of the Names of Dairy Foods in the Labeling of Plant-Based Products, 2018). Among other things, the FDA specifically asked for comment about “consumer understanding regarding the basic nature, characteristics, and properties of these plant-based products,” and “consumer understanding of the nutritional content of plant-based products and dairy foods and the effect, if any, on consumer purchases and use” (FDA, 2018). The Federal Register is the official journal of the U.S. Government that publishes final rules, proposed rules, and public notices to inform citizens about government decisions and proposals. The public is invited

to submit comments on proposed rules by mail, fax, email, or online at Regulations.gov, and agencies are required to consider public comments and justify decisions regarding finalizing, changing, or withdrawing proposed rules (Federal Register tutorial, 2018).

In this paper, we used public comment data submitted in response to this FDA docket to explore commenters' understanding of calcium in dairy products and plant-based alternatives. Our objectives were to determine if knowledge about calcium in dairy vs. plant-based alternatives is associated with product preference and examine the degree to which commenters' understanding of calcium in these products align with current science. Understanding the public's knowledge of the nutritional content of dairy products and plant-based alternatives is critical to current and future food and nutrition policymaking, rulemaking, and policy and program implementation.

### Methods

The FDA accepted public submissions on FDA-2018-N-3522 from September 28, 2018 to January 28, 2019. A total of 11,906 comments of varying length and detail were received by the deadline. We retrieved all comments submitted by the deadline and self-reported commenter characteristics, including country and state or province of residence, and submitter category (e.g., individual consumer, food industry, other industry, health professional, and academia, among others) using a Freedom of Information Act (FOIA) request. This study was deemed exempt by the Institutional Review Board (IRB) at the University of Vermont because the U.S. Federal Register is a public database and commenters are made aware before submission that their comments will become publicly available.

We used a mixed methods approach to summarize and analyze the comments. Following template analysis, we developed a basic coding framework a priori and applied this to four random samples of 20-40 comments (Andriotis, 2010; King, n.d.a, n.d.b). As a team, we met to discuss the adequacy of the coding framework, refined codes, created new codes to capture additional dimensions of the data, and came to consensus on when and how the framework should be applied. The final codebook consisted of characteristic codes (capturing self-described characteristics of commenters, including their preference for dairy products or plant-based alternatives) and content codes (capturing main themes in the data, including discussion of nutrition and health topics related to calcium). Coding consistency using the final codebook was checked between each coder and the principal investigator using a sample of data prior to independent coding. The codebook used for this study, including codes relevant to the present analysis, is provided in Supplementary File 1. As new members joined the coding team, they were given comprehensive training on how to apply the codebook and completed sample coding to check consistency before starting to code independently. Seven coders used the final codebook to code all 11,906 comments in NVivo version 12. Once

coding was complete, two team members reviewed the content assigned to each code, discussed any suggested changes, and updated the coding based on the discussion. We retained one copy of each duplicate submission and form letter and removed the remainder from the dataset (Dinour & Pole, 2017). We also removed off-topic and unusable comments (e.g., those that could not be opened, those in a language other than English, and those submitted by minors). After the removal process was complete, a total of 8,052 comments remained eligible for analysis (Supplementary File 2 includes a figure of the comment refinement process).

The present analysis focuses exclusively on the subset of comments that mentioned calcium ( $n = 244$ ). These comments either stated the term "calcium" or contained phrases that implied a discussion of calcium (e.g., "milk is the leading food source of three of the four nutrients of public health concern"). We used chi-square tests to examine differences in characteristics between commenters who discussed calcium and commenters who did not. Differences were statistically significant if  $P < 0.05$ .

Based on multiple reads of the data, the first author identified major and minor themes throughout the comments that discussed calcium and drafted a code memo to summarize these themes. A second team member read the data and reviewed the code memo to confirm and refine interpretations. Based on consensus reached by the two researchers, the first author added new codes to capture knowledge and beliefs related to three dimensions of calcium nutrition—calcium content, bioavailability, and associated health outcomes—and applied these codes to the comments that discussed calcium, as relevant. A second team member reviewed the content assigned to these new codes and met with the first author to discuss discrepancies. The final coding reflects the decisions from this discussion. We used matrix coding queries to compare submissions discussing calcium from respondents with different "milk" preferences: those who prefer dairy, those who prefer plant-based alternatives, those who consume both, and those with an unclear or neutral preference. We qualified how we reported the data based on the proportion of commenters who shared a response related to each theme (calcium content, bioavailability, and health outcomes) within a preference group: "most" means more than two-thirds; "many" indicates between half and two-thirds; "some" indicates at least one-quarter but less than half; and "a few" or "several" mean less than one-quarter of respondents (Morgan et al., 2018).

### Results

Characteristics for all 8,052 commenters who submitted unique comments and the 244 (3.0%) that discussed calcium are presented in Table 1. Commenters came from across the U.S., and most were individual consumers or represented a food industry or association. About one in three (36.0%) discussed nutrition and health aspects of dairy and/or plant-based alternatives (including themes related to calcium) in their submissions (data not shown).

There were significant differences between commenters who mentioned calcium and those who did not with respect to product preference ( $P < 0.001$ ). About half in both groups (51.2% vs. 49.6%) preferred plant-based alternatives. Compared to those who did not mention

calcium, respondents who mentioned calcium were more likely to prefer dairy and consume both dairy and plant-based products and less likely to have an unclear or neutral preference (all  $P < 0.001$ , data not shown).

Table 1. Characteristics of All Commenters on Federal Register Docket No. FDA-2018-N-3522.

	All respondents (n=8,052)		Respondents who mentioned calcium (n=244)		Respondents who did not mention calcium (n=7,808)		P-value
	n	%	n	%	n	%	
<b>Geographical Census Region</b>							0.09
Northeastern U.S.	668	8.3	27	11.1	641	8.2	
Midwestern U.S.	717	8.9	29	11.9	688	8.8	
Southern U.S.	853	10.6	29	11.9	824	10.6	
Western U.S.	1163	14.4	27	11.1	1136	14.5	
Did not specify or other country	4651	57.8	132	54.1	4519	57.9	
<b>Submitter Category</b>							< 0.001
Individual Consumer	5415	67.2	134	54.9	5281	67.6	
Food Industry/ Association	1591	19.8	47	19.3	1544	19.8	
Health Professional	154	1.9	17	7.0	137	1.8	
Other	892	11.1	46	18.9	846	10.8	
<b>Product Preference</b>							< 0.001
Prefer dairy products	599	7.4	72	29.5	527	6.7	
Prefer plant-based products	4000	49.7	125	51.2	3875	49.6	
Consume both plant-based and dairy products	129	1.6	14	5.7	115	1.5	
Unclear or neutral preference	3324	41.2	33	13.5	3291	42.1	

Source: Author.

Note. Values of  $P < 0.05$  considered statistically significant. Chi-square tests of independence reflect differences between respondents who mentioned calcium and respondents who did not mention calcium.

Comments that discussed calcium content, calcium bioavailability, and health outcomes associated with calcium, were quantified in relation to product preference in Table 2. Over four-fifths (81.1%;  $n = 198$ ) of submissions that mentioned calcium discussed the calcium

content of dairy products, plant-based alternatives, or both; 8% ( $n = 20$ ) explored bioavailability and absorption; and 27% ( $n = 65$ ) noted health outcomes associated with calcium intake or lack thereof.

Table 2. Proportion of Comments Pertaining to Each Calcium Theme by Product Preference

	Any preference <sup>a</sup>	Prefer dairy products	Prefer plant-based products	Consume both plant-based and dairy products	Unclear or neutral preference
<b>Calcium content</b>	198 (100.0%)	66 (33.3%)	95 (48.0%)	9 (4.5%)	28 (14.1%)
<b>Calcium bioavailability</b>	20 (100.0%)	8 (40.0%)	11 (55.0%)	1 (5.0%)	0 (0.0%)
<b>Health benefits/problems associated with calcium intake</b>	67 (100.0%)	32 (47.8%)	29 (43.3%)	1 (1.5%)	5 (7.5%)

Source: Author.

\* Numbers do not sum to 100% (n=244) due to comments being coded across multiple themes and some comments that mentioned other ideas related to calcium, besides calcium content, bioavailability, and health benefits/problems associated with calcium intake.

### Commenters Who Prefer Dairy Products

**Calcium content.** Almost one third (29.5%; n = 72) of commenters who commented on calcium content preferred dairy products. Many accurately emphasized that dairy products are a good source of calcium and discussed calcium in addition to other nutrients (e.g., vitamin D, protein, potassium, vitamin A). Some accurately noted that dairy naturally contains many nutrients, including calcium, and/or that plant-based products must be fortified in order to contain the same nutrients.

“Dairy milk is a proven natural source of high-quality protein, calcium, phosphorus, riboflavin and vitamin B12.”—Association, NY

“Through fortification – not naturally-occurring – some almond beverages contain more calcium, thiamin and vitamin E.”—Association, location not specified

Some commenters who preferred dairy products claimed that plant-based products are nutritionally inferior and/or that cow’s milk is nutritionally superior.

“...dairy milk is a better source than non-dairy milk drink for children to intake bone building nutrients.”—Health Professional, location not specified

“Dairy cow’s milk is a more natural, less manufactured product than plant based beverages, and more importantly it is vastly superior for protein, healthy fat, and calcium content.”—Food Industry, WI

A few commenters discussed the DGA in relation to calcium or noted the DGA’s guidance on plant-based alternatives and how plant-based alternatives may contain calcium, but are not included in the dairy group, except for fortified soy beverages.

“The federal government has dictated in its own dietary guidelines that most of these [plant-based] products aren’t [sic] part of the dairy group because of their nutritional

profile. The USDA’s website, [www.choosemyplate.gov](http://www.choosemyplate.gov), clearly indicates that there are calcium choices for those who do not consume dairy products, though they are not part of the Dairy Group.”—Individual Consumer, OH

Several commenters used the reasoning that plant-based products are not nutritionally equivalent, and therefore, labeling them with dairy terms or related nutrient content claims is misleading. A few cited a survey from the market research firm IPSOS which found a lower proportion of plant-based beverage buyers believed milk was a good source of calcium as compared to dairy drinkers.

“The labeling for these plant-based beverages often suggests they are the ‘perfect substitute’ [external reference] for dairy milk or a ‘nutritious milk replacement’ [external reference] and compare levels of their nutrients to those in dairy milk (e.g., ‘as much calcium as dairy milk’ [external reference]).”—Association, location not specified

“The vast majority believe that the protein content as well as significant nutrients such as Vitamin A, D and Calcium are similar in products if labelled milk!”—Food Industry, IL

**Bioavailability.** Eight commenters who preferred dairy products discussed bioavailability. These comments noted that calcium from dairy is more bioavailable than calcium from plant-based alternatives, which may be accurate depending on a variety of factors influencing absorption; accurately discussed factors that influence bioavailability; and/or mentioned the role of vitamin D in helping with calcium absorption (Calcium, 2021; Chalupa-Krebsdak et al., 2018; Golden et al., 2014; Heaney et al., 2005; Mäkinen et al., 2016; Singhal et al., 2017; Zhao et al., 2005).

“...fortificants like tricalcium carbonate are not always as bioavailable as naturally-occurring vitamins and minerals... There is even evidence that the minerals added to plant-based beverages can precipitate from the solution,

making it unlikely that each serving provides a reliable source of these nutrients”—Food Industry, NY

**Health outcomes.** Almost half of commenters who commented on health outcomes they associated with calcium intake preferred dairy products (48%; n = 32). Some mentioned the importance of dairy and/or calcium in dairy to children’s and adolescent’s development and growth and/or adult health. Some mentioned dairy and/or calcium’s role in preventing osteoporosis or in bone building, maintenance, and/or health. This aligns with current public health messaging, but the strength of the underlying evidence recently has been challenged and debated (USDA & USDHHS, 2020; Bian et al., 2018; Bischoff-Ferrari et al., 2011; Feskanich et al., 2014; Matia-Martín et al., 2019; Vogel et al., 2017; Willett & Ludwig, 2020; Zhang et al., 2021).

“Milk supplies: Bone building nutrients—Calcium, Vitamin D and phosphorus”—Individual Consumer, PA

“As a RN, I encourage my patients to drink milk and use dairy products to prevent osteopenia and osteoporosis. I have cared for too many patients that have fractures that could have been prevented by a higher calcium intake from dairy products.”—Health Professional, IN

Several accurately mentioned that calcium is a nutrient of public health concern and that many Americans under-consume or are deficient in calcium, which milk contains. Some noted that inadequate intake of nutrients like calcium can lead to poor health outcomes like issues with bone health, with an emphasis on the belief that consuming plant-based products in place of dairy could lead to nutrient deficiencies.

“Dairy products are already under-consumed by Americans, according to the Dietary Guidelines for Americans, but even at current levels of consumption (1.7 servings/day), milk is the leading food source of three of the four nutrients of public concern - calcium, vitamin D and potassium - in the diet of American children and adults. Thus, the potential for adverse dietary impacts on overall health posed by consumption of plant-based beverages exclusive of milk are real.”—Private Industry, location not specified

“When I read of youngsters with diseases related to lack of protein or calcium because their mothers were feeding them something they thought was milk and was not, I am saddened.”—Individual Consumer, PA

“Nutrients from dairy foods are difficult to replace in a healthy diet, and if plant-based products are substituted in place of milk, Americans may find themselves nutrient deficient. [external reference]”—Food Industry, WI

### Commenters Who Prefer Plant-Based Alternatives

**Calcium content.** Almost half (48%; n = 95) of commenters who addressed calcium content preferred

plant-based alternatives. Some accurately identified dairy products as a source of calcium. However, a few incorrectly stated that dairy products are not a good source of calcium or reported that milk was fortified with calcium (rather than being naturally rich in calcium). Several comments mentioned that plant-based alternatives to dairy are fortified with calcium. Some claimed that plant-based alternatives, particularly almond “milk” and soy “milk,” have more calcium than dairy products, while a few stated that plant-based alternatives have similar amounts of calcium as dairy products. These claims may or may not be true, depending on the amount of calcium fortified within the plant-based product, which can vary between brands and products (Chalupa-Krebzdzak et al., 2018; Mäkinen et al., 2016; USDA & USDHHS, 2020; Verduci et al., 2019). A few commenters used their belief of adequate calcium content in plant-based alternatives to support the argument that plant-based product labels should be allowed to use dairy terms, like “milk.”

“Dairy is higher in naturally-occurring calcium and fortified with vitamins A and D. However, many plant based products, like soymilk, are fortified with as much calcium and vitamin D as is found in dairy products...”—Individual Consumer, location not specified

“Dairy products are not good sources of calcium and protein...”—Individual Consumer, PA

“...fortified soy milk and almond milk both contain greater amounts of calcium than all forms of dairy milks.”—Individual Consumer, location not specified

Among those who correctly noted that cow’s milk has more naturally occurring calcium than plant-based alternatives, several expressed that there are many non-dairy sources of calcium and that meeting calcium needs is easy on a plant-based diet. Like commenters who preferred dairy products, a few comments cited the inclusion of soy “milk” in the DGA dairy group.

**Bioavailability.** Eleven commenters who mentioned bioavailability preferred plant-based alternatives (55%). A few commenters correctly noted that vitamin D aids in the absorption of calcium, while most stated that calcium from cow’s milk is poorly absorbed.

“...though cow's milk may contain more calcium, that calcium is not necessarily well absorbed due to the amount of phosphorus in cow's milk.”—Health Professional, TN

**Health outcomes.** Nearly half of commenters who preferred plant-based alternatives commented on health outcomes related to calcium (43%; n = 29). Comments revealed misunderstandings of the health outcomes related to calcium intake from dairy products. Some believed that calcium from dairy may contribute to higher rates of osteoporosis, which is misaligned with the majority of current data (Astrup et al., 2020; Thorning et al., 2016; Van Den Heuvel & Steijns, 2018). Some commenters conveyed that among populations who frequently drink milk or intake

high amounts of calcium, like some groups in the U.S., there are higher rates of osteoporosis and bone fractures. This partially aligns with findings from a recent controversial review that found a positive association between high intakes of milk during adolescence and high incidence of fractures in countries with the highest milk consumption (Willett & Ludwig, 2020). Some comments inaccurately expressed that milk “leaches” calcium from the bones, contributing to negative health outcomes.

“...there is scant evidence that high levels of dairy consumption promote the health benefits especially strong bones associated with calcium. In fact, when we look at the rates of hip fracture in postmenopausal women, we find that hip fractures are the most prevalent among groups of women who consume the most dairy products. These populations include northern Europe, the USA, Canada and Australia. In contrast, people from rural Asia and Africa tend to have the lowest rates of osteoporosis. These people generally eat little or no dairy products and have lower overall calcium intake...”—Individual Consumer, location not specified

“Cow breast milk has been shown to leech [sic] calcium from human bones and study after study have proven that the countries with the higher rates of dairy consumption are those with higher osteoporosis.”—Individual Consumer, location not specified

#### **Commenters Who Consume Both Plant-Based Alternatives And Dairy Products**

**Calcium content.** Nine commenters who indicated that they consume both dairy products and plant-based alternatives commented on calcium content. Some recognized that plant-based alternatives are fortified with calcium and some mentioned fortified soy “milk” specifically as a source of calcium.

“USDA included fortified soymilk in [the] Dairy Section in Choose My Plate as a provider of calcium, vitamin D, and potassium.”—Individual Consumer, location not specified

**Bioavailability.** One commenter who consumed both products commented on bioavailability. This individual shared the belief that our bodies do not absorb the calcium from milk.

**Health outcomes.** One commenter who consumed both products expressed that calcium is valuable for bones and for weight loss.

#### **Commenters With An Unclear Or Neutral Preference**

**Calcium content.** Less than one quarter of commenters that commented on calcium content had an unclear or neutral preference (14%; n = 28). As with other preference groups, some commenters accurately noted that dairy products are good sources of calcium.

“Generally, milk serves as a dietary source of protein,

calcium, vitamin A, and potassium.”—Individual Consumer, location not specified

Some mentioned that plant-based products, when fortified, can also provide calcium and other nutrients. However, some indicated that these products are not nutritionally equivalent to dairy.

“Plant-based alternatives to dairy milk do not have the same naturally occurring nutrients and tend to be fortified with vitamin D and calcium”—Academia, location not specified

“As a registered dietitian nutritionist, I am concerned with the use of “milk,” “yogurt” and “cheese” to describe plant-based beverages or foods that are not nutritionally equivalent to cow milk, particularly for protein, calcium and vitamin B12”—Health Professional, location not specified

“It is true that they are nutritionally distinct, but many of them are fortified with the nutrients for which cows’ milk is best known: calcium, Vitamin B-12, and Vitamin D (which, by the way, isn’t found naturally in cows’ milk either).”—Individual Consumer, UT

**Bioavailability.** No commenters with an unclear or neutral preference commented on bioavailability.

**Health outcomes.** Five commenters who had an unclear or neutral preference mentioned health outcomes related to calcium (7%). Three of these comments discussed calcium in relation to bone health.

“Cow’s milk provides the right amount of bone-building nutrients: Calcium, Vitamin D, Protein, Phosphorus, Magnesium, Potassium, Vitamin B12, Zinc -and it’s a complete protein source as well.”—Individual Consumer, CA

Two expressed concerns that Americans are under consuming calcium and vitamin D, and one comment mentioned that the calcium and vitamin D in dairy are important for the growth and development of children.

### **Discussion**

To our knowledge, this is one of few studies that has examined public understanding of calcium in dairy products and plant-based alternatives, and the first to use submissions to a federal rulemaking process as a method to examine knowledge surrounding calcium (Bus & Worsley, 2003; Consumer perceptions: Dairy milk and plant-based milk alternatives, 2018). Although the FDA specifically requested feedback on consumer understanding of the nutritional content of dairy foods and plant-based alternatives, only 3.0% of submissions mentioned calcium, a nutrient commonly associated with dairy. These findings suggest that dietary calcium may not be a leading factor when comparing dairy products and plant-based

alternatives. Although prior research has found nutrition or health considerations to be motivating in purchasing decisions, other factors, including sustainability, animal welfare, cost, taste or flavor, familiarity or habit, and lactose intolerance are also known to be important (Bus & Worsley, 2003; Harwood & Drake, 2020; Leiserowitz et al., 2020; Marcinow et al., 2017; Nolan-Clark et al., 2011). For example, in a study of lactose-free milk consumers, growing up drinking dairy milk and knowing its nutritional benefits were reasons for purchasing lactose-free milk, but nutrition and label claims, such as “high calcium,” did not seem to be important overall to purchase decision (Rizzo et al., 2020).

Of the three evaluated dimensions of calcium nutrition, we found commenters most likely to discuss the calcium content of different products. This was unsurprising given that Nutrition Facts labels in the U.S. show the amount of calcium and percent Daily Value of calcium per serving, but do not provide information on bioavailability or links with health (How to understand and use the Nutrition Facts label, 2020). In general, commenters accurately evaluated the calcium content in dairy and plant-based alternatives; however, they often emphasized information that aligned with their product preference. For example, those who preferred dairy explained that fluid milk is a good source of calcium and is nutritionally superior to plant-based alternatives, and those who preferred plant-based alternatives explained that some fortified plant-based alternatives contain more calcium than dairy milk. Both groups recognized that some plant-based alternatives are fortified with calcium. These results align with the Theory of Motivated Reasoning, which posits that people often come to favored conclusions using reasoning based in evidence and arguments influenced by their preferences (Epley & Gilovich, 2016). In other words, people often unintentionally seek out information and sources that support their viewpoint (Epley & Gilovich, 2016). With respect to calcium metabolism and health outcomes associated with dairy intake, those who preferred plant-based alternatives demonstrated greater misunderstanding and beliefs misaligned with current evidence than those who preferred dairy products or had a neutral or unclear preference. Still, there were misunderstandings in both groups. The findings suggest the need for well-targeted nutrition education on calcium and dietary sources of calcium, especially for populations that consume little or no dairy products.

In light of evidence on factors that influence calcium bioavailability in dairy and fortified plant-based alternatives, the lack of comments on calcium bioavailability suggests that many people are not aware of how calcium is metabolized in the body (Chalupa-Krebdak et al., 2018; Dietary Guidelines Advisory Committee, 2015; Heaney et al., 2005; Hess et al., 2020; Mäkinen et al., 2016; Matia-Martín et al., 2019; Schuster et al., 2018; USDA & USDHHS, 2020). Calcium absorption is influenced by amount of calcium consumed, age and life stage, and other components in food that can inhibit calcium absorption (Calcium, 2021). Studies exploring

bioavailability in products fortified with calcium indicate that nutrition content and fortification techniques and ingredients may influence calcium bioavailability (Bus & Worsley, 2003; Chalupa-Krebdak et al., 2018; Mäkinen et al., 2016). Additionally, calcium may be more easily separable from the other components in fortified beverages, which could lead to decreased calcium intake if the beverage is not properly shaken (Chalupa-Krebdak et al., 2018).

Discrepant beliefs surrounding dairy and health may be explained by the inconsistent findings linking milk and milk components to health. Previous research has found health knowledge and beliefs to be a potential barrier to dairy product intake (Nolan-Clark et al., 2011; Racey et al., 2017). Although the U.S. Government promotes dairy intake in part because of its calcium content, recent literature has contradicted the DGA evidence-based recommendations surrounding dairy and calcium. A 2020 review of over 100 studies related to milk and health, summarized the literature on risks of possible adverse outcomes related to the consumption of dairy milk and noted that countries with the highest intakes of milk and calcium usually have the highest rates of hip fractures. The review offered critique that studies supporting U.S.

recommendations for milk consumption have been limited in size and duration and focus on high habitual calcium intake. The review suggested that the current body of evidence does not support higher dairy consumption as a means of hip fracture prevention. Further, the review discussed calcium intake among children and concluded that there is no evidence that high calcium intake is needed during childhood to prevent fractures later in life, and conversely, that current data suggest high intakes of milk may actually contribute to fracture risk (Willett & Ludwig, 2020). The review was publicly critiqued by other researchers in the field, highlighting the lack of consensus on the role of milk in health (Astrup et al., 2020).

In recent years, research has shifted towards looking at overall dietary patterns versus single nutrients because people eat multiple food groups and nutrients at the same time (USDA & USDHHS, 2015; USDA & USDHHS, 2020). However, single nutrients, such as calcium, and the knowledge of individual foods' nutrient composition may be important to achieving an adequate diet, especially for populations with dietary restrictions. Prior research has found many consumers are unable to accurately assess whether their calcium intake is adequate (Holland & Moffat, 2017; Yu et al., 2020). While calcium is obtainable from plant-based foods, replacing dairy with plant-based alternatives may compromise calcium intake, and most Americans fall short of calcium recommendations regardless of whether they follow a plant-based diet (Karlsen et al., 2019; Seves et al., 2017; Calcium, 2021; USDA & USDHHS, 2020). Our findings suggest that the U.S. public, including—but not limited to—individual consumers, may benefit from clearer nutrition messaging related to calcium.



## Limitations

There are some limitations to this research. First, comments submitted to the U.S. Federal Register may not be representative of the views or knowledge of the U.S. public, as the beliefs of individuals and organizations that did not leave comments may be different from those who did comment. For example, more commenters preferred plant-based alternatives in comparison to dairy products, which may differ from preferences of the general population, since total dairy milk sales remain higher than plant-based alternative sales (Retail sales data: Plant-based meat, eggs, dairy, 2021). Further, given different motivations of those submitting comments on behalf of themselves versus an organization, some perspectives may be over- or underrepresented. Second, 142 of the duplicates removed from the dataset mentioned calcium but were not individually considered in our analysis. Most of the duplicates removed were form letters that supported the Plant Based Foods Association and expressed the idea that calcium is easily obtained from plant-based foods. Including these duplicates in our analysis would have further supported our finding of nutrition knowledge gaps among those who prefer plant-based alternatives. However, the Federal Register process is not a vote, and comments supported by scientific evidence are often more influential than many form letters (Tips for submitting effective comments, n.d.). Lastly, comments were coded by a team of researchers, which may have offered room for subjectivity and individual bias. However, we utilized preliminary coding followed by discussions to come to consensus on coding decisions and to refine the codebook, along with extensive data quality checks and cross-examination of coding decisions to produce more reliable, valid research.

## Conclusions

This research finds that for participants in this federal rulemaking process, dietary calcium was not a priority consideration when comparing dairy products and plant-based alternatives. With a growing number of people transitioning to plant-based diets and using plant-based alternatives to replace animal products, our findings suggest that additional nutrition education, especially targeted to those who avoid dairy products or prefer plant-based alternatives, may be warranted to address nutrition misunderstandings and support adequate calcium intake (Neff et al., 2018; Nolan-Clark et al., 2011). Given the current and historic emphasis on calcium in the DGA and Nutrition Facts labels, more detailed labeling related to this nutrient may not be adequate. Recent market research has found sales of plant-based foods to be driven by younger generations and non-Caucasian consumers (Consumer insights, n.d.). More research is needed to characterize this

growing population and identify optimal mechanisms for reaching them with relevant nutrition information.

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## Author Contributions

Conceptualization, S.G.G. and E.H.B.; Methodology, S.G.G. and E.H.B.; Investigation, S.G.G., B.E.C., and E.H.B.; Writing—Original Draft, S.G.G.; Writing—Review and Editing, E.H.B, B.E.C., L.P, and M.T.N.; Funding Acquisition, S.G.G.; Supervision, E.H.B.

## Conflict of interest statement:

We have no conflicts of interest to disclose.

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