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# Nutrient composition of milk and plant-based milk alternatives: A cross-sectional study of products sold in Australia and Singapore

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ABSTRACT

Dairy and non-dairy (plant-based) alternatives are promoted as an essential component of a healthy diet. The purpose of this study was to evaluate the range of dairy milks and plant-based milk alternatives in supermarkets in Australia and Singapore, and to explore nutritional differences within the category, and between countries. Product information was collected in store from packaging. Products were sorted into dairy milks and plant-based milk alternatives, and further categorised as (i) breakfast drinks (12 % of products); (ii) plain milks (62 %); or (iii) flavoured milks (26 %). The nutrient profiles of products were tested for differences using Kruskal Wallis and Mann-Whitney U tests. Flavoured products contained almost double the median sugar content of plain products (8.3 g v. 4.6 g, $p = 0.005$). Two-thirds of the product range were dairy milks, which contained nearly four times the median saturated fat content (1.1 g v. 0.3 v, $p < 0.0001$) and more than double the amount of sugar (5.1 g v. 2.6 g, $p < 0.0001$) of plant-based milk alternatives, but three times more protein (3.3 g v. 1.0 g, $p < 0.0001$). Between countries, generally, calcium contents were similar across products, likely due to fortification of plant-based milk alternatives. Compared to Singapore, dairy milk and plant-based milk alternative products sold in Australia were generally higher in energy, protein and fat, but lower in carbohydrate content. Food supply differences between Singapore and Australia may be cultural and have nutritional implications.

## 1. Introduction

Food based dietary guidelines promote the consumption of dairy and non-dairy alternatives as an essential component of a healthy diet (Comerford et al., 2021; National Health and Medical Research Council, 2020; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020). Dairy milk is a nutrient-dense source of energy and high-quality protein, and contains a range of micronutrients including vitamin A, B2, B6 and B12, iodine, phosphorous, zinc and calcium (Ilesanmi-Oyelere & Kruger, 2020). In milk consuming countries, dairy milk plays a key role in growth and development throughout the lifecycle (especially in childhood and adolescence), such as for promoting bone health (O'Neil, Nicklas, & Fulgoni, 2018).

Non-dairy milk alternatives (plant-based milk alternatives) are available for those who avoid dairy for reasons such as milk protein allergy and lactose intolerance (Sethi, Tyagi, & Anurag, 2016; Valencia-Flores, Hernández-Herrero, Guamis, & Ferragut, 2013), concerns for animal welfare (Tsakiridou, Tsakiridou, Mattas, & Arvaniti, 2010) and concerns about environmental sustainability (Carlsson Kanyama, Hedin, & Katzeff, 2021). Health is another motivator behind the increased demand for plant-based milk alternatives (IBISWorld, 2020) which may also be preferred over dairy milk for their common perceived benefits of being lactose free, cholesterol free, and lower in energy (Drewnowski, Henry, & Dwyer, 2021; Sethi et al., 2016). However, doubts have been raised regarding their nutritional equivalence to their dairy counterparts (Drewnowski et al., 2021; Sethi et al., 2016). In fact, Food Standards Australia and New Zealand (FSANZ) mandate an advisory warning on plant-based beverages "that the product is not suitable as a complete milk replacement for children under 5 years old" (Food Standards Australia New Zealand (FSANZ), 2016).

Plant-based milk alternatives are derived from nuts (e.g., almond), legumes (e.g., soy), fruits (e.g., coconut), and grains (e.g., oat), or a combination of these (Sethi et al., 2016). Ideally, plant-based milk alternatives would provide equivalent levels of vitamins and minerals,

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without the need to elicit compensating changes in dietary patterns to meet requirements. However, by nature, these products are not high in calcium, or other micronutrients expected from dairy milk. Plant-based milk alternatives may be fortified with essential vitamins and minerals, so their nutrient profile is more comparable to dairy milk and to reduce any requirement for nutritional supplementation. Apparent consumption of almond and soy milks in Australia has increased by 31 % and 16 %, respectively, between 2018–19 and 2019–20 (Australian Bureau of Statistics, 2022). Similarly, in Singapore there has been an increase in plant-based protein consumption, with consumer interest rising steadily as plant-based brands increase their retail presence. For example, the oat-based milk company "Oatly" launched at local supermarkets in 2020 and soon after, in 2021, partnered with local beverage producer Yeo Hiap Seng to build a production factory in Singapore to support the rapidly growing Asian market (Ho, 2022). Despite growing interest and consumption, however, there is limited evidence regarding whether these products are nutritionally equivalent to cow's milk (Drewnowski et al., 2021; Zhang, Hughes, & Grafenauer, 2020). An audit of plain plant-based milk alternatives (n = 115) available in Australian supermarkets between November 2019 and January 2020 found just over 50 % of products were fortified, and only one third contained a similar calcium content to cow's milk (Zhang et al., 2020). However, nutrient composition data for plant-based milk alternatives collected in store were compared to reference data for dairy milks, from the FSANZ Food Composition Database, rather than data from products available in supermarkets, so the findings should be interpreted with caution.

Dairy milk and plant-based milk alternatives are available in both plain and flavoured varieties (and some are consumed/promoted as a liquid substitute for breakfast), with a wide range of nutrient compositions. Coyle et al. (2019) compared the sugar content of flavoured dairy products across Australia, England and South Africa. For the three countries combined, there was a similar number of flavoured versus unflavoured milk varieties (n = 468 and n = 547, respectively). Overall, flavoured milks had nearly double the total sugar content of unflavoured milk. However, there were significant differences between the average sugar content of flavoured milks between the three food supplies, with higher mean values reported in England compared with Australia and South Africa (Coyle, Ndanuko, Singh, Huang, & Wu, 2019). This study did not investigate the broader nutrient differences of plain and flavoured plant-based milk alternatives between countries, nor explore if there was a difference between dairy and plant-based milk alternatives.

The purpose of this study was to provide an overview of the range of dairy milk and plant-based milk alternatives in supermarkets in Australia and Singapore, and to explore differences within the category, and between countries. Factors investigated included the availability and variety of products, nutrient composition and ingredients. Australia and Singapore were chosen due to the availability of data, and to allow for comparison between two different high-income countries within the Asia-Pacific (APAC) region. Australia is a large, dairy-exporting country. By comparison, Singapore is a small island state whose food supply relies on imported goods from over 170 countries (Teng, 2020). While there are also differences between the two countries in terms of their shopping practices and culinary traditions, as well as labelling laws (Food Standards Australia New Zealand (FSANZ), 2021; Singapore Food Agency, 2019; State Administration for Entry-Exit Inspection and Quarantine of the People's Republic of China, 1998; Zhang & Jakku, 2021), Australia is one of Singapore's major food suppliers (Australian Trade and Investment Commission, 2023). As seen during the Covid-19 pandemic, having a solid-cross border strategy is important to ensure food security (UNCTAD, 2023). An important part of building such national strategies is understanding the product range and availability within the primary producing country versus trading partners, as is the case for these two countries. There are.

## 2. Materials and methods

### 2.1. Data collection

Data for dairy milk and plant-based milk alternatives sold in Australia (2019) were obtained from the FoodTrack™ database; an Australian database for packaged food and beverages developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the National Heart Foundation of Australia. The methods for data collection have been described in detail elsewhere (Brooker, Hendrie, Anastasiou, & Colgrave, 2022; Wooldridge, Riley, & Hendrie, 2021). Briefly, with permission from local or national store managers, nutrition-trained data collectors visited four major retailers (Coles, Woolworths, IGA and ALDI; 8 store locations) in metropolitan Victoria, Australia, using a customised App with barcode recognition software to collect nutrient, price and images of products for sale. In the absence of a similar database in Singapore, the FoodTrack™ infrastructure was adapted to collect data for dairy milk and plant-based milk alternatives sold in Singapore (2020). Trained data collectors visited four major retail supermarkets (Cold Storage, Giant, NTUC FairPrice and Sheng Siong) and two major convenience stores (7-Eleven and Cheers; 12 store locations in total). Information available for the products included manufacturer, brand and product names, serving information, nutrition information (when provided) from the nutrition information panel, and ingredients listings.

### 2.2. Product inclusion and exclusion criteria

Products included in the analysis were beverages made from either dairy or non-dairy (plant) milk alternatives. Condensed and evaporated milks were excluded, as were infant products. Milk modifiers, such as drinking chocolate, and flavourings, such as syrups used to make milkshakes were also excluded.

### 2.3. Product categorisation

Products were divided into dairy- or plant-based milks, and further categorised as either (i) breakfast drinks; (ii) plain milk or plant-based milk alternative; or (iii) flavoured milk or plant-based milk alternative, based on information provided on the packaging, according to the study definitions (see Table 1). The main milk ingredient(s) were also extracted. Ingredients lists of included products were also individually inspected to determine whether the product contained any fortificants (i.e., added vitamins or minerals).

### 2.4. Data treatment

Nutrient values which were recorded on packaging as '<X' were recorded as their upper limit (e.g., <1 was recorded as 1). Where products did not display all or some nutrient information, data were recorded as missing values. Outliers were identified using minimum and maximum values and by viewing boxplots. These values were then checked by reviewing the original food package images and corrected if necessary.

### 2.5. Statistical analysis

Data were analysed using the Statistical Package for Social Sciences (SPSS) version 26 (IBM, New York, USA). Variables were checked for normality using the Shapiro-Wilk test and visual inspection of histograms. Most data distributions were considered non-normal; distributions of continuous variables were described using median and 25th and 75th percentiles.

The number and proportion of plant-based milk alternatives and dairy milks were calculated for each subcategory (breakfast drinks, plain dairy milk and plant-based milk alternatives and flavoured dairy milk

**Table 1**
Description of the subcategories for products collected in the milk and plant-based milk alternatives grocery category used in this study.

| Subcategory | Definition and examples |
|---|---|
| Breakfast drinks | Products designed or marketed to be consumed at a breakfast occasion. |
| | Protein breakfast smoothies – tend to use the word 'breakfast' in product name. |
| Milk – plain (may be fresh, uht or powdered) | Regular fat (i.e., full cream) or fat-modified, other modified e.g., lactose free, goats milk – plain varieties only |
| | Buttermilk |
| | Fermented milk |
| | Plant-based milk alternatives, e.g., Nut milks, oat milk, rice milk, soy milk, coconut milk (positioned as a drink) – plain varieties only |
| | Powdered milks requiring reconstitution (shelf-stable) |
| Milk – flavoured (may be fresh, uht or powdered) | Regular fat (i.e., full cream) or fat-modified, other modified e.g., lactose free, goat – flavoured varieties only (e.g., Ice-coffee, strawberry, chocolate) |
| | Milkshakes, smoothies based on dairy or plant-based milk alternative |
| | Ready to drink protein smoothies |
| | Plant-based milk alternatives, e.g., nut milks, oat milk, rice milk, soy milk, coconut milk (positioned as a drink) – flavoured varieties only (e.g., vanilla, chocolate) |
| Milk modifiers and flavourings (may be syrup or powdered) | Drinking chocolate, malted drinks, flavoured milkshake mixes (usually concentrated liquid) |
| | These can be in concentrated liquid form (milkshake mixes) or powdered form |

and plant-based milk alternatives) for both countries. Differences in the proportion of products across countries were examined by chi-squared tests. To test for nutrient content differences between categories of breakfast drinks, plain milks and flavoured milks, Kruskal Wallis tests were used with Bonferroni post-hoc adjustment. Mann-Whitney U tests were used for pairwise comparisons of the distributions across the dairy milk and plant-based milk alternatives categories. To avoid skewing nutrient data, when the same product was available in different pack sizes, only one entry was retained for the ingredient and nutrient analyses. Products which only presented nutrition information in the products dry format were also excluded from the ingredient and nutrient analyses. Statistical significance was taken to be a p-value of $< 0.05$.

## 3. Results

### 3.1. Product range and availability

A total of 903 dairy milk and plant-based milk alternative products were identified across the Australian and Singaporean datasets in the FoodTrack™ database (Fig. 1) with Singapore having more products in each category. The distribution of breakfast drinks, plain and flavoured dairy milk and milk alternative products was similar between Australia and Singapore; plain dairy milk and plant-based milk alternatives were the most common products, followed by flavoured dairy milk and plant-based milk alternatives then breakfast drinks. Proportionally, there were significantly more breakfast drinks available in Singapore compared with Australia ($\chi(1) = 6.6$, $p = 0.010$; Table 2).

Four products ($n = 2$ plain; $n = 2$ flavoured) collected in Singapore had a combination of plant and dairy ingredients (e.g., soy and cow's milk). These products were categorised as either plant-based milk alternatives or dairy milks according to their primary ingredient ($n = 3$ plant-based, $n = 1$ dairy). The majority of products in the database ($n = 587$, 65 %) were dairy milks. Between countries, the proportion of dairy- and plant-based breakfast drinks ($\chi(1) = 12.5$, $p < 0.001$) and plain milks ($\chi(1) = 4.6$, $p = 0.032$) were different (Table 2).

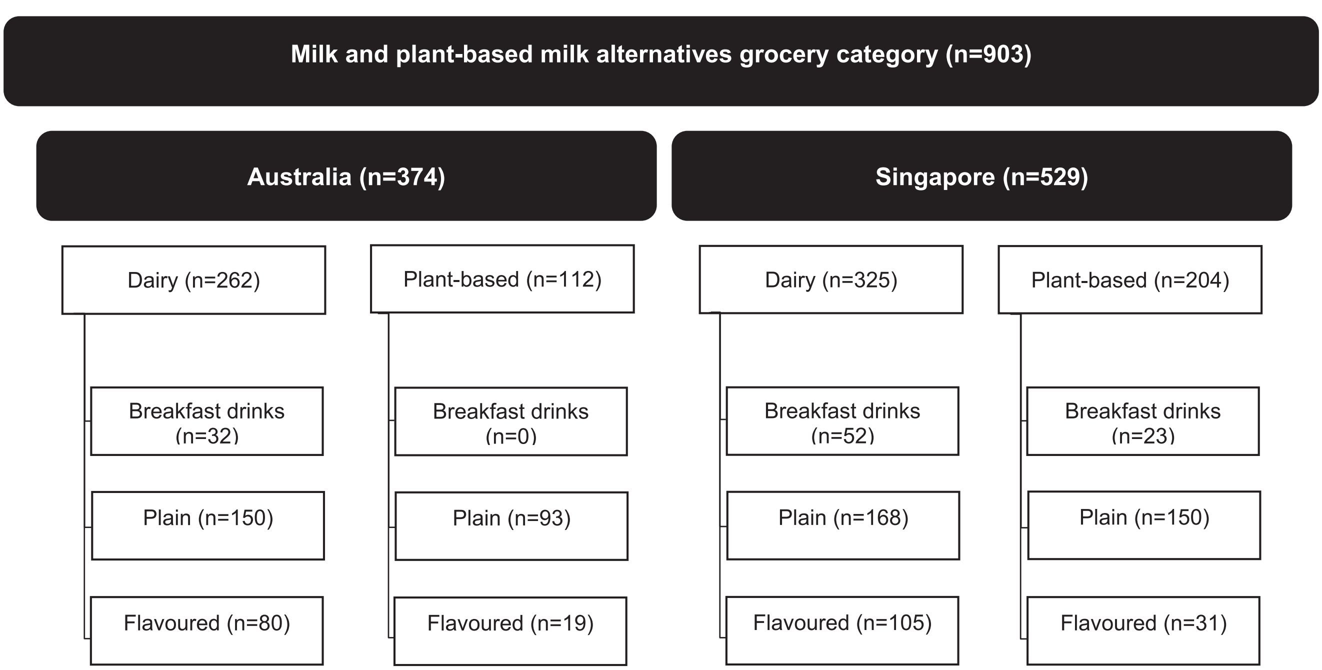


**Fig. 1.** Overview of the milk and plant-based milk alternatives grocery category and subcategory of products included in the analysis. *Note:* Numbers above represent the count of products included in the analysis of product range and variety, and includes both ready-to-drinks and powdered products. To avoid skewing nutrient data, when the same product was available in different pack sizes, only 1 entry was retained for the ingredient and nutrient analyses. Products which only presented nutrition information in the products dry format were also excluded from the ingredient and nutrient analyses. See Supplementary Table S3 for details.

**Table 2**
Number and proportion of milk and plant-based milk alternative products collected within each subcategory in Australia (2019) and Singapore (2020).

| Subcategory | Australia (n = 374) | | Singapore (n = 529) | | Between country differences |
|---|---|---|---|---|---|
| | n | % | n | % | p-value ‡ |
| Breakfast drinks | 32 | 8.6 % | 75 | 14.2 % | **0.010*** |
| *Dairy milks* | 32 | 8.6 % | 52 | 9.8 % | **<0.001*** |
| *Plant-based milk-alternatives* | 0 | 0.0 % | 23 | 4.3 % | |
| Plain milk and alternatives | 243 | 65.0 % | 319 | 60.3 % | 0.138 |
| *Dairy milks* | 150 | 40.1 % | 168 | 31.8 % | **0.032*** |
| *Plant-based milk-alternatives* | 93 | 24.9 % | 150 | 28.4 % | |
| Flavoured milk and alternatives | 99 | 26.5 % | 135 | 25.5 % | 0.797 |
| *Dairy milks* | 80 | 21.4 % | 105 | 19.8 % | 0.574 |
| *Plant-based milk-alternatives* | 19 | 5.1 % | 31 | 5.8 % | |

Note: Data were collected in 2019 (Australia) and 2020 (Singapore). ‡ chi-square tests; *indicates statistical significance.

### 3.2. Product variety

A breakdown of the food source of dairy- and plant-based milks for both countries, by subcategory are illustrated in Fig. 2. There were two different sources of dairy milk: cow and goat milks. In both countries, cow's milk was the most common dairy milk available (Australia n = 260, 99 %; Singapore n = 319, 98 %).

Of the 316 plant-based milk alternatives collected in Australia and Singapore, 71 products (22 %) contained more than one plant source and were described as 'mixed-plant milks' (Australia n = 15; Singapore n = 56). There were 30 plant source combinations (see Supplementary Table S1 for details), most of which were plain (n = 54, 76 %). The number of different plant sources in mixed-plant milks ranged from two (n = 45, 63 %) to six (n = 6, 8 %).

To compare the range of all plant-based milk alternatives between countries, mixed-plant milks were subsequently re-grouped into their primary milk ingredient (i.e., mixed plant products and those containing only one plant-milk ingredient). Soy was the most common primary source of plant-based milk in Singapore (n = 105, 51 %) and almond milk was the most common source in Australia (n = 48, 43 %). Some primary plant-based milk ingredients were unique to Singapore (e.g., black sesame, hazelnut, pistachio, adzuki bean, and walnut), and pea protein was unique to Australia (Fig. 2).

### 3.3. Ingredient and nutrient analyses

Of the 903 products collected, 676 products were included in the ingredient and nutrient analyses (Australia, n = 302; Singapore, n = 374 (55 %)). Twenty-four products were excluded on the basis that the nutrition information was only presented for the products dry format, and 203 products were excluded because they were duplicate products (i.e., the same products available in different pack sizes). See Supplementary Table S2 for product counts included in ingredient and nutrient analyses by subcategory.

#### 3.3.1. Fortification

Just over one third (n = 254, 38 %) of products across both countries contained one or more fortificants (Supplementary Table S3). Overall, 20 % (n = 81 of 409) of dairy milk products and 65 % (n = 173 of 267) of plant-based milk alternatives were fortified. More than half of breakfast drinks were fortified (n = 33, 55 %), and about a third of plain (n = 162, 37 %) and flavoured milks (n = 50, 34 %) were fortified.

There was a greater proportion of fortified dairy milks in Singapore (Australia: n = 22, 11 %; Singapore: n = 59, 27 %), whereas a greater proportion of plant-based products were fortified in Australia (Australia: n = 76, 70 %; Singapore: n = 97, 61 %). The average number of fortificants added to products was 3.6 ± 3.2 (range 1 to 15). On average, breakfast drinks had the greatest number of fortificants in both countries (Australia, 8.8 ± 0.6; Singapore 6.8 ± 4.7) compared with plain milks (Australia, 2.3 ± 2.2; Singapore 3.1 ± 2.7) and flavoured milks (Australia, 2.1 ± 1.9; Singapore 4.3 ± 3.1). In Australia, the most common fortificant added to dairy milks were Vitamins A and C (n = 17 products, 9 %) and Vitamin D (n = 48, 22 %) was most common in Singaporean dairy products. Calcium was the most common fortificant added to plant-based milk alternatives in both countries (Australia: n = 75, 69 %; Singapore: n = 84, 53 %). Fig. 3 illustrates the types and

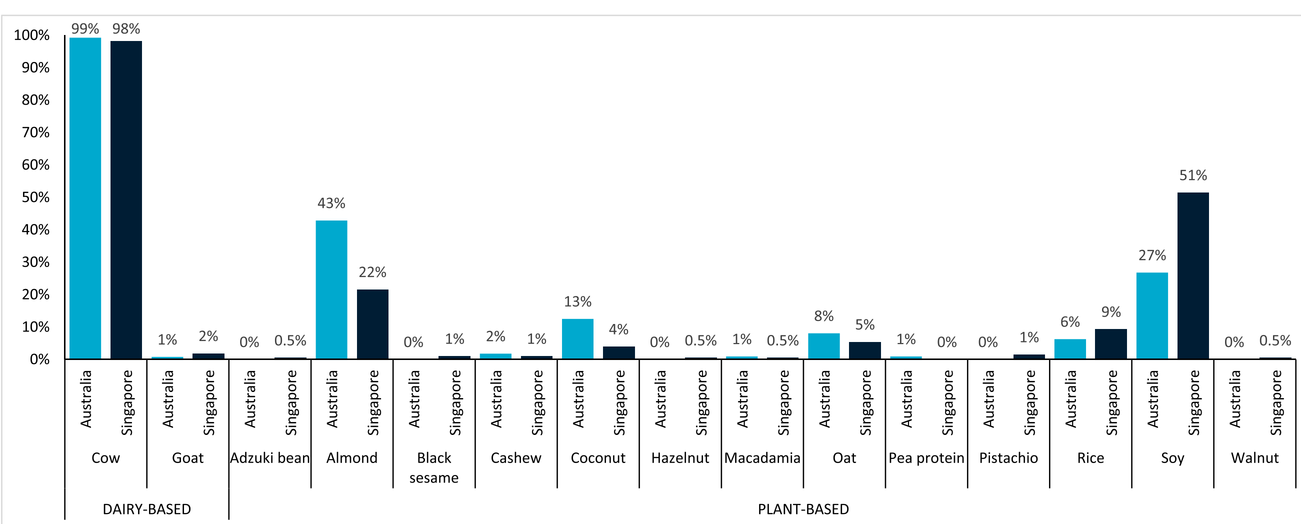


**Fig. 2.** Primary dairy or plant source of milk and plant-based milk alternative products collected in Australia (2019) and Singapore (2020) *Note:* Data may not add to 100 % due to rounding.

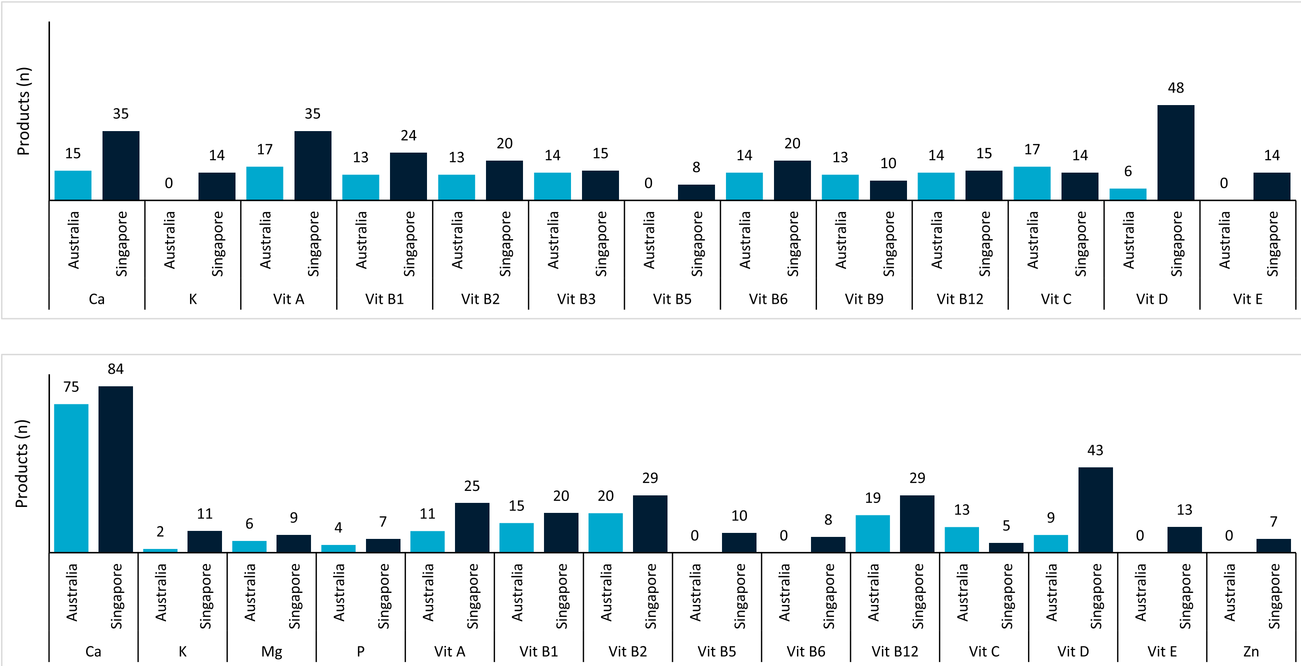


**Fig. 3.** Type and frequency of fortificants added to products in Australia and Singapore in Dairy milks (Top); and Plant-based milk alternatives (Bottom). *Note:* Fortificants with <5 products in both countries not displayed. *Abbreviations:* Ca, Calcium; K, Potassium; Mg, Magnesium; P, Phosphorous; Vit, Vitamin; Zn, Zinc.

**Table 3**
Nutritional composition (/100 mL) of milk and plant-based milk alternative products collected within each subcategory in Australia (2019) and Singapore (2020).

| Subcategory | Energy (kJ) | Protein (g) | Total fat (g) | Saturated fat (g) | Total carbohydrate (g) | Sugar (g) | Fibre (g) | Calcium (mg) |
|---|---|---|---|---|---|---|---|---|
| Breakfast drinks | | | | | | | | |
| Australia (n = 21) | 300 (295–329)* | 3.4 (3.3–7.0)* | 1.5 (1.4–1.7) | 0.3 (0.2–1.0) | 10.0 (7.1–11.4) | 6.4 (6.3–7.5)* | 1.6 (1.5–1.6)* | 120 (120–160)* |
| Singapore (n = 39) | 259 (227–269)* | 1.2 (0.8–1.9)* | 1.5 (0.9–1.7) | 0.8 (0.5–1.0) | 10.0 (8.9–11.6) | 5.5 (4.2–6.5)* | 0.6 (0.5–0.9)* | 69 (60–120)* |
| Plain milk | | | | | | | | |
| Australia (n = 202) | 213 (162–264) | 3.2 (1.0–3.4) | 2.0 (1.3–3.4) | 1.0 (0.3–2.2)* | 4.8 (3.6–5.1) | 4.5 (2.0–4.9) | 0.3 (0.0–0.75) | 120 (115–122) |
| Singapore (n = 238) | 206 (158–265) | 3.1 (1.1–3.4) | 1.8 (1.2–3.3) | 0.4 (0.2–1.4)* | 4.9 (4.0–6.0) | 4.6 (2.4–5.0) | 0.2 (0.0–0.5) | 120 (110–128) |
| Flavoured milk | | | | | | | | |
| Australia (n = 79) | 284 (241–341)* | 3.2 (3–3.4)* | 2.2 (1.5–3.5)* | 1.4 (0.8–2.3)* | 8.6 (6.9–9.6)* | 8.3 (5.6–9.1) | 0.4 (0.1–0.6) | 114 (110–120) |
| Singapore (n = 97) | 256 (218–294)* | 2.5 (1.4–3.0)* | 1.5 (0.9–2.1)* | 0.6 (0.2–1.1)* | 9.1 (7.6–10.4)* | 8.2 (6.3–9.7) | 0.4 (0.0–0.5) | 120 (79–130) |
| *Dairy milks* | | | | | | | | |
| Australia (n = 194) | 270 (214–302)* | 3.4 (3.3–3.6)* | 2.1 (1.4–3.5)*, | 1.4 (0.9–2.3)* | 5.2 (4.8–8.6)* | 5.0 (4.7–7.7) | 0.0 (0.0–1.0) | 120 (114–123) |
| Singapore (n = 215) | 260 (206–281)* | 3.2 (2.2–3.4)* | 1.6 (0.9–3.3)* | 0.9 (0.6–2.1)* | 6.1 (4.9–9.7)* | 5.4 (4.7–8.3) | 0.0 (0.0–0.5) | 120 (110–130) |
| *Plant-based milk alternatives* | | | | | | | | |
| Australia (n = 108) | 173 (110–231) | 1.0 (0.6–3.0) | 2.0 (1.4–2.7)* | 0.3 (0.2–0.5) | 3.6 (0.8–6.0)* | 1.9 (0.4–3.4)* | 0.5 (0.3–1.0) | 120 (80–120) |
| Singapore (n = 159) | 195 (140–240) | 1.2 (0.6–2.8) | 1.7 (1.2–2.1)* | 0.3 (0.2–0.4) | 5.9 (2.6–8.1)* | (1.3–5.8)* | 0.5 (0.2–0.8) | 120 (69–120) |

Note: Data are presented as Median (25th–75th percentile); *, indicates statistical significance ($p < 0.05$) within subcategory, between Australia and Singapore.

frequency of fortificants used in selected dairy milks and plant-based milk alternatives. See Supplementary Table S4 for a full list and frequency of fortificants present.

### 3.3.2. Nutrient composition

The proportion of products displaying nutrition information on pack in Australia and Singapore is presented in Supplementary Fig. S1. Calcium content was displayed on 89 % of products (n = 270) in Australia and 73 % of products (n = 271) in Singapore. The nutrient composition of products available in Australia and Singapore are provided in Table 3.

*3.3.2.1. Breakfast drinks, plain and flavoured milks.* Across the entire sample, breakfast drinks were significantly higher in total carbohydrate and fibre, and lower in total fat (median content/100 mL) than both plain and flavoured milks ($p < 0.05$ for all). Flavoured milks were significantly higher in sugar than breakfast drinks ($p < 0.0001$) and plain milks ($p = 0.005$). Breakfast drinks and flavoured milks were both higher in energy than plain milks ($p < 0.0001$). There were no differences in protein or saturated fat between the three subcategories of products (Table 3).

Between countries, plain milks had similar nutrient profiles (per 100 mL) for energy and most nutrients, but Australian products were higher in saturated fat than products available in Singapore (1.0 g v 0.4 g; $p = 0.001$). Breakfast drinks in Australia were higher in energy (300 kJ v. 259 kJ; $p < 0.0001$), protein (3.4 g v. 1.2 g; $p < 0.0001$), sugar (6.4 g v. 5.5 g; $p = 0.002$), fibre (1.6 g v. 0.6 g; $p < 0.0001$) and calcium (120 mg

v. 69 mg; $p < 0.0001$) than those available in Singapore. Flavoured milks in Australia were higher in energy (284 kJ v. 256 kJ; $p = 0.005$), protein (3.2 g v. 2.5 g; $p < 0.0001$), total fat (2.2 g v. 1.5 g; $p < 0.0001$) and saturated fat (1.4 g v. 0.6 g; $p < 0.0001$), but lower in total carbohydrate (8.6 g v. 9.1 g; $p = 0.38$) than those available in Singapore (Table 3).

*3.3.2.2. Dairy milks and plant-based milk alternatives.* Across the entire sample, generally, dairy milks were higher in energy, protein, total and saturated fat, total carbohydrates and sugar (per 100 mL; $p < 0.05$ for all). There were some differences in the nutrient profiles of dairy milks and plant-based milk alternatives between countries. Dairy milks collected in Australia were higher in energy (270 kJ v. 260 kJ; $p = 0.005$), protein (3.4 g v. 3.2 g; $p < 0.001$), total fat (2.1 g v. 1.6 g; $p < 0.0001$) and saturated fat (1.4 g v. 0.9 g; $p < 0.0001$), but lower in total carbohydrate (5.2 g v. 6.1 g; $p = 0.008$) than those in Singapore. Plant-based milk alternatives collected in Australia were higher in total fat (2.0 g v. 1.7 g; $p = 0.01$), but lower in total carbohydrate (3.6 g v. 5.9 g; $p < 0.0001$) and sugar (1.9 g v. 3.5 g; $p < 0.0001$) compared with plant-based milk alternatives in Singapore (Table 3).

## 4. Discussion

The purpose of this study was to provide an overview of the range of dairy milks and plant-based milk alternatives sold in Australia and Singapore, and to explore differences within the category, and between countries. As Australia is one of the main suppliers of food to Singapore (Australian Trade and Investment Commission, 2023), understanding the product range and availability (rather than consumption) in each country could be useful for informing strategies for food production. Factors investigated in this analysis included the variety of products, the nutrient composition and the ingredients. In both countries, there was more than double the number of plain milks compared with flavoured milks. There were some nutritional differences between the sub-categories of products which seem to reflect their intended purpose. Breakfast drinks were higher in carbohydrates and fibre compared with plain and flavoured milks, and flavoured milks were higher in sugar than other products. Dairy milks were more common than plant-based milk alternatives, and made up about two thirds of the category. Overall, the nutrient profile of dairy and plant-based milk alternatives varied; dairy milks were higher in energy and macronutrients than plant-based milk alternatives, however calcium contents were similar, likely due to fortification of plant-based milk alternatives.

Generally, dairy milk and plant-based milk alternatives sold in Australia were higher in energy, protein and fat, but lower in carbohydrates than products collected in Singapore. It was beyond the scope of this research to explore the reasons for the differences between nutrient compositions between countries, however, insights can be inferred by the types of products found within these categories, and from the wider literature. For example, the higher total carbohydrates found in Singapore may be driven by the presence of cereal drinks (milk drinks which also contained oats, rice or other grains), which were unique to the Singaporean dataset. Other differences may have been driven by consumer taste preferences. Our previous work analysing the differences between sweetened or flavoured non-milk beverages in Singapore and Australia, revealed a higher reliance on sugar in the Singaporean drinks supply (Anastasiou et al., 2023), which is replicated in this dataset. Health concerns also may play a role; a survey of barriers to consuming dairy milk in Singapore reported that weight gain is commonly cited as a perceived disadvantage of drinking dairy milk (Bhaskaran, 2017). This may explain the lower fat content of the Singaporean compared with Australian milk and milk alternatives.

A limited range of beverages are promoted in food-based national dietary guidelines (often including dairy milk and plant-based milk alternatives) while the category can contribute significantly to population energy and nutrient intake. Dairy milk and plant-based milk alternatives are only infrequently consumed as pure beverages by Australian adults. From the most recent Australian National Dietary Survey (2011–12) <1 % of adults consumed a plant-based milk alternative as a pure beverage, and <10 % consumed plain or flavoured dairy milks (Riley, Hendrie, & Baird, 2019), and in fact coffee makes a greater contribution to total calcium intake in Australian adults than milk or flavoured milk as a beverage because a high percentage of Australians have coffee, and most with milk. In Singapore's most recent National Nutrition Survey (2010), nearly 50 % of Singaporean residents reported that they do not usually drink milk or milk-based drinks at all (Health Promotion Board, 2013). This percentage, however, may be increasing as higher incomes and increased health awareness drive dairy intake (Bhaskaran, 2018) and milk intake is promoted as a good source of dietary calcium for an aging population (Gan et al., 2022).

One key finding from this analysis was the larger range of products available on the Singaporean compared with Australian market, which was especially apparent in the breakfast drinks category. Previous market research on Australians compared with Singaporean consumers has found that Australians have a collection of traits associated with higher rates of uncertainty-avoidance, leading to a preference to avoid trying new products, and a dislike of proliferation of choice within shopping environments (Leo, Russell-Bennett, & Cierpicki, 2005). Conversely, Singaporeans are less brand-conscious and less likely to be overwhelmed by choice in shopping environments. These traits are associated with the individualistic culture of Australia, compared with the collectivist culture of Singapore, and may also explain the apparent greater number of dairy milk and plant-based milk alternatives in Singapore (30 % more products collected) than Australia. Another reason could be the larger number of supermarket and convenience stores which were surveyed in the Singaporean dataset, compared with Australia ($n = 6$ versus $n = 4$) as different stores may stock different products.

The larger range of breakfast drinks found in Singapore may be partly driven by the inclusion of milk teas in the breakfast drink category, which are popular products in Singapore due to the climate (Ong et al., 2021). The popularity of breakfast drinks is reflected in a survey which found that the majority of Singaporeans consume beverages (other than water) at breakfast time more regularly than other times of the day (Hirschmann, 2020). Although the same report found coffee was the most popular breakfast drink of Singaporeans (Hirschmann, 2020).

This study also assessed the variations between dairy milk and plant-based milk alternatives. Individuals are shifting towards more plant-based dietary patterns (Hargreaves, Raposo, Saraiva, & Zandonadi, 2021). Consequently, alternative protein products are becoming more accessible and available (Brooker et al., 2022; Zhang et al., 2020). In this study, one third of the products collected were plant-based beverages. Singapore had a greater proportion of plant-based beverages compared with that of Australia (39 % versus 30 %), and a more diverse range of plant-based milk varieties. These findings are reflected in previous dietary surveys. In Australia, the per person apparent consumption of dairy milk substitutes was about 17 g in 2021–21 (Australian Bureau of Statistics, 2022). In contrast, mean daily intakes of soy milk among Singapore residents was about 52 g in 2010 (Health Promotion Board, 2013). There are several possible reasons for this difference. First, there are higher rates of lactase deficiency among Asian people compared to Caucasians (Goh, Mohd Said, & Goh, 2018; Vuorisalo et al., 2012), and thus, people in Singapore may be more conscious of consuming lactose-containing dairy products and seek plant-based alternatives. Second, and as mentioned previously, weight gain is commonly cited as a perceived disadvantage of drinking dairy milk, and a barrier to regular consumption among Singaporean residents (Bhaskaran, 2017), which may also contribute to the higher proportion of plant-based milk alternatives available in Singapore. Third relates to the cultural acceptability of soy; soy products are commonly consumed among Asian populations (Zhang et al., 2017). This may increase acceptability of a range of soy products, for example in one study there was higher acceptability of novel soy products among Malaysian compared with Jordianian consumers (Al-Nabulsi et al., 2014), likely because soy products are a culturally appropriate food in Malaysia.

Parallel to the increased interest in plant-based milk alternatives are concerns about their lack of nutritional equivalence to their dairy counterparts, specifically regarding protein and calcium (Drewnowski et al., 2021). Currently, there are no nutritional requirements for plant-based milk alternatives to be fortified, however, Drewnowski et al. developed a set of standards for plant-based beverages and have encouraged adoption by the food industry, public health regulatory authorities, and standardisation bodies such as the Codex Alimentarius (Drewnowski et al., 2021). In this study, the median content of protein in dairy milks was almost three times that of plant-based milk alternatives, but the median calcium contents between milk types were similar, likely attributable to fortification of products. Approximately two thirds of plant-based milk alternatives were fortified, and for more than 90 % of these the fortificants included calcium. There were some interesting differences between products collected in Australia and Singapore. There were nearly three times as many plant-based milk alternatives and nearly ten times as many dairy milks fortified with Vitamin D in Singapore compared with Australia, suggesting product adaptation to population needs. Despite its geographical location and uniform seasonal hours of sunlight, Vitamin D deficiency is a problem for Singaporean residents. In a recent cross-sectional study of 114 adults, nearly half were considered Vitamin D deficient (<20 ng/mL) (Bi, Tey, Leong, Quek, & Henry, 2016). In comparison, the prevalence of Vitamin D deficiency in Australian adults is estimated at 20 % (Malacova et al., 2019).

A strength of this study was the use of the FoodTrack™ data collection methodology which include quality control measures to enhance data integrity and allows for a standardised cross-country comparison. Previous studies have been limited by small samples sizes in single countries (Wierzejska, Siuba-Strzelińska, & Jarosz, 2017; Zhang et al., 2020), or have had a single nutrient focus (Coyle et al., 2019). Another strength of this study is the clear definition of dairy milk and plant-based milk alternatives and their subcategories, which was easy to operationalise and use across both countries. Despite its strengths, some limitations of this descriptive study must be acknowledged. In Australia, only products available for sale in major supermarkets in metropolitan Victoria were collected, therefore, it is unlikely that the products included in this study cover the complete product offering. However, the supermarket and grocery industry in Australia is highly concentrated, with more than 80 % of revenue shared between four companies—Woolworths 37.4 %, Coles 28.4 %, ALDI 10.5 % and Metcash (owns IGA) 7 % (Youl, 2022) and supermarket businesses have national distribution networks, so it is likely the data presented herein provide a reasonable representation of the packaged dairy milk and plant-based milk alternative products that contributed to the bulk of the sales for the category in the retail sector in Australia, at the time of collection. There was a greater number of dairy milk and plant-based milk alternative products collected in Singapore versus Australia. It is unknown if this is a true difference between the two food supplies, or a result of the inclusion of convenience stores in the Singaporean data collection protocol (compared with major retailers (only) in Australia). Finally, data collection was disrupted in Australia due to Covid-19 restrictions, therefore, the comparison between countries was made across different years (Australia, 2019 and Singapore, 2020). Although it is unlikely this would have had a profound effect on the results, small differences between countries due to different years of collection cannot be ruled out. Similarly, Singaporean data collection took place during the Covid-19 pandemic. It is possible that there were some changes to the food supply as a result of the pandemic, however, it is unknown to what extent this impacted study findings. Reports from other countries have found that UHT milk purchasing increased (Scacchi, Catozzi, Boietti, Bert, & Siliquini, 2021). However, short duration heat treatments such as ultra-high temperature processing have limited impact on the nutritional composition of products (Barraquio, 2014). This study only assessed the availability of products, and not consumption of these beverages. Future research applying sales-weighted analyses would be useful to understand how often these products are purchased and consumption surveys would provide further insight into how products are used and consumed.

## 5. Conclusions

Food retail is a key setting that influences the diets and health of children and adults. Herein we present a comparison of dairy milks and plant-based milk alternatives sold in two high-income countries: Australia and Singapore. Key differences included a wider availability of products in Singapore, especially for breakfast milks, differences in the types of fortificants, and the nutrient composition of products. Primary ingredients in the plant-based milk alternatives also differed between countries, with soy being most common in Singapore, compared with almond milk being the most common in Australia. Differences are likely due to market preferences. Cross-country comparison of products sold in supermarkets requires standardised data collection methodology and study designs which account for differences in the retail setting.

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## CRediT authorship contribution statement

**Paige G. Brooker:** Conceptualization, Methodology, Data curation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing. **Kim Anastasiou:** Conceptualization, Methodology, Data curation, Writing – review & editing. **Benjamin P.C. Smith:** Conceptualization, Methodology, Data curation, Funding acquisition, Writing – review & editing. **Rebecca Tan:** Conceptualization, Methodology, Data curation, Writing – review & editing. **Xenia Cleanthous:** Methodology, Funding acquisition. **Malcolm D. Riley:** Conceptualization, Methodology, Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The FoodTrack™ data presented in this study are not publicly available for commercial reasons.

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## Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2023.113475.

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