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ORIGINAL CONTRIBUTION

The role of dairy foods in lower greenhouse gas emission and higher diet quality dietary patterns

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Abstract

Purpose There is conflicting advice about the inclusion of dairy foods in a lower greenhouse gas (GHG) emission dietary pattern. Our purpose was to assess the prevalence of dairy food intake among higher diet quality and lower GHG emission diets in Australia and within these diets assess the association between level of dairy food intake and adequate intake of a broad range of nutrients.

Methods Dietary intake data collected using a 24-h recall process were sourced from the most recent Australian Health Survey. Diet quality was assessed by level of compliance with the food group-based Australian Dietary Guidelines. A subgroup of 1732 adult (19 years and above) daily diets was identified having higher diet quality score and lower GHG emissions (HQLE). Intake of core dairy foods (milk, cheese, yoghurt) was assessed and nutrient profiling was undertaken for 42 macro- and micronutrients.

Results The HQLE subgroup had 37% higher diet quality score and 43% lower GHG emissions than the average Australian adult diet ($P < 0.05$). Intake of dairy foods was very common (90% of HQLE diets) and greatly exceeded the intake of non-dairy alternatives (1.53 serves compared to 0.04 serves). HQLE daily diets in the highest tertile of dairy food intake were more likely to achieve the recommended intake of a wide range of nutrients, including calcium, protein, riboflavin, vitamin B12, folate, phosphorous, magnesium, iodine and potassium compared to other HQLE daily diets.

Conclusion Core dairy foods have an important role for achieving adequate nutrient intakes in a healthy and lower GHG emission dietary pattern in Australia.

Keywords Micronutrients · Nutrient adequate intake · Nutritional quality · Protein · Public health nutrition · Sustainable diet

Introduction

The latest special report of the Intergovernmental Panel on Climate Change (IPCC) draws renewed attention to the subject of sustainable diets and the need for urgent adoption of lower greenhouse gas (GHG) emission dietary patterns [1]. The food system is estimated to contribute between 19 and 29% of global GHG emissions [2], and the potential for dietary emissions reduction appears quite high. Studies that have assessed the GHG emissions of individual self-selected diets have shown very large ranges in emissions, even exceeding tenfold in some cases [3–8]. In part, this has to do with differences in the total quantity of food eaten. It also has to do with the types of foods chosen and their relative GHG emissions intensity. As livestock products tend to have higher GHG emissions intensity relative to many plant-based foods, as one way to reduce dietary GHG emissions a

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common recommendation is to reduce or to avoid the consumption of meat and dairy foods [9–19]. However, it has also been rightly noted that meat and dairy foods can be an important source of nutrients, including nutrients that tend to be under consumed relative to recommended levels [20–22].

In the case of dairy foods, they can be an important source of protein and calcium, as well as phosphorus, potassium, magnesium, iodine and vitamins A, B12, and riboflavin. A variety of evidence also indicates health benefits from the consumption of milk, cheese and yoghurt [23–29]. The question therefore arises as to the role of nutrient-rich dairy foods in a lower GHG emission dietary pattern. It has been argued that the contribution that dairy foods make to total dietary GHG emissions should be balanced against the high nutritional value [30, 31]. Some non-dairy substitutes, although they may have lower GHG emissions, do not offer an equivalent profile of nutrients [32, 33]. In addition, diets with lower levels of dairy intake are not always lower in overall GHG emissions [34, 35]. The findings of a systematic review in which 64% of lower GHG emission diets were linked to worse nutritional and health indicators, including higher sugar intake and lower micronutrient intake [36], highlight the risks associated with environmental recommendations to selectively avoid particular higher GHG emission core foods that have traditionally formed part of a healthy diet.

It is difficult to generalize about dietary strategies to achieve healthy diets with lower GHG emissions because food systems vary in different regions, as do the local food cultures, local public health nutrition challenges in achieving recommended intakes of macro- and micronutrients, as well as the importance of specific foods in relation to under consumed nutrients by particular population subgroups [37]. In addition, most opportunities to intervene in food systems or in public health are at the local or national scales rather than global [38]. As such, the relevance of global assessments and recommendations about sustainable diets is questionable. In Australia, a large (> 9000) dataset of adult daily diets obtained from the Australian Health Survey was previously assessed for GHG emissions and diet quality score [39]. When higher quality diets with lower GHG emissions (i.e. diets that scored positively for both attributes) were compared to diets with lower diet quality and higher GHG emissions (i.e. diets that scored more negatively on both attributes), the differences in total dietary GHG emissions were 44% for males and 46% for females. These results underscore the large potential for dietary GHG emissions reduction through a wider adoption of dietary patterns that align with recommendations and that are already prevalent in the community.

This study involved a further examination of the subgroup of Australian daily diets having higher diet quality score and lower GHG emissions. This subgroup is important because it reflects the actual food patterns of those Australians already having more desirable dietary characteristics. As such, these dietary patterns can be considered realistic alternatives for Australians with poorer quality and/or higher GHG emission diets. In particular, our purpose was to understand the role of dairy foods in these more desirable dietary patterns, since currently there appears conflicting advice about their consumption. On the one hand, the Australian Dietary Guidelines [40] recommend that most Australians need to consume more dairy foods. However, on the other hand, Australians are being encouraged to adopt plant-based diets [41]. Therefore, there is a need for a greater understanding of the role of dairy foods within the context of a healthy and sustainable Australian diet. The aim of the study is to support the adoption of healthy and sustainable dietary patterns.

Methods

Background data

Dietary intake data was obtained from the 2011–2013 Australian Health Survey (AHS), which is the most recent and most comprehensive population survey containing dietary intake data conducted in Australia by the Australian Bureau of Statistics (ABS). The AHS is nationally representative and comprises three components, one being the National Nutrition and Physical Activity Survey [42], whereby detailed dietary intake data were collected using a 24-h recall process from 12,153 participants across Australia over a 13-month period. The complex sampling method and design of the survey make possible the estimation of dietary intake for the Australian population as well as demographic subgroups through the application of weighting factors. Detailed sampling and demographic information are available from the ABS [43]. The interview components of the Survey were conducted under the Census and Statistics Act of 1905. For relevant components, ethics approval was sought and gained from the Australian Government Department of Health and Ageing's Departmental Ethics Committee [43]. Specifically, the dietary data available for 9341 adults (19 years and above) were used along with the matching demographic information.

To allow food and nutrient intakes to be estimated from the dietary intake data, the ABS classifies each of the 5645 individual foods into around 500 food categories using an 8-digit code. Individual foods are disaggregated into their food group components (e.g. amount of dairy foods in serves and grams) [44]. These data were used to estimate dairy foods contained within multicomponent foods and mixed dishes in categories: milk, cheese, yoghurt and non-dairy alternatives. Dairy foods as a component of discretionary foods were not included in the estimation of dairy food intake. To quantify the GHG emissions of each daily diet, we used GHG emissions factors for Australian foods and ingredients reported previously [3]. This data source comprised GHG emissions data for 192 food categories, listed in the original article [3]. In summary, the GHG emission factors were developed using a highly disaggregated input–output model of the Australian economy that describes the economy-wide transactions between economic sectors. The model quantifies how demand for specific goods and services leads to GHG emissions across the economy (i.e. the full supply chain). Detailed information about the model is available in the associated reference [3]. The input–output approach to modelling GHG emissions was deemed appropriate because of the national scale of the study. Dietary intake data are not linked to specific agricultural production systems or supply chains which would be amenable to analysis by process-based life cycle assessment. Input–output modelling also has the advantage of providing a complete assessment of GHG emissions associated with food production, avoiding the truncation errors associated with the application of a system boundary as practiced in process-based life cycle assessment [45–47]. Consequently, the GHG emission values may appear high relative to other studies based on process-based life cycle assessment.

Higher diet quality and lower GHG emission subgroup

A subgroup of Australian adult daily diets was identified, having the characteristics of higher diet quality score and lower GHG emissions. First, for each individual daily diet a quality score was assigned using the Dietary Guideline Index of Golley et al. [48], with the scoring adapted to the food group-based dietary intake targets for adults described in the Australian Dietary Guidelines [40]. The Diet Quality Index reflects overall compliance with the Guidelines in terms of the amount and quality of food consumed from the core food groups, discretionary foods and beverages, as well as diet variety. The index consists of nine components and diets are ascribed a score out of 100, where a higher score reflects greater conformance to the guidelines.

Daily diets were subsequently sorted into four quadrants, stratified by gender and nutrient reference value age group (19–30, 31–50, 51–70 and 70 years and above) [49], ranking them as either higher or lower in diet quality, and higher or lower in GHG emissions, excluding those daily diets within 0.25 standard deviations of the mean for each parameter. It is well established that GHG emissions are positively correlated with total energy intake [3, 5]. Therefore, stratification was employed to achieve a balance of daily diets in each quadrant according to gender and age group. Without stratification, the lower GHG emission quadrants would be biased toward the daily diets of females and those aged 70 and above, who consume, on average, less dietary energy. Through this process, a higher diet quality and lower GHG emission (HQLE) subgroup was isolated for further analysis, comprised of 1732 adult daily diets. The composition by age group and gender is shown in Supplementary Information Table 1.

Dairy food analysis

The Australian Dietary Guidelines [40] distinguish between core dairy foods, including milk (powdered, evaporated, condensed and fluid of all fat types), yoghurt (medium and lower fat, plain and flavoured varieties), and cheese (hard and soft of all fat types), and discretionary dairy foods, such as cream, ice cream, and butter. Non-dairy alternatives, including calcium fortified soy, rice, almond and oat beverages, are also recognised and included within the dairy food and alternatives food group. Discretionary dairy foods, that are not a necessary part of a healthy diet, and like all discretionary foods should only be eaten occasionally and in small amounts, were not further studied. The 1732 HQLE daily diets were subsequently assessed to determine whether they contained core dairy foods. In addition, for each daily diet, the quantity of core dairy foods and non-dairy alternatives was determined (in serves and grams). Serving sizes refer to 250 ml of fluid milk or non-dairy beverage, 40 g of hard cheese, 200 g of yoghurt, based on the Australian Dietary Guidelines [40].

The HQLE daily diets were also divided into tertiles according to the grams of core dairy foods. The composition of the tertiles by age group and gender is shown in Supplementary Information Table 2. Two other specific groups were also formed. The first consisted of HQLE daily diets of persons who had self-reported that they were avoiding dairy foods. The second consisted of those daily diets which met the recommended intake of foods from the dairy foods and alternatives food group defined in the Australian Dietary Guidelines [40].

Nutritional profiling

Nutrient profiling was undertaken for 42 macro- and micronutrients in relation to the official Nutrient Reference Values published jointly by the Australian and New Zealand governments [49]. Initially, the nutrient density of the HQLE subgroup of daily diets was assessed relative to the population average diet (all 9341 adult daily diets). The purpose of this assessment was to verify the superior nutrient density of the HQLE subgroup of daily diets which had been identified using a food group-based diet quality index. Comparisons were subsequently made between the subsets of HQLE daily diets described in the Section above namely, the tertiles of daily diets defined by grams of dairy foods, the daily diets of individuals who self-identified as avoiders of dairy foods, and daily diets meeting the recommended intake for dairy foods and alternatives. Assessments were also performed relative to gender and nutrient reference value age groupings.

Statistical analysis

Statistical analyses were performed using the IBM SPSS statistical software package version 23 (SPSS Inc., Chicago, IL, USA). Summary estimates were weighted to reflect the demographic structure of the Australian population using weights based on age, gender, and residential area that are included in the dataset by the Australian Bureau of Statistics. An additional weighting factor was applied to correct for the day of the week the survey was recorded, because the percentage of subjects reporting their intake for Saturday and to a lesser extent Friday were under-represented. The population weights were rescaled to the size of the sample for inferential statistics. A common feature of 24-h dietary recall surveys is the possibility that participants did not always recall accurately, or chose to misrepresent, the foods and portion sizes consumed. Therefore, to assist in the interpretation of the survey data, the ABS provides estimates of the under-reporting prevalence. These factors, 21% for females and 17% for males, were uniformly applied to all dietary intake data. While there is the possibility that under-reporting was biased toward certain types of foods, such as discretionary foods, and individuals of particular weight status, there exists insufficient evidence to allocate under-reported food energy more specifically.

Mean (and standard errors) nutrient density and mean (SE) intake of the five major food groups plus discretionary foods were examined for the total adult population as well as the HQLE subgroup. Dairy consumption in the HQLE subpopulation was examined by broad age groupings (19–30, 31–50, 51–70, 70 + years) for proportion consuming and by age group and gender for mean (SE) serves of total dairy and its subcomponents (milk, yoghurt, cheese, and dairy alternatives). Mean grams and serves (SE) of total dairy intake for this subgroup were analysed by low, medium and high dairy consumers, as well as proportion consuming and the proportion that met a selection of nutrient reference value targets.

Differences between the HQLE subgroup and population estimates were tested for statistical significance by first calculating the approximate standard error of the difference between the two estimates ($SE(x–y)$). Likely significance was then tested using the following test statistic $(x - y)/(SE(x - y))$. If the resulting test statistic was greater than 1.96, a statistical difference was assumed with a confidence level of 95%. This test provided a more conservative approach as the standard error is likely to be lower than that derived from this approximation given that one estimate comes from a subpopulation of the other.

Differences between dairy intake (serves and grams) by tertiles of dairy intake for the HQLE subgroup were tested using one-way ANOVA with post hoc comparisons. Differences between tertiles in the proportion of people meeting dairy intake guidelines and nutrient reference value targets were tested using Chi square.

Results

Comparison of HQLE daily diets with the reference population

Compared to the average Australian adult daily diet, the HQLE subgroup had 37% higher diet quality score and 43% lower GHG emissions ($P < 0.05$; Table 1). As reported previously [3], the major factor that differentiated the HQLE subgroup of daily diets was a greatly reduced intake of discretionary foods. On average, the HQLE subgroup of adult daily diets contained less than half the number of serves of discretionary foods compared to the overall adult population (2.1 serves compared to 5.1 serves; Supplementary Information Table 3). The HQLE subgroup of adult daily diets was also characterised by higher intake of fruit, vegetables and grain (cereal) foods as well as lower intake of meat and alternatives. Intake of dairy foods and alternatives was 0.2 serves lower in the HQLE subgroup (Supplementary Information Table 3). The HQLE subgroup of daily diets was also associated with Australians who were more likely to be in the normal weight range, assessed by body mass index, and less likely to be obese, than the overall adult population (Table 1). Other healthy lifestyle attributes associated with the HQLE subgroup of daily diets included greater activity levels and lower incidence of smoking. While the HQLE subgroup of diets was associated with Australians with higher average levels of educational attainment, differences in socio-economic status were not significant (Table 1).

The HQLE subgroup of adult daily diets was identified using a diet quality index that assessed overall compliance with the food group-based Australian Dietary Guidelines [40]. Consistent with this, the nutrient density of the HQLE subgroup of daily diets was also higher than the average adult diet (Table 2). Nutrient density values were more than 10% higher for 19 beneficial nutrients and more than 5% higher for several others. In addition, the nutrient density values were more than 10% lower for three nutrients to limit, namely alcohol (– 67%), trans-fatty acids (– 28%), and saturated fat (– 15%), as well as more than 5% lower for total fat, sodium and cholesterol. The only beneficial micronutrients that were lower in the HQLE diets were vitamin B12 (– 5.5%) and zinc (– 5.8%). A complete description of the

Table 1 Characteristics of the higher diet quality and lower GHG emission (HQLE) subgroup

Characteristic	HQLE subgroup	Population estimate	$P < 0.05$
Sample size	1732	9341	
Age, mean (years)	45.4	45.5	
Males (%)	45.7	45.8	
Diet quality score (out of 100)	58.7	42.6	*
Dietary GHG emissions (kg CO_2e day^{-1})	11.1	19.4	*
Body mass index (%)			
Underweight	1.1	1.5	
Normal range	34.9	30.7	*
Overweight	29.6	31.3	
Obese	18.7	21.9	*
Measurement not taken	15.7	14.5	
Dairy avoidance (%)	5.1	4.7	
Activity level (%)			
Inactive	16.5	20.4	*
Insufficiently active	25.5	26.4	
Sufficiently active for health	57.5	52.5	*
Not known	0.6	0.7	
Current daily smoker (%)	8.4	15.8	*
Education (%)			
Bachelor or postgraduate degree	33.4	28.7	*
SEIFA quintile (%)[a]			
Lowest 20%	16.7	17.9	
Second quintile	20.2	20.4	
Third quintile	20.2	20.0	
Fourth quintile	20.3	19.3	
Highest 20%	22.6	22.3	

[a]Geographically determined socio-economic index; https://www.abs.gov.au/websitedbs/censushome.nsf/home/seifa

nutrient contents of HQLE daily diets is presented in Supplementary Information Tables 4, 5, 6.

Prevalence of dairy in the HQLE subgroup of daily diets

Dairy foods (milk, cheese, yoghurt) were found to be a very common constituent of HQLE daily diets in Australia (Table 3). Taking all gender and age groups together, 90% of HQLE daily diets contained dairy foods. The proportion was slightly higher for females and slightly higher for older age groups (e.g. 70 years and above; Table 3).

On average, HQLE daily diets contained 1.53 serves of core dairy foods (milk, cheese and yoghurt). Intake of milk was highest (0.99 serves), followed by cheese (0.39 serves), and then yoghurt (0.14 serves; Table 4). Intake of non-dairy alternatives was very small (0.04 serves). Taken together, the intake of dairy and non-dairy alternatives was 1.60 serves per day (Table 4), which is well below the Australian Dietary Guideline [40] recommended intake of 2.5 serves per day for 19–50-year-old adults and up to 4 serves per day for women aged 70 years and above.

Dairy intake and nutrient adequacy

The HQLE subgroup of adult daily diets was divided into tertiles according to dairy food (milk, cheese and yoghurt) intake (Table 5; Supplementary Information Table 2). For the low and medium intake tertiles, the average intake was 0.31 and 1.43 serves of dairy foods, respectively, corresponding to 70.9 and 233.5 g of dairy food intake. For these two tertiles, almost none of the daily diets achieved the recommended intake of dairy foods and alternatives described in the Australian Dietary Guidelines [40]. In contrast, the high dairy intake tertile included an average of 3.16 serves of dairy foods and almost 60% of these daily diets achieved the recommended intake of dairy foods and alternatives. Two other groups were studied. First, those daily diets in the HQLE subgroup associated with individuals who had self-identified as an avoider of dairy foods. This group of

Table 2 Nutrient density[a] of the higher diet quality and lower GHG emission (HQLE) subgroup of adult (19+years) daily diets (N=1732) compared to the total sample of adult daily diets (N=9341)

Nutrient	HQLE subgroup	All adults	Difference%	Nutrient	HQLE subgroup	All adults	Difference%
Provitamin A	584	392	49.0*	Carbohydrate (excl sugar alcohols)	28.5	26.2	8.8*
Omega 3	48.8	34.6	41.0*	Selenium	11.7	10.8	8.2*
Retinol equiv	137	101	36.4*	Polyunsaturated fat	1.4	1.3	7.3*
Dietary fibre	3.7	2.7	33.7*	Linoleic acid	1.2	1.1	6.8*
Vitamin C	16.7	12.5	33.2*	Alpha-linolenic acid	0.2	0.2	5.8*
Folate natural	44.0	34.8	26.5*	Vitamin B6	0.2	0.2	5.5*
Total folates	72.3	58.5	23.7*	Caffeine	22.9	21.7	5.3
Dietary folate equiv	91.3	74.4	22.8*	Phosphorus	179	173	3.6*
Vitamin E	1.5	1.2	21.4*	Niacin equiv	5.0	4.9	2.4*
Folic acid	28.3	23.7	19.5*	Niacin (B3)	2.9	2.8	2.0
Thiamin (B1)	0.2	0.2	19.3*	Total sugars	12.1	11.9	1.6
Moisture	437	369	18.4*	Protein	10.5	10.7	− 1.8*
Magnesium	47.9	40.5	18.3*	Monounsaturated fat	3.1	3.2	− 2.0*
Starch	16.2	13.9	17.0*	Total fat	7.9	8.3	− 5.1*
Iodine	23.8	20.8	14.5*	Sodium	272	287	− 5.3*
Calcium	109	96.1	13.9*	Vitamin B12	0.5	0.5	− 5.5*
Riboflavin (B2)	0.3	0.2	13.0*	Zinc	1.2	1.3	− 5.8*
Preformed vitamin A	40.3	35.6	13.0	Cholesterol	32.4	35.0	− 7.3*
Potassium	390	346	12.9*	Saturated fat	2.7	3.1	− 14.5*
Iron	1.4	1.3	9.6*	Trans-fatty acids	113	156	− 27.9*
Carbohydrate (with sugar alcohols)	28.7	26.3	9.0*	Alcohol	0.5	1.6	− 67.1*

*Denotes $P<0.05$

[a]Nutrient density expressed as g/MJ (dietary fibre, moisture, starch, carbohydrate, fat, linoleic acid, alpha-linolenic acid, sugars, protein, alcohol), mg/MJ (omega 3, vitamins C, B1, B2, B3, B6, E, calcium, iron, magnesium, phosphorus, potassium, caffeine, sodium, zinc, cholesterol, trans-fatty acids), or µg/MJ (selenium, vitamin B12, iodine, provitamin A, retinol equivalents, preformed vitamin A, natural folate, total folates, folic acid and dietary folate equivalents)

Table 3 Prevalence of core dairy food[a] consumption (% of daily diets) in the higher diet quality and lower GHG emission (HQLE) subgroup of Australian adult (19+years) daily diets (N=1732)

Gender	19–30 years	31–50 years	51–70 years	70+years	19+years
Male	90.9	88.4	87.6	90.8	88.9
Female	83.3	92.4	93.1	94.7	91.1
All adults	87.6	90.3	90.3	93.0	90.0

[a]Core dairy foods include milk, cheese and yoghurt, and exclude discretionary dairy foods and non-dairy alternatives

90 daily diets had a mean dairy food intake of 0.89 serves and 7.7% met the recommended intake of dairy foods and alternatives in the Australian Dietary Guidelines [40]. Second, those daily diets in the HQLE subgroup that specifically met the Australian Dietary Guideline recommendations for dairy foods and alternatives. This group of 301 daily diets had a mean intake of dairy foods (milk, cheese, yoghurt) of 3.56 serves (Table 5).

HQLE daily diets that contained higher levels of dairy food intake were more likely to achieve recommended dietary intake levels of a wide range of vitamins and minerals (Table 6). For example, only 5.4% and 21.4% of daily diets in the low and medium dairy intake tertiles achieved the recommended intake of calcium. This compared to 73.9% for the high dairy intake tertile. Other nutrients where the difference in the proportion of daily diets achieving the recommended intake exceeded 20% included protein, riboflavin, vitamin B12, folate, phosphorous, magnesium, iodine and potassium. Daily diets in the low dairy food intake tertile performed better only in regard to omega 3 fatty acids, where 42.1% achieved the recommended dietary intake compared to 37.0% (Table 6). This is possibly explained by the low dairy food intake tertile having slightly higher average intake from the food group that includes lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes (Supplementary Information Table 7).

In many ways, HQLE daily diets associated with dairy avoiders were similar to low and medium dairy consumers.

Table 4 Mean intake of core dairy foods[a] and non-dairy alternatives[b] (serves day^{-1})[c] within the higher diet quality and lower GHG emission (HQLE) subgroup of Australian adult (19 + years) daily diets (N = 1732)

Gender	Category	19–30 years	31–50 years	51–70 years	70 + years	19 + years
Male	All dairy and alternatives	1.90	1.71	1.64	1.48	1.72
	Core dairy foods	1.81	1.63	1.54	1.41	1.63
	Milk	1.18	1.07	1.01	0.86	1.06
	Yoghurt	0.19	0.11	0.15	0.07	0.14
	Cheese	0.44	0.45	0.38	0.48	0.43
	Non-dairy alternatives	0.03	0.03	0.05	0.02	0.03
Female	All dairy and alternatives	1.56	1.49	1.43	1.35	1.47
	Core dairy foods	1.50	1.44	1.38	1.24	1.42
	Milk	0.89	0.96	0.90	0.82	0.92
	Yoghurt	0.21	0.13	0.14	0.15	0.15
	Cheese	0.40	0.35	0.35	0.28	0.35
	Non-dairy alternatives	0.06	0.05	0.04	0.10	0.05
All adults	All dairy and alternatives	1.75	1.60	1.54	1.41	1.60
	Core dairy foods	1.67	1.54	1.46	1.32	1.53
	Milk	1.05	1.02	0.95	0.84	0.99
	Yoghurt	0.20	0.12	0.14	0.11	0.14
	Cheese	0.42	0.40	0.37	0.37	0.39
	Non-dairy alternatives	0.04	0.04	0.05	0.07	0.04

[a]Core dairy foods include milk, cheese and yoghurt and exclude discretionary dairy foods and non-dairy alternatives

[b]Non-dairy alternatives include soy beverage, rice beverage, and almond beverage, among others

[c]Serving sizes refer to 250 ml of milk or non-dairy beverage, 40 g of hard cheese, 200 g of yoghurt; based on Australian Dietary Guidelines [40]

Table 5 The higher diet quality and lower GHG emission subgroup of adult (19 + years) daily diets in Australia (N = 1732)

Group	Number	Dairy foods: mean intake[a] (serves day^{-1})	Non-dairy alternatives: mean intake (serves day^{-1})	% Meeting recommended intake[b]
Low dairy intake tertile	603	0.31	0.09	1.2
Medium dairy intake tertile	669	1.43	0.02	0.3
High dairy intake tertile	489	3.16	0.02	59.8
Dairy avoiders	90	0.89	0.20	7.7
Meeting recommended intake of "dairy and alternatives"	301	3.56	0.09	100

Within this subgroup, the characteristics of daily diets having low, medium and high content of dairy foods, daily diets associated with people who self-selected as avoiders of dairy foods, and daily diets that met the Australian Dietary Guideline recommended intake of "dairy foods and alternatives" are shown

[a]Intake refers to core dairy foods (i.e. milk, cheese and yoghurt) and excludes butter, cream, ice cream and other discretionary foods

[b]Recommended intake refers to dairy foods and non-dairy alternatives

For example, 22.2% of these daily diets achieved the recommended intake of calcium. However, this group of HQLE daily diets did perform marginally better for linoleic acid, omega 3 fatty acids, dietary fibre and vitamins C and E. The group of HQLE daily diets meeting the recommended dietary intake for dairy foods and alternatives was similar to the high dairy intake tertile in most respects (Table 6).

Discussion

At present, there is conflicting advice about the role of dairy foods (like milk, cheese and yoghurt) in a lower GHG emission healthy diet. On the one hand, many nationally recommended diets, including the Australian Dietary Guidelines published by the National Health and

Table 6 The higher diet quality and lower GHG emission subgroup of adult (19 + years) daily diets in Australia (*N* = 1732)

Nutrient	RDI/AI[a]					EAR[a]				
	Low dairy	Med dairy	High dairy	Avoiders	Meeting ADG	Low dairy	Med dairy	High dairy	Avoiders	Meeting ADG
Protein	71.6	86.5	94.9	74.3	97.1	88.8	94.2	98.6	86.3	99.6
Linoleic acid	31.5	37.6	33.3	49.1	33.9					
ALA[b]	48.5	56.7	57.0	53.4	54.3					
Omega 3	42.1	38.0	37.0	43.9	31.9					
Dietary fibre	46.7	48.3	54.1	60.4	52.8					
Thiamin (B1)	56.1	66.2	75.8	59.0	78.3	66.7	79.1	84.4	70.4	85.3
Riboflavin (B2)	48.5	82.2	97.3	75.6	99.1	60.2	89.2	98.9	80.1	99.6
Niacin (B3)	96.1	97.6	99.9	97.2	99.6	98.6	99.6	100	100	100
B6	44.8	46.8	47.9	47.6	56.9	54.5	57.8	62.8	57.5	69.6
B12	46.9	71.2	96.1	61.3	97.3	58.0	82.9	97.8	72.2	97.9
Folate	69.9	81.4	91.3	62.7	91.0	82.1	88.8	94.8	83.0	95.2
Vitamin A	38.8	44.5	51.3	38.9	53.7	55.5	60.1	72.5	62.8	76.6
Vitamin C	78.0	80.7	72.8	81.9	75.8	86.9	89.8	84.3	92.1	87.5
Vitamin E	62.1	65.6	61.4	79.4	58.7					
Calcium	5.4	21.4	73.9	22.2	94.4	9.1	42.2	90.8	30.1	98.9
Phosphorus	58.2	84.1	98.3	69.0	99.4	95.0	99.4	100	94.7	100
Zinc	30.3	37.2	47.5	41.2	46.7	44.0	53.4	66.7	48.9	68.3
Iron	47.0	55.8	65.9	50.1	65.5	81.1	83.8	86.4	89.2	85.5
Magnesium	35.9	51.9	63.1	48.0	66.4	55.6	66.0	83.1	74.1	85.8
Iodine	40.7	59.7	91.1	54.0	91.2	67.9	87.9	97.9	68.8	97.2
Selenium	66.9	64.5	72.0	66.4	71.2	79.0	79.4	85.1	71.8	85.6
Potassium	25.6	37.1	57.1	37.6	61.6					

Within this subgroup, daily diets having low, medium and high content of dairy foods, daily diets associated with people who self-selected as avoiders of dairy foods, and daily diets that met the Australian Dietary Guideline recommended intake of "dairy foods and alternatives" that met nutrient reference values (%)

[a]RDI (recommended dietary intake), AI (adequate intake) and EAR (estimated average requirement) as defined by the Australian Government, National Health and Medical Research Council [49]

[b]*ALA* Alpha-linolenic acid

Medical Research Council [40], specifically encourage the intake of core dairy foods. In addition, in many countries, including Australia, dairy foods are currently consumed at levels below what is recommended [16], meaning that an increased consumption is encouraged as beneficial for health. However, on the other hand, prominent statements about sustainable diets have emphasised the need to greatly reduce the consumption of livestock products, such as dairy foods, across the general population. For example, the EAT-Lancet Commission on healthy diets from sustainable food systems has formulated a healthy reference diet with only 250 g of dairy foods a day, arguing that even small increases in dairy food intake would make it difficult for the food system to remain within planetary environmental boundaries [9]. Similarly, the Food Climate Research Network, based at the University of Oxford, suggests that dairy foods (or alternatives) need to be eaten only in moderation [50]. Other authors have proposed vegan solutions to lowering dietary GHG emissions that exclude dairy foods altogether [51], or solutions involving the substitution of dairy foods with cereals [18, 52] despite the lack of nutritional equivalence [53].

One problem with the current dialogue around sustainable diets is that it is largely based on hypothetical dietary scenarios and lacks the necessary contextualisation needed to support public health nutrition strategies [37]. Nutritional needs are not the same for men and women and across life stages and nutritional gaps important to one subgroup may not be important to another. Within a local context, foods tend not to be consumed independently, but rather grouped in combinations as meals that are characteristic of the local food culture. For all these reasons, national nutrition surveys are a rich source of information about actual dietary patterns within a community. Using a large (*N* = 1732) subgroup of daily diets from the Australian Health Survey that were found to be higher in diet quality and lower in GHG emissions (HQLE), we assessed both the prevalence of dairy food consumption across this subgroup and the relationship between dairy food intake and nutrient adequacy. This study has demonstrated that core dairy foods (milk, cheese, yoghurt) are a very common constituent of HQLE daily diets in Australia (present in 90% of all HQLE diets; Table 5). Furthermore, higher levels of dairy food intake within the HQLE subgroup of daily diets were associated with significantly higher attainment of adequate intake of a broad range of individual nutrients (Table 6).

These results have important implications for future dietary guidelines. In Australia, as elsewhere, there is interest is amending dietary guidelines to reduce the environmental impacts of the food system in addition to achieving the traditional public health objectives [54–56]. These results demonstrate, that in the Australian dietary context, the current recommended intake of dairy foods is compatible with a dietary pattern that has substantially lower GHG emissions. The GHG emissions of the HQLE subgroup of daily diets were more than 40% lower than the overall adult population (Table 1), which is consistent with Australia's Intended Nationally Determined Contribution to GHG emissions reduction under the Paris Agreement of 50–52% per capita by 2030 [57], as further cuts to food system GHG emissions are possible through process improvement in food production as well as food waste avoidance. Dairy food waste in the Australian food system has previously been assessed at 29% [58]. What is important to note is that the HQLE subgroup of daily diets already exist in the Australian community, they are relatively common, and therefore realistic. Of the HQLE subgroup of daily diets, 301 met the recommended intake of dairy foods and alternatives (Table 5).

Also important are the significant risks to adequate nutrition of HQLE daily diets that have only low to moderate intake of dairy foods (Table 6). In recent years, countries such as Canada and the UK that have a similar long tradition of dairy food consumption have moved away from specifying a recommended number of serves of dairy foods in their national dietary guidelines. For example, the latest Eatwell Guide published by Public Health England in association with the Welsh Government, Food Standards Scotland and the Food Standards Agency in Northern Ireland recommends having some dairy or dairy alternatives [59]. The Canadian food guide no longer recognises dairy foods and alternatives as a unique food group and makes no specific recommendation about number of serves or serving sizes [60]. Our results suggest that dairy foods make a critical nutritional contribution to healthy diets with lower GHG emissions and that high levels of intake of dairy foods and alternatives should continue to be strongly encouraged to increase the likelihood of achieving adequate intakes of nutrients such as calcium, for which dairy foods are a key source.

The HQLE daily diets of persons identifying as dairy avoiders were also specifically examined. On average, these daily diets included 0.89 serves of core dairy foods (milk, cheese, yoghurt), which was between the level of dairy intake of the low and medium intake tertiles (Table 5). As such, most did not exclude dairy foods altogether. Studies in Australia have found that most dairy avoiders are motivated by media and friends and perceptions that dairy foods are unhealthy or fattening rather than a medical diagnosis [61]. Compared to the low and medium dairy intake tertiles, more of these daily diets achieved the recommended intake of dairy foods and alternatives, indicating that some of them contained high levels of intake of non-dairy alternatives. That said, the proportion achieving the recommended intake was still very low (7.7%; Table 5). In Australia, the range of non-dairy alternative foods made from soy, coconut, almond, rice and other cereals has expanded greatly in recent years, catering to the preferences of dairy avoiders. Many of these foods are fortified with calcium, in some cases to the same level as dairy foods. However, our results indicate that the daily diets of dairy avoiders were generally poorer in nutrient adequacy than the daily diets in the high dairy food intake tertile. These results suggest that dairy avoiders might benefit from the provision of additional educational information about the risks of avoiding dairy foods and the need for greater care in meal planning to achieve adequate nutrition.

This study was based on secondary analysis of data collected during the most recent national health survey in Australia that included dietary intake (2011–2013). The analysis used 1 day of dietary recall data which is not intended to be representative of usual intake, but rather an indication of consumption across the population at the time of the survey. A limitation of the data is its age with the most recent food trends not captured. The very large sample and systematic data collection process mean that the dataset is considered to be of high quality. Nevertheless, the under-reporting phenomenon, characteristic of all 24-h dietary recall surveys, is another limitation. Food intake was adjusted to account for the estimated under-reporting prevalence. However, this adjustment was uniformly applied to all foods and portion sizes. As discretionary foods are potentially more likely to be under-reported, it is possible that the nutritional contribution of these foods was marginally under-estimated and the nutritional contribution from core foods was marginally over-estimated. If so, our results may marginally underestimate the criticality of core dairy foods within HQLE diets. It is also relevant to note that the HQLE daily diets were selected based on only a single environmental attribute, namely GHG emissions. Other important environmental aspects of the food system, such as water footprint [62], were not considered. In the Australian context, milk production has a moderate water footprint, lower than many fruits, nuts, rice, summer legumes and summer oilseeds [62]. As such, the consumption of higher levels of dairy products is unlikely to adversely impact dietary water footprints.

To conclude, Australian daily diets were identified that were both higher in diet quality and lower in GHG emissions. Core dairy foods (milk, cheese, yoghurt) were found to be a typical constituent of these HQLE daily diets. Additionally, within this group, higher levels of dairy food consumption were associated with significantly higher attainment of adequate intake of a broad range of individual nutrients. These results underscore the critical role of dairy foods in achieving adequate nutrient intake within the context of a healthy and lower GHG emission dietary pattern.

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Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest. The authors exercised freedom in designing the research, performing the analyses and making the decision to publish research results. Dairy Australia (DA) partially funded this research. However, DA did not have any role in design of the study, analysis of data or interpretation of results. The decision to publish was made prior to funding and before the results were known. DA had no role in the preparation of the manuscript.

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