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# Investigating the Health Impacts of Plant-based Milk Ingredients: Additives and Oxalate

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## ABSTRACT

**Background:** Plant-based milk alternatives have become increasingly popular over the years and numerous commercial products are already available. The aim of this study was to investigate the use of additives in plant-based milk alternatives. In addition, the percentage of contribution of soymilk and almond milk towards the recommended daily (RDI) Intake of oxalate was also estimated.

**Methods:** The ingredient labels in 81 plant-based milk alternatives were used to identify the type and frequency of use of additives. Moreover, the mean plant material content was also extracted from the ingredient labels and was used to estimate the percentage of contribution of plant-based milks (for soymilk and almond milk) towards the RDI of oxalate.

**Result:** More than half of 81 plant-based milk alternatives contain additives among which 43 products (53.1%) contain thickening agents and 22 products (27.2%) contain emulsifiers. Additives were found more in soymilk (73.9%) followed by almond milk (60%). The percentage contribution of soymilk towards the RDI of oxalate was estimated to be higher than that for almond milk which was statistically significant ($p<0.004$). The outcome is valuable to the consumer as well as to the nutritionist to avoid excess consumption and exposure to additives and oxalate.

**Key words:** Almond milk, Oxalate, Plant-based milk, Soymilk, Thickening agents.

## INTRODUCTION

The rising emergence of lactose intolerance, milk allergies and problems due to diets rich in cholesterol are leading toward a growing demand for dairy alternatives (Haas *et al.*, 2019). Furthermore, dietary lifestyles such as veganism, vegetarianism, lacto-vegetarianism and ovo-vegetarianism have also contributed largely to the rising demand for dairy alternatives such as plant-based foods specially milks.

The health effects of plant-based milk alternatives have been studied in terms of both positive and negative effects. Plant-based milk alternatives have positive effects because of rich antioxidant activity and good fatty acids which reduce the risk of cardiovascular diseases, cancer, atherosclerosis and diabetes. However, plant-based milk alternatives products also have various negative health effects including lack of protein content, low bioavailability of minerals and vitamins and oral health problems (Aydar *et al.,* 2020). It was evident by looking into the literature that there was a wide interest to investigate and explore the nutritional differences between the plant-based milk alternatives and their counterpart the cow's milk as well as the health impact of consuming such products on infants, children and adults (Paul *et al.,* 2020; Vanga and Raghavan, 2018). On the other hand, it was noticed that there are lack of information about additives such as thickening agents in terms of types and frequency of use in plant-based milk alternatives. In addition, the percentage of contribution of plant-based milk alternatives towards the recommended daily intake (RDI) of the anti-nutrient "oxalate", a risk factor for nephrolithiasis, is not well documented. Therefore, the aim of this research study is to investigate the above two issues. The ingredient labels of soymilk and almond milk were used as a source of information for the type of additives used as well as to estimate the percentage of contribution of these products towards the RDI of the anti-nutrient "oxalate". The outcome of this research will complement the existing information that will create better-informed consumers in relation to the health impact of plant-based milks' ingredients.

## MATERIALS AND METHODS

This research work was approved by the Research and Ethics Committee at the College of Pharmacy, National University of Science and Technology. Plant-based milk alternatives are sold only in large supermarket outlets in Muscat and they are displayed side by side with fresh milk in the refrigerated section and/or on shelves with pasteurized/long life milk. The products were selected from various supermarket outlets across Muscat in the period

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from January 2021 to May 2021. Permission was obtained from the store managers and person in charge of supermarkets to take 360° camera snapshot of the outer package of the selected products including the ingredient label for further study and analysis. The inclusion criteria were set for plant-based products that are clearly mentioning the term “milk” in the outer package. Products that were presented as dessert or yoghurt based were excluded. Ingredient label is meant to provide consumers with a reliable source of information. Also, the ingredient label was clear in stating the plant material content (*e.g.*, percentage of almond). Therefore, in this study the ingredient label of the selected products was used to extract related information to achieve the purpose of this study. The information obtained from the selected products were: 1) additive types and frequency of use and 2) the mean plant material content which was used to estimate the percentage of contribution of plant-based milk alternatives (for soymilk and almond milk) towards the RDI of oxalate. The price tag of each product was also collected to compare the market price between these products.

### Statistical analysis

The data were evaluated using SPSS 23.0 package program. The statistical correlation between the plant contents of different types of plant-based milks was done using ANOVA. The independent Student’s t-test was used to correlate between the estimated percentages of RDI of oxalate for soymilk and almond milk. A criterion p-value of $<0.05$ was used to determine statistical significance.

## RESULTS AND DISCUSSION

There were a variety of plant-based milk alternatives found in the market, a total of 81 products selected in which 23 products of soymilk, 20 products of almond milk, 13 products of coconut milk, 12 products of oat milk, 9 products of rice milk and 4 products of hazelnut milk and all these products were manufactured in one of these countries: EU (Belgium, The Netherland, Italy, Poland, France), UK, USA, Australia and Indonesia. The market price of these products showed that hazelnut milk was the most expensive among all with the mean price of 2.125 Omani Riyals (5.50 USD) and the cheapest was the soymilk with the mean price of 1.330 Omani Riyals (3.60 USD). The data collected from these products can be presented here in two parts.

### Types of additives used in the selected plant-based milk alternatives

Table 1 shows in numbers the types and frequency of use of various additives. Among the 81 products, 43 products (53.1%) contain thickening agents followed by 22 products (27.2%) contain emulsifiers. The plant-based milk variants that has the most number of additives used is the soymilk (73.9%) followed by almond milk (60%). Six types of gums were recorded: Gellan gum, Carragenan gum, Carob bean (lacust bean) gum, Guar gum, Xanthan gum and pectin gum. Gellan gum was the commonly used gum which appeared in 33 products. Moreover, some of these gums were seen in combinations of two or three in 13 products. The common emulsifier used was sunflower lecithin.

### The plant material content and the percentage of RDI of oxalate

The ingredient labels of the plant-based milks list the product contents which mainly start with water and a plant material such as (coconut cream, almond, soybeans, brown rice, hazelnut and oat). The highest content was recorded to be 15.5% per 100 ml in rice milk products which also can be translated into 15.5 g rice in 100 ml of rice milk. For other plant-based milk products the plant material content was: 11.9% oat, 8.8% Soybeans, 8% coconut cream, 3.7% hazelnut and 3.45% almond.

The anti-nutrient oxalate is found naturally in plants and plant-based products. Among the plant-based milk alternatives found in the market and according to literature almond and soybeans are both contain oxalate in various quantities that is largely exceeding the amounts reported in other types *e.g.*, oat and coconut milks. Lowest amount of oxalate reported in almond is 192 mg and the highest is 469 mg in 100 g almond, while lowest amount of oxalate reported in soybeans is 82 mg and highest is 285 mg in 100 g soybeans. Through knowing the amount of almond (3.45 g) and soybeans (8.8 g) in their related milk products the amount of Oxalate (in mg) per 100 mls of milk can be estimated. Moreover, the percentage of RDI of oxalate can also be estimated based on the RDI of 50 mg oxalate per day. Table 2 shows the estimated intake of oxalate from almond which can be in the range of 6.6 mg to 17 mg oxalate per 100 ml intake of almond milk which is lower than what is estimated for soymilk. The soymilk products provide 50.2% of the RDI of oxalate.

In this discussion section, it is important to highlight the fact that Nutritional values provided by plant-based milk alternatives vary between the types; almond, soybeans, rice, oat, hazelnut and coconut, as well as with cow’s milk (Vanga and Raghavan, 2018). Nowadays, plant-based milk alternatives are mostly fortified with calcium, vitamin D and vitamin B complex and there are original and unsweetened options, which make these products attractive and competitive to cow’s milk in the dairy market. On the other hand, it was reported in the literature that almond milk and soymilk are the most consumed globally and this is because the almond milk has a nutty pleasant creamy taste and soymilk is sold in much cheaper affordable prices (Schuster *et al*., 2018). This research supports that fact that almond milk and soymilk are found in wide range of brands and flavors in the Omani market with 20 and 23 products respectively. Moreover, the price of soymilk products was significantly lower that of the almond milk products which makes it more affordable and accessible to a wider range of consumers. In this section, two issues are going to be discussed based on the results obtained and almond milk and soymilk are going to be the main focus of our discussion.

**Type and frequency of use of additives**

The function of additives such as thickening agents and emulsifiers is to increase the viscosity of the aqueous phase in order to inhibit the creaming of lipid droplets or the sedimentation of insoluble matter hence enhancing product stability, quality, or nutritional attributes (McClements, 2020).

Table 1 shows the type and frequency of use of additives in the studied sample. Additives appear in 17 products of soymilk (73.9%) which is the highest among other plant based milks and among these additives thickening agents are found in 53.1% of the products. Thickening agents can be used to create desirable textural, or mouth feel attributes, numerous kinds of biopolymers were being employed as thickening agents, which vary in their molecular, physical, functional and biological properties. The two most common thickening agents recorded in the selected products in order are: gellan gum and carrageenan gum. The gellan gum is a high molecular weight polysaccharide gum produced by a pure culture fermentation of a carbohydrate by strains of *P. elodea* (ATCC 31461) and is authorized as a food additive in the European Union (EU) in accordance with Annex II

**Table 1:** The type and frequency of use of additives in the selected plant-based milk alternatives.

| **1- General findings** | | |
|---|---|---|
| Number of products | Type of additives | Percentage of total products (n=81) |
| 43 products | Thickening agents | 53.1% |
| 22 products | Emulsifiers | 27.2% |
| 14 products | Acidity regulators | 17.3% |
| 4 products | Anti oxidants | 4.9% |
| **2- The distribution of additives in plant based milk alternatives** | | |
| Plant-based beverage variants | Products containing additives | Percentage |
| Soymilk (n=23) | 17 products | 73.9% |
| Almond milk (n=20) | 12 products | 60% |
| Coconut milk (n=13) | 7 products | 53.8% |
| Oat milk (n=12) | 6 products | 50% |
| Hazelnut milk (n=4) | 2 products | 50% |
| Rice milk (n=9) | 3 products | 22.2% |
| **3- Types and frequency of use of thickening agents appeared in all study sample** | | |
| Type of thickening agents | Frequency | |
| Gellan gum | 33 | |
| Carragenan gum | 9 | |
| Carob bean (lacust bean) gum | 7 | |
| Guar gum | 6 | |
| Xanthan gum | 4 | |
| Pectin gum | 2 | |

**Table 2:** Estimate of oxalate content in 100 mls of the selected sample products of almond milk and soymilk beverages based on the reported oxalate in the literature◊.

| **Almond milk (n=20 products)** | | | | |
|---|---|---|---|---|
| Mean weight of Almond in 100 mls: | Estimate of oxalate content (1) | Percentage of RDI | Estimate of oxalate content (2) | Percentage of RDI |
| 3.45 g of almonds | 6.6 mg | 13.2% | 17 mg | 34%* |
| **Soymilk (n=23 products)** | | | | |
| Mean weight of soybeans in 100 mls: | Estimate of oxalate content (3) | Percentage of RDI | Estimate of oxalate content (4) | Percentage of RDI |
| 8.8 g of soybeans | 7.2 mg | 14.4% | 25.1 mg | 50.2%* |

◊(1) based on 192 mg in 100 g almond.
(2) based on 469 mg in 100 g almond.
(3) based on 82 mg in 100 g soybeans.
(4) based on 285 mg in 100 g soybeans.
*Significant $p<0.004$.

and Annex III to Regulation (EC) No 1333/2008 and was assigned the code (E148). A recent report by the European Food Safety Authority in 2018 concluded that there is no safety concern in using gellan gum as a food additive (EFSA, 2018). The second common thickening agent is carragenan which is a sulfated galactose polymer derived from several species of red seaweeds of the class Rhodophyceae. This molecule has been used for several decades by the food industry and is considered safe for human consumption. This classification was initially based on its high molecular weight, low absorption from the gastrointestinal (GI) tract. A series of *in vitro* and *in vivo* studies on carrageenan conducted by the research group of J.K. Tobacman from 2001 to 2014 as well as a study done by Choi *et al*. (2012) reporting a potential harmful effect of carrageenan in inducing inflammatory reactions in the GIT (Bhattacharyya *et al.,* 2013; Tobacman, 2001). Such studies provoked thorough reviews of such claims by the Joint FAO/WHO Expert Committee on Food Additives (JECFA, 2015) and by McKim (2014) and Weiner (2014) in separate publications in 2014. The outcome of such reviews reassured the safety of using carrageenan in food industry.

**The percentage contribution of plant-based milks towards the RDI of Oxalate**

Oxalate is a strongly oxidized and corrosive compound with good chelating activity, synthesized by a broad range of animals, plants and microorganisms. Oxalate and its salts are extensively spread in numerous plant tissues as the end products of metabolism. Oxalate content in foodstuffs has long been a concern in human diets, due to the negative health effects connected to a high intake of oxalate (Siener *et al.,* 2017). Accumulating evidence from animal and human studies suggests that dietary oxalate may have a greater impact on kidney function than previously recognized. Oxalate is primarily eliminated through the kidneys by both glomerular filtration and tubular secretion. Therefore, long term and high intake of dietary oxalate leads to increased urinary oxalate excretion that is linked to different kidney-related conditions and injuries such calcium oxalate nephrolithiasis (Bargagli *et al*., 2020).

Soybeans (legumes) and almonds (nuts) are among the foods that are known to contain high content of oxalate. The reported amounts of oxalate in soybeans and almonds per 100 g in the literature varies greatly; in soybeans the range is from 82 to 285 mg oxalate and in almonds the range is from 192 to 469 mg oxalate (Ellis and Lieb, 2015; Petroski and Minich, 2020). The discrepancy in the oxalate concentrations of plant foods can be related to growing conditions (*e.g.*, light exposure, soil quality, level of maturity), harvest time, variety and different analytical methods used for oxalate extraction and determination (Siener *et al.,* 2017). Table 2 shows the percentage contribution of 100 ml of soybean and almond milks towards the RDI of oxalate. The percentage contribution was calculated based on the combination of following information: mean amount of soybean and almond in the selected products, the oxalate content in mg which is reported in the literature for soybean and almond and the RDI of oxalate per day which is around 50 mg. The percentage contribution for soymilk can be estimated as low as 14.4% and as much as 50.2%, while for almond milk it can be estimated as low as 13.2% and as much as 34%. Based on the statistical analysis a 100 ml of soymilk has a more significant contribution to oxalate intake when it is compared to the 100 ml of almond milk. In a simple calculation, a cup of soymilk (240 ml) will contribute from 34.5% to 120.5% of the RDI of oxalate. There were two related studies which reported a link between the consumption of soymilk and almond milk with high intake of oxalate. Massey *et al.* (2002) conducted an experiment involving human volunteers to measure and examine the oxalate absorption by measuring changes in urinary oxalate excretion after ingestion of soy based products including the ingestion of 480 ml (2 cups) of soy beverage. The study concluded that the frequent intake of soy based products may lead to hyperoxalurea and may be a risk factor for nephrolithiasis (CaOx kidney stone formation) in susceptible individuals. Another study by Ellis and Lieb (2015) reported the case of three children one of whom was advised to avoid dairy products due to her lactose intolerance condition and as a result switched to drinking 3 to 4 cups (720 to 960 ml) of almond milk daily along with the consumption of moderate amounts of almond yogurt and almond butter. The authors found a possible link between the moderate to high ingestion of almond milk and hyperoxalurea that may increase the risk of nephrolithiasis. The outcomes presented in the above studies and this current study come in agreement that moderate to high ingestion of soymilk and almond milk can increase the risk of nephrolithiasis. Therefore, there are three ways that can be suggested to reduce the risk of ingesting high amount of oxalate and at the same time keep these products (soymilk and or almond milk) as part of a healthy life style. First is to reduce the daily ingestion of these products to less that 100 ml for soymilk which may provide 14.4% and as much as 50.2% of RDI of oxalate and 150 ml of almond milk which may provide 19.8% and as much as 51%. The second option is to look for products which contain less plant based content. Soymilk products (n=23) selected in this study have a range of soybean content as low as 4.8 g/100 ml to as high as 14 g/100 ml and the mean was 8.8 g/100 ml. Therefore people can go for products which show low soybean content in their ingredient label such as "Australia's own organic soymilk" or "Alpro soya light". The same applicable to almond milk products (n=20) have a range of almond content as low as 1 g/100 ml to as high as 10 g/100 ml and the mean was 3.45 g/100 ml. Therefore people can go for products which show low almond content in their ingredient label such as "Rude health almond". If these two above options are not applicable; inconvenient amounts of milk per day and/or the brands mentioned above are not available in the market, here it comes a third option which is switching to another type of plant based milk alternatives such as oat milk or coconut milk.

## CONCLUSION

There is a wide range of plant-based milk alternatives offered in the Omani market which reflects consumer acceptance for such products. Additives were found in more than half of the selected products and the common additive type was thickening agents. Estimating the amount of oxalate per intake and the percentage contribution of commercially available plant-based milks towards the RDI of oxalate is inexistent in the literature. Therefore, the outcome of this study would provide a guidance for the consumers in buying such products to avoid excess consumption and prevent the possible effect on health and risk of nephrolithiasis.

**Conflict of interest:** None.

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