Estimation of fluoride concentration in commercially available vegan brands of milk in India

Arya P. Gopalakrishnan[1], Subramaniam Ramanarayanan[1], Jesline M. James[1], Priya Babu[1], Suneesh Kuruvilla[1], Pooja Latti[2]

AFFILIATION
1 Department of Public Health Dentistry, Indira Gandhi Institute of Dental Sciences, Kothamangalam, Kerala, India
2 Department of Public Health Dentistry, Annoor Dental College and Hospital, Muvattupuzha, Kerala, India

CORRESPONDENCE TO
Subramaniam Ramanarayanan. Department of Public Health Dentistry, Indira Gandhi Institute of Dental Sciences, Kothamangalam, 686691, Kerala, India. E-mail: subbds@gmail.com ORCID iD: https://orcid.org/0000-0003-2863-6708

KEYWORDS
fluoride, vegan milk, alternate milk, milk fluoridation, dentists

Received: 16 September 2023, **Revised:** 10 June 2024, **Accepted:** 12 June 2024
Public Health Toxicol. 2024;4(2):11
https://doi.org/10.18332/pht/189993

ABSTRACT

INTRODUCTION Bovine milk has been consumed for ages and is an important source of protein. Despite the benefits, its consumption has been declining. Alternate milk beverages include milk from plant sources. These vegan products have reported health benefits and are also expected to contain fluoride in varying concentrations. An analysis of fluoride intake through these dietary sources can indicate the risk of toxicity and help the dentist decide the appropriate fluoride intake. The study was conducted to assess and compare the fluoride concentration in commercially available vegan milk in India.

METHODS An in vitro study was conducted on a total of 24 types of vegan milk (non-dairy milk) commercially available in India. Bovine milk was used as the control. The vegan kinds of milk in this study included almond milk, soy milk, coconut milk, oats milk, cashew milk, walnut milk, rice-walnut milk, rice-hazelnut milk, and rice almond milk. Fluoride estimation was done using a fluoride ion-selective electrode. The fluoride levels were tabulated and summarized. Comparison of fluoride levels between the products was done using Kruskal Wallis ANOVA followed by Mann Whitney U test for pairwise comparison.

RESULTS The fluoride concentration ranged from 1.05–4.66 ppm in almond milk, 1.06–5.08 ppm in soy milk, 0–4.46 ppm in coconut milk, 0–6.30 ppm in cashew milk, and 0–4.67 ppm in oats milk. Walnut milk had fluoride concentration of 0.56 ppm. The combinations of rice milk, namely rice-walnut milk, rice-hazelnut milk, and rice-almond milk, all belonging to the same brand, did not contain fluoride.

CONCLUSIONS The presence of fluoride was detected in 20 (19 vegan milk, and 1 bovine milk the control) of the 26 milk brands (25 vegan and 1 bovine) studied. The concentration of fluoride varied across the various types and brands of milk.

INTRODUCTION

Beverages are no longer only thought of as ways to quench one's thirst in the modern world. Consumers look out for specific functionality in these beverages, which is part of their lifestyle. The functionality of these beverages may be to address different needs and lifestyles, boost energy, fight aging, fatigue, and stress, and target specific diseases, and the sector is still expanding[1].

Bovine milk has been consumed for ages and is an important source of protein[1,2]. Despite the benefits, its consumption has been declining among children[3]. The downsides associated with bovine milk include the possible presence of pathogens such as salmonella and *Escherichia coli*, the increasing prevalence of allergy to bovine milk, and conditions such as lactose intolerance[3]. There is also an increasing concern about high fat and lactose content in bovine milk, genetic engineering, antibiotics, hormones, and a greater awareness of animal abuse in factory farming. All these have led to increased availability and consumption of alternate milk beverages. These include milk from plant sources namely soy, almond, cashew, rice, coconut, hazelnut, oats, and walnut[2].

Alternate milk products may have reported health benefits[4]. Most of them have low fat and no cholesterol

content. They have a healthy combination of mono- and poly-unsaturated fatty acids. They are easily digestible and are rich in vitamins and minerals[4].

In recent times, there has been an increase in the number of consumers switching to a vegan diet, and as a result demand for vegan food has increased notably in many industrialized countries. The term vegan food refers to products without animal-based food ingredients[5].

The concept of veganism has been widely approached and has spread to almost all the food industries starting from vegan burgers to vegan meat. One more food option that could be veganized is milk[5].

The widespread use of fluoride has caused a great impact on the control of dental caries disease around the world[6]. Fluoride is a 'double-edged sword', though, because too much of it can result in dental fluorosis, which discolors teeth and increases their susceptibility to cavities. In India, fluorosis is a serious public health issue[6].

Milk fluoridation is a method of systemic fluoride delivery where fluoride in concentrations of 2.5–5 ppm (parts per million) is added to milk for therapeutic benefits in the prevention of dental caries[7]. There is a significant amount of evidence that proves bovine milk contains a negligible amount of fluoride[8]. Fluoride naturally occurs in cereals, nuts, legumes, and seeds, in addition to vegetables, seafood, tea leaves, etc.[9,10].

The vegan kinds of milk or plant-based milk alternatives are manufactured using cereals such as oats and rice; legumes such as soy; and nuts such as almonds, coconut, cashew nut, hazelnut, and walnut[2]. Hence, vegan milk preparations also are expected to contain fluoride in varying concentrations, unlike bovine milk.

Determining the recommended intake of fluoride for an individual is a challenging task for the dentist, as there exist many natural and dietary sources of fluoride. The adequate intake of fluoride from all sources (including non-dietary sources) is 0.05 mg/kg body weight per day for both children and adults, including pregnant and lactating women[11,12]. The European Food Safety Authority (EFSA) recommends a dietary intake of fluoride through dietary sources ranging from 0.05–0.15 mg/kg[12]. The Food and Nutrition Board of the United States has set the levels for the daily tolerable upper intake levels of fluoride from all sources as 1.3 mg for ages 1–3 years, 2.2 mg for ages 4–8 years, and 10 mg for ages ≥9 years[13]. An analysis of fluoride intake through these dietary sources including the vegan kinds of milk can not only indicate the risk of toxicity (if fluoride is more than the permitted amount) but can also help the dentist decide the appropriate fluoride intake needed for a therapeutic effect on teeth with a minimal chance of causing fluoride toxicity (if fluoride is within the permissible amount).

A thorough literature search revealed a lack of data assessing the fluoride concentration of the vegan kinds of milk commercially sold in India. This research is an attempt to address this knowledge gap. The aim of the study was to assess and compare the fluoride concentrations in commercially available vegan brands of milk in India.

METHODS

The study was an *in vitro* study. It was conducted on a total of 24 types of commercially available vegan milk (non-dairy milk) in India. Bovine milk was used as the control. A thorough market search in online shopping sites and supermarkets of Kochi city in Kerala state of India was done to identify the common types of vegan milk available in India. The vegan milk available in India includes almond milk, soy milk, coconut milk, cashew milk, rice and walnut milk, rice and hazelnut milk, oats milk, and walnut milk.

The alternative vegan milk products from various brands commercially available in India include Sofit®, So good®, Raw Pressery®, Urban Platter®, SOLH®, Dabur®, Cocomama®, KLF®, Mylk®, Borges®, Only Earth®, Tendo®, Altco®, Milkin®, Oatey®, Punjab Agriventure®, Bio basics® were included in the study. Bovine milk Milma® was used as the control. A total of 24 types of commercially available vegan milk were included in the study. The type of milk, brand name, manufacturer, place of manufacture, ingredients, and expiry date for each sample of milk were recorded. The vegan kinds of milk included 4 almond milk, 4 soy milk, 4 coconut milk, 6 oats milk, 2 cashew milk, 1 walnut milk, 1 rice and walnut milk, 1 rice and hazelnut milk, and 1 rice and almond milk. The commercially available concentrations were used without dilution to simulate the natural method of consumption. The details of the product used are summarized in Table 1. The vegan kinds of milk were either obtained from the local market or purchased online. The milk products were stored as per the manufacturer's instructions before analysis.

Fluoride analysis

Fluoride estimation in vegan milk products was determined by electrochemical means using a fluoride ion-selective electrode coupled with an ion analyzer. Before estimating the fluoride content in milk, the instrument was calibrated using a total ionic strength adjustment buffer (TISAB)[14,15]. The reading was recorded from the ion meter in parts per million (ppm). Each sample was analyzed in triplicate to ensure consistency of findings.

Statistical analysis

The fluoride levels of the commercially available vegan milk product brands of each type of vegan milk were tabulated and summarized as mean ± standard deviation. Shapiro Wilk test was used to identify the normality of the distribution. Comparison of fluoride levels between the products was done using Kruskal Wallis ANOVA followed by Mann Whitney U test for pairwise comparison. The concentration of fluoride in each type of vegan milk was summarized as mean ± standard deviation, range, and median. The non-parametric tests were used as the data were not normally

Table 1. Details regarding the products used in the study

Type of vegan milk	Brand name	Ingredients	Place of manufacture
Almond milk	Sofit®	Water, sugar, almond paste (5%), soya protein isolate (2%), oligofructose (1.5%), cocoa solids (0.8%), emulsifiers [460(i) and 466, 471], mineral tricalcium phosphate, flavors, edible common salt, acidity regulator, thickener	Mandideep, Bhopal, Madhya Pradesh MH67322
	So Good®	Water, sugar, almond (3%), mineral premix (0.24%), flavor, emulsifier (INS 322), stabilizer (INS 418), salt, acidity regulator [INS 500(ii)], vitamin premix	Pune, Maharashtra SB2116GB6
	Urban Platter®	Water, almond (4%), stabilizer (INS 170), iodized salt, emulsifier (INS 322), stabilizer (INS 410, INS 418)	Pasaka, Bhutan VCK2703
	Raw Pressery®	Water, almond (5%), emulsifier (INS 322), acidity regulator (INS 341, INS 332), stabilizer (INS 410, INS 170, INS 148)	Pune, Maharashtra SB2164CA6
Soy milk	Sofit®	Water, soya beans (13.6%), acidity regulator [500 (ii) oligofructose dietary fiber (0.1%)], flavors	Mandideep, Bhopal, Madhya Pradesh HM13022/03
	So Good®	Water, soya beans (16%), sugar, cocoa (1%), mineral premix (0.2%), salt, stabilizer (INS 407), vitamin premix (0.01%), acidity regulator [INS 500(ii)]	Mandideep, Bhopal, Madhya Pradesh SMCS05221
	SOLH®	Water, soybeans (11.5%), oligofructose, dietary fiber (1%), flavors, emulsifier (INS 466), acidity regulator (INS 314), vitamin premix (0.01%)	Palghar, Maharashtra SF220708
	Urban Platter®	Soya beans, water	Palghar, Maharashtra MH050322
Coconut milk	Urban Platter®	Coconut cream, water	Tirupur, Tamil Nadu
	Dabur®	Coconut milk (55.1%) [coconut milk, water, stabilizer (INS 415)], water, coconut cream concentrate (8.27%) [coconut extract, water, emulsifiers, stabilizers (INS 471, INS 435, INS 466)] and preservative (INS 223), emulsifiers and stabilizers [INS 460 (i), INS 412, INS 466, INS 407, INS 433]	Mandideep, Bhopal, Madhya Pradesh 90009 M03
	Cocomama®	Coconut milk (coconut cream), water, stabilizer (E415)	Tirupur, Tamil Nadu
	KLF Coconad®	Real coconut milk extract, water, stabilizer E 466, acidity regulator E 330, class II preservative E223, E211	Tingalur, Tamil Nadu CM016/B
Cashew milk	So Good®	Water, cashew paste (2.8%), mineral premix (0.25%), flavor, emulsifier (INS 322), salt, stabilizer (INS 418), acidity regulator [INS 500(i)], vitamin premix	Pune, Maharashtra SB2009BC6
	Mylk®	Filtered water, cashews, barnyard, millets, oats, sunflower oil, dipotassium phosphate, calcium carbonate, guar gum	Tirupur, Tamil Nadu PT126A
Rice and walnut milk	Borges®	Water, rice (14%), walnuts (5%), gellan gum, sea salt	Viladrau, Spain L1251
Rice and hazelnut milk	Borges®	Water, rice (14%), hazelnuts (3%), stabilizer, gellan gum, sea salt	Viladrau, Spain L0672
Rice and almond milk	Borges®	Water, rice 12%, almonds 4%, gellan gum, sea salt	Viladrau, Spain L1211

Continued

Table 1. Continued

Type of vegan milk	Brand name	Ingredients	Place of manufacture
Oats milk	Altco®	Water, oats (11%), rapeseed oil 2.5%, calcium carbonate, sunflower lecithin, gellan gum, dicalcium phosphate, dipotassium phosphate, nature identical flavor, naturally occurring sugars	MW53A0036 Kohlapur, Maharashtra, India
	Milkin®	Water, Oats, 1% or less canola oil, dicalcium phosphate, tricalcium phosphate, salt	Palghar, Maharashtra
	Punjab Agriventure limited®	Water, oats (10%), rapeseed oil, dipotassium phosphate, guar gum	Fatehgarh Sahib, Punjab M1861117/2
	Slicc®	Water, oats 11%, sunflower oil, Himalayan pink slat, dipotassium phosphate, calcium carbonate, sunflower lecithin, gellan gum, vitamin D and vitamin B12	Palghar, Maharashtra CL03
	Oatey Oat Milk®	Water, oats 10.5%, low erucic acid, rapeseed oil 2.5%, calcium carbonate, tricalcium phosphate, dipotassium phosphate, citrus fibre, Himalayan pink salt, gellan gum, vitamin B1, B2, B12.	Kolhapur, Maharashtra OATBM01
	Oatey Millet Milk®	Oats, sprouted sorghum, sprouted cowpeas, sprouted amaranth, sprouted finger millets – 11%, low erucic acid rapeseed oil, calcium carbonate, tricalcium phosphate, dipotassium phosphate, citrus fiber, Himalayan pink salt, gellan gum, vitamin B1, B2, B12.	Kolhapur, Maharashtra MLTM01
Walnut milk	Tendo®	Water, walnut 6%, xanthum gum	Tirupur, Tamil Nadu PT21358

distributed. The analysis was done using Statistical Package for Social Sciences (SPSS) software, version 19.0 for Windows.

RESULTS

Table 2 summarizes the fluoride concentrations in the milk samples tested. The presence of fluoride was detected in 19 (18 vegan milk, and 1 bovine milk the control) of the 25 milk brands (24 vegan and 1 bovine) studied. The concentration of fluoride varied across the various types of milk. The concentration also varied across the different brands of each type of milk. The fluoride concentration ranged 1.05–4.66 ppm in almond milk, 1.06–5.08 ppm in soy milk, 0–4.46 ppm in coconut milk, 0–6.30 ppm in cashew milk, and 0–4.67 ppm in oats milk. Walnut milk had a fluoride concentration of 0.56 ppm. The combinations of rice milk, namely, rice and walnut milk, rice and hazelnut milk, and rice and almond milk, all belonging to the same brand, did not contain fluoride. The highest individual fluoride concentration was found in So Good® cashew milk and the least (no fluoride detected) was found in Borges® rice and walnut milk, Borges® rice and hazelnut milk, Borges® rice and almond milk, Dabur® coconut milk, and Punjab Agriventure Ltd® oats milk.

Among all the 24 vegan milk brands assessed for fluoride concentration, the maximum concentration was observed in So Good® cashew milk. Inferential analysis showed that among the types of almond milk, Sofit® and So Good® had comparable fluoride concentrations ($p=0.878$). Urban Platter® and Raw Pressery® had significantly higher concentrations of fluoride ($p<0.001$). Among soy milk, So Good® had significantly higher concentrations than Sofit®, Urban Platter®, and SOLH® ($p<0.001$). Sofit®, So Good®, and Urban Platter® had comparable levels of fluoride ($p=0.098$, $p=0.097$, respectively). Coconut milk brands also showed wide variations. Fluoride was absent in Dabur®. Amongst the rest, KLF Coconad® showed the highest fluoride concentrations, significantly greater than Cocomama® and Urban Platter®. The last two had comparable levels of fluoride ($p=0.545$). Among the two cashew milk brands, So Good® showed higher levels compared to Mylk® which did not contain any fluoride. Six brands of oats milk were analyzed of which, Punjab Agriventure Ltd® had no fluoride. Among the rest, Slicc® had a significantly higher concentration than the rest of the oats milk types. Milkin® and Oatey Millet milk® had comparable concentrations of fluoride ($p=0.967$).

Table 3 summarizes the mean fluoride concentrations in various types of vegan milk that are commercially available in India. As the data varied across various brands of the same type of milk, the tabulation included the range and median. The maximum mean fluoride concentration was observed in cashew milk (3.15 ppm), followed by almond milk (2.55 ppm), soy milk (2.42 ppm), coconut milk (1.72 ppm), oats milk (1.71 ppm), walnut milk (0.56 ppm), bovine milk (0.02 ppm), rice and walnut milk (0 ppm), rice and hazelnut milk (0 ppm), and rice and almond milk (0 ppm). No significant

Table 2. Fluoride concentration (ppm) assessed in vitro in the milk samples tested*

Brand name	Fluoride concentration (ppm) Mean ± SD
Sofit® Almond Milk	1.05 ± 0.05
So Good® Almond Milk	1.25 ± 0.19
Urban Platter® Almond Milk	3.27 ± 0.28
Raw Pressery® Almond Milk	4.66 ± 0.57
Sofit® Soy Milk	1.06 ± 0.03
So Good® Soy Milk	5.08 ± 0.52
Urban Platter® Soy Milk	1.76 ± 0.03
SOLH® Soy Milk	1.77 ± 0.35
Urban Platter® Coconut Milk	1.35 ± 0.32
Dabur® Coconut Milk	0
Cocomama® Coconut Milk	1.05 ± 0.13
KLF Coconad® Coconut Milk	4.46 ± 0.41
So Good® Cashew Milk	6.30 ± 0.12
Mylk® Cashew Milk	0
Borges® Rice and Walnut Milk	0
Borges® Rice and Hazelnut Milk	0
Borges® Rice and Almond Milk	0
Altco® Oats Milk	0.32 ± 0.31
Milkin® Oats Milk	2.17 ± 0.21
Punjab Agriventure Ltd® Oats Milk	0
Slicc® Oats Milk	4.67 ± 0.31
Oatey® Oats Milk	0.79 ± 0.23
Oatey® Millet Milk	2.31 ± 0.09
Tendo® Walnut Milk	0.56 ± 0.02
Milma® Bovine Milk	0.02 ± 0.05

*The measurement was done in triplicate.

difference was observed between mean concentrations of almond milk, soy milk, coconut milk, and oats milk; and between bovine milk, rice and walnut milk, rice and hazelnut milk, and rice and almond milk.

DISCUSSION

Eighteen of the vegan kinds of milk, among the twenty-four tested, contained fluoride in various concentrations. The surge in the availability and consumption of vegan kinds of milk can be due to the increasing concerns about high fat and lactose content in bovine milk, conditions such as lactose intolerance, implementation of plant-based diets, genetic engineering, antibiotics, hormones, and greater awareness of animal abuse in factory farming. Little research is available on the impact of these beverages on oral health although *in vitro* data suggest these milks have cariogenic potential[8].

A wide variety of vegan milk brands are marketed commercially in India. They are available in a range of flavors. An analysis of the vegan milk products used in the study showed that most of them are manufactured in India and a few are manufactured in other countries and marketed in India[16].

The ingredients of vegan kinds of milk vary across various brands. Considerable variations were also observed in the concentration of the active ingredients namely almond, soy, coconut, cashew, oats, rice, and walnut across various brands. The other ingredients include water, stabilizers, emulsifiers, acidity regulators, permitted colors and flavors, binding, and thickening agents. Few of the commercially available products included a combination of the active ingredients mentioned above. The composition of the kinds of milk used in the study showed wide variation and a lack of uniformity concerning the ingredients.

Major differences existed between the different types of vegan kinds of milk and among different brands of the same type of vegan milk.

The fluoride concentration in the 4 brands of almond milk

Table 3. Mean fluoride concentrations (ppm) assessed in vitro in various types of vegan kinds of milk commercially available in India

Type of vegan milk	Fluoride concentration (ppm)		
	Mean ± SD	Range	Median
Almond milk	2.55 ± 1.58	1.04–5.07	2.23
Soy milk	2.42 ± 1.65	1.03–5.64	1.78
Coconut milk	1.72 ± 1.75	0.0–4.90	1.12
Cashew milk	3.15 ± 3.45	0.0–6.44	3.1
Rice and walnut milk	0	0	0
Rice and hazelnut milk	0	0	0
Rice and almond milk	0	0	0
Oats milk	1.71 ± 1.64	0.0–5.00	1.52
Walnut milk	0.56 ± 0.02	0.54–0.58	0.56
Bovine milk	0.02 ± 0.005	0.02–0.03	0.03

ranged 1.05–4.66 ppm. This reflects a high concentration of fluoride in the almond milk samples. Similar studies on almond milk conducted in the USA in the year 2019, revealed a range of 0.17–0.80 ppm among the 12 brands tested[8]. According to a study conducted on the assessment of fluoride levels in 144 different foods commercialized in the European region, the fluoride concentration in almonds stood out at 3.70 ± 0.96 mg/kg[10]. The composition of each type of almond milk was significantly different from the others.

Four brands of soy milk were analyzed for fluoride content. The first three brands were the same as that of almond milk. The fluoride concentrations ranged 1.06–5.08 ppm. The results are in contrast with the study conducted in the United Kingdom in 2014, where it was reported that the median fluoride concentration of all soya milk was 0.293 µg/mL with a range 0.015– 0.964 µg/mL[17]. A study conducted in Thailand in 2016 indicated a fluoride concentration in 76 brands of soy milk ranging 0.01–3.78 µg/mL[18]. In the study conducted in the USA in 2019, the concentration ranged 0.11–0.65 ppm across 6 brands[8]. The maximum fluoride concentration among soy milk brands was observed in So Good®. The product had the maximum concentration of soya beans (16%) among the lot, and contained sugar, cocoa and mineral premix. This could be the possible reason for an increased concentration in the product.

In the present study, 4 brands of coconut milk were analyzed for fluoride content. One of the 4 products did not show any presence of fluoride. The rest 3 brands showed a concentration ranging 1.05–4.46 ppm. The concentrations shown by two brands are comparable with the results of a study conducted in Thailand[19]. However, among the three brands tested in the study conducted in the USA[8], the concentration ranged 0.18–0.29 ppm. Studies assessing fluoride in coconut milk are sparse. A study conducted to assess the concentration in coconut water in Iran, showed a range of 2.680–4.160 ppm[20].

Among the available brands, only one product was marketed as cashew milk, which contained about 2.8% of cashew paste. The other product was cashew and oats milk. The analysis of fluoride content revealed a high concentration of 6.3 ppm in cashew milk. The observation is in sharp contrast with the results of the study conducted in the USA, where the concentrations ranged 0.1–0.54 ppm among four different brands. However, cashew and oats milk did not show any presence of fluoride.

Market search revealed that rice milk was available in India in combination with nuts, namely hazelnuts, almonds, and walnuts. All three combinations are marketed by Borges®, all of which are manufactured in Spain. None of the three products showed the presence of fluoride. A study conducted among 20 rice milk products across 6 brands in Thailand, showed concentrations ranging 0.01–5.51 ppm[21].

Six products containing oats milk were analyzed. The fluoride concentrations ranged 0–4.67 ppm. Two products had concentrations 2.31 ppm and 2.17 ppm, respectively. The other three products had <1 ppm concentration.

The concentration in the only available walnut milk was 0.56 ppm, which was lower compared to the product tested in the Thailand study[19]. Walnuts have demonstrated a fluoride concentration of about 3.53ppm in a study conducted in Europe in 2020[10].

Fluoride concentration in the locally obtained bovine milk ranged 0.02–0.03 ppm. The observation is consistent with other studies conducted on bovine milk[8,14].

Among the 24 tested brand products, 4 were manufactured outside India (Urban Platter® almond milk in Bhutan and Borges® brand of rice and walnut milk; rice and hazelnut milk; and rice and almond milk in Spain). Fluoride was absent in all three Borges® products manufactured in Spain. Urban Platter® almond milk showed about 3.5 ppm fluoride. Although the place of manufacture of the vegan is significant, the place of cultivation of the active ingredients and the fluoride concentration in the groundwater play a more significant role, as the fluoride can get incorporated through the process of cultivation.

The 24 vegan milk products tested belonged to 16 different brands. Three products each from So Good® (almond milk, soy milk, cashew milk), Urban Platter® (almond milk, soy milk, coconut milk) and Borges® (rice and walnut milk; rice and hazelnut milk; rice and almond milk) were included in the study. It was observed that all the products belonging to Borges® had no detectable fluoride concentration. The three So Good® products showed a wide range of 1.25 to 6.30 ppm, and the urban platter products ranged 1.35–3.27 ppm. Two products from Sofit® (almond milk and soy milk) had concentrations of 1.05 and 1.06 ppm, respectively. Two products from Oatey® (oats milk, and oats and millet milk) had concentrations of 0.79 ppm and 2.31 ppm, respectively.

Determining the fluoride content of commonly consumed beverages is a challenge for the dentist[8]. These wide variations make it challenging for dentists to advise families on fluoride use. Currently, manufacturers are not required to report the fluoride levels on their products, but with the rising level of fluorosis, and existing endemic fluoride belts in India, this information, if mandated to be labeled on the product, would help dentists in determining the appropriate dose of fluoride for children and educate the consumers and dentists. The study addresses the gap in knowledge regarding the assessment of fluoride concentration of vegan milk commercially marketed in India. Although few studies have estimated fluoride levels in vegan milk, no available studies were found in the existing electronic literature that assessed fluoride levels in vegan kinds of milk commercially marketed in India, thereby highlighting the relevance of this study.

Strengths and limitations

Strengths of the study include the wide variety of vegan milk products belonging to 17 different commercially available

brands in India that were tested. To ensure reliability, the tests were conducted in triplicate. The products were selected based on market research. The study enabled the comparison of fluoride concentration among different brands of the same type of vegan milk. It is an important observation that significant differences existed across brands that indicate a lack of uniformity in the composition and concentration of active ingredients.

A possible limitation of this study involved the use of a different number of samples for each brand. Moreover, the ingredients and concentrations of active ingredients varied across the brands. The lack of uniformity in the composition is reflected in the variation of fluoride levels across the products. Due to market limitations, a uniform number of vegan milk samples could not be obtained for each type of vegan milk. Also, there is a possibility that variation exists between batches, and only one batch was tested in this study. Available literature regarding the topic in the Indian scene was sparse and hence not many studies were available for comparison.

Very recently, increased awareness of cow's milk protein allergy and intolerance, and a higher preference for vegan dietary habits have influenced parents towards frequently choosing cow's milk substitutes for children, comprising other mammalian milk types and plant-based milk beverages[22].

The presence of nutritional labels with fluoride concentrations on the products could allow individuals to optimally use fluoride for caries reduction while reducing the risk of fluorosis. These vegan kinds of milk are either directly consumed in the commercially available form as a beverage or used in conjunction with other cereals, fruits, nuts or millets. These additives can individually contribute to the fluoride intake. Moreover, few kinds of milk are used for cooking. Hence detailed studies on analyzing the fluoride levels in vegan milk and the influence of additives and cooking on the products, and bio-availability of fluoride can further provide insights into this and enable dentists, dieticians and nutritionists to monitor and recommend optimal fluoride levels for therapeutic benefits.

CONCLUSIONS

The study was conducted to assess and compare the fluoride concentrations in 25 commercially available vegan kinds of milk in India. A total of 17 different brands were included. The presence of fluoride was detected in 19 of the 25 vegan types of milk studied. The concentration of fluoride varied across the various types of milk. The combinations of rice milk, namely, rice and walnut milk, rice and hazelnut milk, and rice and almond milk, all belonging to the same brand did not contain fluoride. Among all the 25 vegan milk brands assessed for fluoride concentration, the maximum concentration was observed in a brand of cashew milk, followed by soy milk. These results may guide dentists in dietary recommendations.

REFERENCES

1. Sethi S, Tyagi SK, Anurag RK. Plant-based milk alternatives an emerging segment of functional beverages: a review. J Food Sci Technol. 2016;53(9):3408–3423. doi:10.1007/s13197-016-2328-3
2. Hettinga K, van Valenberg H, de Vries S, et al. The host defense proteome of human and bovine milk. PLoS One. 2011;6(4):e19433. doi:10.1371/journal.pone.0019433
3. Vanga SK, Raghavan V. How well do plant based alternatives fare nutritionally compared to cow's milk? J Food Sci Technol. 2018;55(1):10–20. doi:10.1007/s13197-017-2915-y
4. Karimidastjerd A, Gülsünoğlu Konuşkan Z. Health benefits of plant-based milks as alternatives to conventional milk. In: Health and Science 2021. Efe Academy Publishing; 2021.
5. Janssen M, Busch C, Rödiger M, Hamm U. Motives of consumers following a vegan diet and their attitudes towards animal agriculture. Appetite. 2016;105:643–651. doi:10.1016/j.appet.2016.06.039
6. Pagliari AV, Moimaz SAS, Saliba O, Delbem ACB, Sassaki KT. Analysis of fluoride concentration in mother's milk substitutes. Braz oral res. 2006;20:269–274. doi:10.1590/S1806-83242006000300016
7. Sampaio FC, Levy SM. Systemic fluoride. Fluoride and the Oral Environment. 2011;22:133–145. doi:10.1159/000325161
8. Townsend JA, Thompson T, Vaughn S, et al. Analysis of fluoride content in alternative milk beverages. J Clin Pediatr Dent. 2019;43(6):388–392. doi:10.17796/1053-4625-43.6.5
9. The Nutrition Source. Fluoride. Accessed June 10, 2024. https://www.hsph.harvard.edu/nutritionsource/fluoride/
10. Jaudenes JR, Gutiérrez ÁJ, Paz S, Rubio C, Hardisson A. Fluoride risk assessment from consumption of different foods commercialized in a european region. Applied Sciences. 2020;10(18):6582. doi:10.3390/app10186582
11. European Food Safety Authority. Scientific Opinion on Dietary Reference Values for fluoride. EFSA; 2013. Accessed June 10, 2024. https://www.efsa.europa.eu/en/efsajournal/pub/3332
12. Guth S, Hüser S, Roth A, et al. Toxicity of fluoride: critical evaluation of evidence for human developmental neurotoxicity in epidemiological studies, animal experiments and in vitro analyses. Arch Toxicol. 2020;94(5):1375-1415. doi:10.1007/s00204-020-02725-2
13. Office of Dietary Supplements. Fluoride. NIH; 2023. Accessed June 10, 2024. https://ods.od.nih.gov/factsheets/Fluoride-HealthProfessional/
14. Gupta P, Gupta N, Meena K, Moon NJ, Kumar P, Kaur R. Concentration of fluoride in cow's and buffalo's milk in relation to varying levels of fluoride concentration in drinking water of Mathura city in India- A pilot study. J Clin Diagn Res. 2015;9(5):LC05-LC7. doi:10.7860/JCDR/2015/12850.5902
15. Ocak E, Köse Ş. Determination of fluoride in water, milk and dairy products. Fluoride. 2018;51(2):182-192.
16. Good Food Institute IN. Insights on the plant-based dairy category in India. GFI India; 2024. Accessed June 10, 2024. https://gfi-india.org/insights-on-the-pbd-category-in-india/.
17. Lal H, Zohoori FV, Omid N, Valentine R, Maguire A. The fluoride

contents of commercially-available soya milks in the UK. Br Dent J. 2014;217(4):E8–E8. doi:10.1038/sj.bdj.2014.736
18. Rirattanapong O, Rirattanapong P. Fluoride content of commercially available soy milk products in Thailand. Southeast Asian J Trop Med Public Health. 2016;47(1):160–164.
19. Rirattanapong P, Rirattanapong O. Fluoride content of commercially available nut based milk products in Thailand. Southeast Journal of Tropical Medicine and Public Health. 2019;20(4):798–804.
20. Fluoride Action Network. 2019. Fluoride content of coconut water and its risk assessment. Accessed June 10, 2024. https://fluoridealert.org/studytracker/35269/
21. Rirattanapong P, Rirattanapong O. Fluoride content of commercially available rice milk products in Bangkok, Thailand. The Southeast Asian Journal of Tropical Medicine and Public Health. 2019;50(6):1220–1220. Accessed June 10, 2024. https://journal.seameotropmednetwork.org/index.php/jtropmed/article/view/55
22. Elvira Verduci, Sofia D'Elios, Lucia Cerrato, et al. Cow's Milk substitutes for children: nutritional aspects of milk from different mammalian species, special formula and plant-based beverages. Nutrients. 2019;11:1739. doi:10.3390/nu11081739

CONFLICTS OF INTEREST
The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

FUNDING
There was no source of funding for this research.

ETHICAL APPROVAL AND INFORMED CONSENT
Ethical approval was obtained from the Institutional Ethics Committee of Indira Gandhi Institute of Dental Sciences, Kothamangalam (Approval number: IEC/IGIDS/03/2022; Date: 24 June 2022).

DATA AVAILABILITY
Data sharing is not applicable to this article as no new data were created.

PROVENANCE AND PEER REVIEW
Not commissioned; externally peer reviewed.