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ORIGINAL RESEARCH

The nutritional profile of plant-based meat analogues available for sale in Australia

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Abstract

Aims: To assess the nutritional quality of plant-based meat analogues in Australia, compared to equivalent meat products, and to assess levels of micronutrient fortification in meat analogues.

Methods: This cross-sectional study used nutrition composition data for products collected in 2021 from major supermarkets in Australia. Nutritional quality was assessed using the health star rating, energy (kJ), protein (g), saturated fat (g), sodium (mg), total sugars (g), and fibre content (g) per 100 g, and level of food processing using the NOVA classification. Proportion of products fortified with iron, vitamin B_{12} and zinc were reported. Differences in health star rating and nutrients between food categories were assessed using independent *t*-tests.

Results: Seven hundred ninety products ($n = 132$ plant-based and $n = 658$ meat) across eight food categories were analysed. Meat analogues had a higher health star rating (1.2 stars, 95% CI: 1.0–1.4 stars, $p < 0.001$), lower mean saturated fat (−2.4 g/100 g, 95% CI: −2.9 to −1.8 g/100 g, $p < 0.001$) and sodium content (−132 mg/100 g, −186 to −79 mg/100 g, $p < 0.001$), but higher total sugar content (0.7 g/100 g, 0.4–1.1 g/100 g, $p < 0.001$). Meat analogues and meat products had a similar proportion of ultra-processed products (84% and 89%, respectively). 12.1% of meat analogues were fortified with iron, vitamin B_{12} and zinc.

Conclusion: Meat analogues generally had a higher health star rating compared with meat equivalents, however, the nutrient content varied. Most meat analogues were also ultra-processed and few are fortified with key micronutrients found in meat. More research is needed to understand the health impact of these foods.

KEYWORDS
alternative protein, nutrient profiling, plant-based meat, sodium, total sugar

Hannah Melville and Maria Shahid should be considered joint first authors.

1 | INTRODUCTION

Plant-based meat alternatives include meat analogues, which are products designed to mimic meat products and act as a substitute for meat protein.[1] Meat analogues are typically highly processed and made from plant-based vegetable protein (soy protein, wheat protein, pea and rice protein, or a combination) or fermentation-based fungus protein (mycoprotein).[2] In recent years, consumer demand has led to the proliferation of new and accessible products that emulate the structure, texture, taste and appearance of traditional meat products.[2,3] In 2019, plant-based meat analogues contributed to over $150 million in Australian consumer spend, with 75% of this spend being in the food service industry and 25% in the grocery industry.[4] By 2030, domestic sales from the Australian plant-based sector is estimated to rise to almost $3 billion.[4]

Processed meats have been classified as a Group 1 carcinogen by the World Health Organization (WHO) and International Agency for Research on Cancer (IARC).[5] They have also been associated with increased risk of stroke,[6,7] cardiovascular disease[8] and type two diabetes mellitus (T2DM).[8,9] In Australia, processed meats have been classified as discretionary foods within the national dietary guidelines and consumers are advised to limit these meats as part of a healthy diet.[10] Moreover, recent national and global dietary recommendations have emphasised the need to eat both healthy and environmentally sustainable diets, which largely involves limiting consumption of meat and increasing intake plant-based foods including plant-based protein such as legumes.[11,12] The growing awareness of the health and environmental concerns of high meat consumption, particularly regarding the meat industry's role in greenhouse gas emissions, loss of land, water shortages and biodiversity loss[13] has been a major driver for the growth of plant-based meat analogues.[14–16]

Despite the increase in the popularity and presence of plant-based meat analogues, there is limited evidence regarding the healthiness of these products, particularly those currently available for sale in Australia. There is also little evidence regarding how the micronutrient content of plant-based meat analogues compares against animal-based meat equivalents. This is important given animal-based meats provide a key source of micronutrients in the diet, particularly iron, vitamin B_{12} and zinc[17]—micronutrients which are essential for health.[10] Understanding the nutritional profile and extent of fortification of meat analogues is particularly important for individuals who regularly substitute traditional meat products with plant-based meat analogues, such as people following a vegan, vegetarian or plant-based diet.

It is within this context that the primary aim of this study was to assess and compare the nutrient content and nutritional quality of plant-based meat analogues and their equivalent meat products in Australia. The food categories studied were burgers, meatballs, mince, sausages, bacon, coated poultry, plain poultry, and meat with pastry. The nutritional quality of these products was evaluated using two indicators of healthiness: the Australian and New Zealand Health Star Rating (HSR) front-of-pack nutrient profiling system[18] and the NOVA classification system for level of food processing.[19,20] To investigate whether plant-based meat analogues compare to animal-based meat products at the micronutrient level, we also assessed the prevalence and levels of iron, zinc, and vitamin B_{12} in plant-based meat analogues.

2 | METHODS

This study has been designed and completed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology—Nutritional Epidemiology (STROBE-nut) guidelines. Ethics approval was not required for this study.

Data was extracted from the 2021 Australian FoodSwitch database (FoodSwitch),[21] which contains nutritional information for packaged food and beverage products available for sale from the four major supermarkets in Australia: Coles, Woolworths, Independent Grocers of Australia (IGA), and Aldi. All the supermarkets surveyed in this study were located in the Sydney metropolitan area and data were surveyed between January and June of 2021. Trained data collectors took photos of each product to capture information including the barcode, front of pack labelling, nutrient data per serve and per 100 g as reported on the nutrition information panel (NIP), ingredients list, health claims, and manufacturer information. Information was then extracted from the photos and entered into the FoodSwitch database by data entry personnel using standardised procedures.[22]

For this study, we included meat analogues only that is, products designed to mimic meat made from plant-based ingredients. Products that are not meat analogues, such as tofu, tempeh and falafel were not included. Seafood-style and dairy-style products were also excluded as these products deserve a separate assessment. Included products were then assigned to eight categories according to their product name and FoodSwitch food category (burgers, meatballs, mince, sausages, bacon, coated poultry, plain poultry, and meat with pastry) (Table 1). Plant-based meat analogues that did not fit into any of the eight categories were excluded from the analysis.

TABLE 1 Product categorisation and description

Food categories	Plant-based meat analogue sub-categories	Meat product sub-categories
Burgers	Patties, burgers	Patties, burgers
Meatballs	Meatballs, mince balls	Meatballs, rissoles
Mince	Mince, ground meat	Mince
Sausages	Sausages, hotdogs, frankfurters, brats	Sausages, hotdogs, franks, frankfurters, chipolatas, cocktails
Bacon	Bacon, rashers, bits, strips, pieces	Bacon rashers, bacon pieces
Coated poultry	Nuggets, tenders, breaded, crumbed, schnitzels, southern style	Chicken nuggets, tempura, fried, popcorn, poppers, parmigiana, tenders, breaded, buffalo, crumbed, schnitzels, southern style, kievs
Plain poultry	Chicken bites, strips, shredded, slices, pieces, chunks	Canned chicken, sliced chicken, raw flavoured cuts for example, breast and thigh
Meat with pastry	Meat pies, sausage rolls	Pies, sausage rolls, pasties, spring rolls

As a comparator, we included all meat products that corresponded to each of the eight plant-based meat categories. This was based on a product's name and corresponding FoodSwitch food category. We further excluded both plant-based meat analogues and meat products that were missing nutrient information. An overview of inclusion and exclusion criteria is provided in Supplementary Figure 1.

The HSR is a front-of-pack labelling system that summarises some aspects of a product's nutritional quality using a rating from 0.5 stars (least healthy) to five stars (most healthy). It is based on an algorithm that incorporates a range of nutritional components including total energy (kilojoules), saturated fat, sodium, and total sugar content.[23] In some cases, it also considers the amount of dietary fibre and protein, and the fruit, vegetable, nut and legume content.[23] The HSR system is a voluntary government system and therefore not all products display the HSR logo.[24] For products where the HSR logo was not displayed, the FoodSwitch database automates the application of the HSR algorithm and is therefore able to calculate the HSR value for all products listing the necessary information on pack.[25] As Australian nutrient declaration does not mandate declaring dietary fibre or fruit, vegetable, nut and legume content on pack, where missing, these details were estimated using information from the ingredients list, generic food composition databases, or by comparison to similar products, as previously described.[22]

The level of processing of both plant-based meat analogues and meat products was determined using the NOVA classification system.[19] The NOVA system categorises products into four groups based on the extent and purpose of industrial food processing. These are Group 1: Unprocessed or minimally processed foods (e.g., rice, meat, fish, milk, eggs, fruit, vegetables, nuts, and seeds); Group 2: Processed culinary ingredients (e.g., sugar, oils, butter); Group 3: Processed foods (e.g., canned fruit, canned fish, freshly baked bread, some cheeses); and Group 4: Ultra-processed foods.[19] The ultra-processed food category "is made up of snacks, drinks, ready meals and many other product types formulated mostly or entirely from substances extracted from foods or derived from food constituents. Ultra-processed foods are made possible by use of many types of additives, including those that imitate or enhance the sensory qualities of foods or culinary preparations made from foods."[19] Examples of ultra-processed food products include "carbonated soft drinks; sweet, fatty or salty packaged snacks; candies (confectionery); mass produced packaged breads and buns, cookies (biscuits), pastries, cakes and cake mixes; margarine and other spreads; sweetened breakfast 'cereals' and fruit yoghurt and 'energy' drinks; pre-prepared meat, cheese, pasta and pizza dishes; poultry and fish 'nuggets' and 'sticks'; sausages, burgers, hot dogs and other reconstituted meat products; powdered and packaged 'instant' soups, noodles and desserts; baby formula."[19]

Products were initially classified to the NOVA food classification system at the food category level for example, all plant-based meat burger products were assigned as ultra-processed. However, as the literature states that ultra-processed foods are best identified at the individual product level according to presence of industrially produced ingredients found exclusively in these products for example, flavours, flavour enhancers, colours, emulsifiers, emulsifying salts, artificial sweeteners, thickeners, and foaming, anti-foaming, bulking, carbonating, gelling and glazing agents,[19,26] we further reassigned individual products according to presence of these ingredients to improve the accuracy of our classification.[27,28] In this step, foods classified as processed (NOVA 3) at the food category level that contained industrially produced ingredients were reclassified as ultra-processed (NOVA 4), and foods originally classified as ultra-processed but contained no ultra-processed ingredients were reassigned to the processed food category. The number of meat analogues and meat products reclassified from processed to

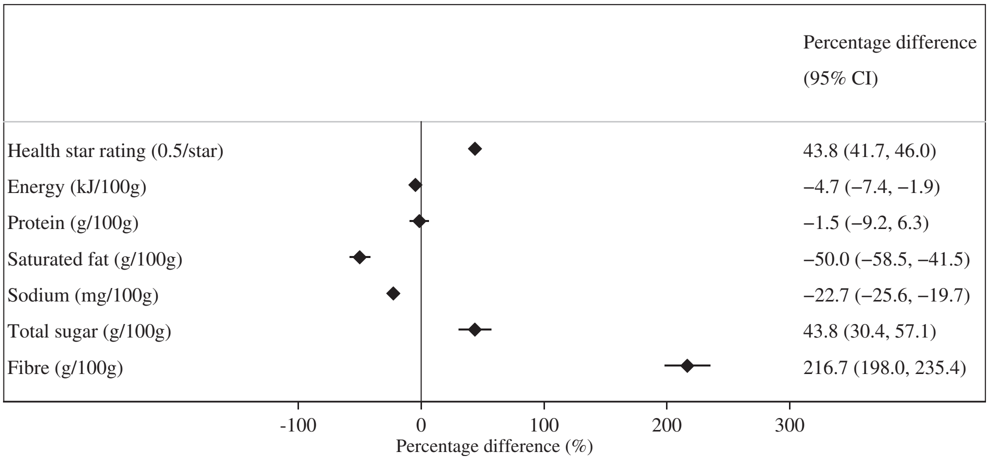

FIGURE 1 Difference in health star rating, energy and nutrient content of plant-based meat analogues compared to meat products

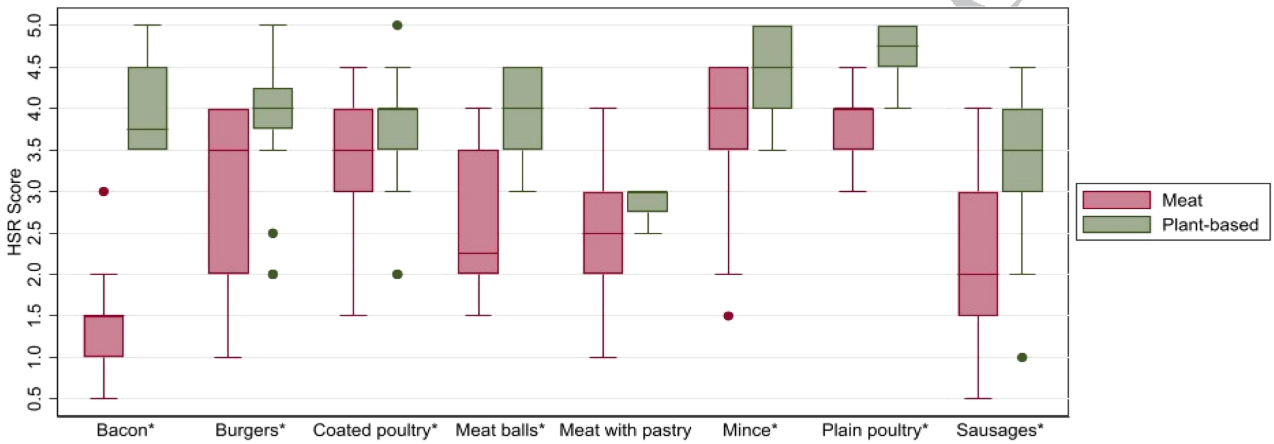

FIGURE 2 Comparison of health star rating (HSR) across plant-based meat analogues and meat products. The HSR system assigns products a rating from 0.5 stars (least healthy) to 5 stars (most healthy) to represent the overall nutritional quality of a product. * denotes significant difference between means ($p \leq 0.05$)

ultra-processed foods, and vice versa, is described in Supplementary Figure 2.

When determining the presence and extent of fortification, the nutrients of interest were iron, vitamin B_{12} and zinc. We identified fortification of plant-based meat analogues by searching for key terms in the ingredients list, including "iron," "vitamin B_{12}" or "cobalamin," and "zinc." As manufacturers are required to display the amount of fortified nutrients on the NIP as per Australian New Zealand Food Standards Code (FSANZ) Standard 1.2.8 Nutrition Information Requirements,[29] we obtained the amount of each nutrient by using information provided on the NIP. The units of measurement as reported on the NIP are mg/100 g for iron and zinc and mcg/100 g for vitamin B_{12}.

The percentage differences in the HSR and nutrient content (energy (kJ/100 g), protein (g/100 g), saturated fat (g/100 g), sodium (mg/100 g), total sugars (g/100 g), dietary fibre (g/100 g)) of plant-based meat analogues compared to meat products were reported using a forest plot as mean difference (%) and 95% confidence intervals (CI). The HSR and nutrient content of plant-based meat analogues and meat products were also reported as mean and standard deviation (SD), with dietary fibre reported separately as it is not mandatory on the NIP and is therefore only present on a subset of products.[30] A comparison of the HSR and nutrient content of plant-based meat analogues versus meat products was assessed overall and across each of the eight food categories using independent *t*-tests. The proportion of plant-based meat analogues and meat products (%) falling within each of the four NOVA categories were reported across each of the eight food categories.

The prevalence of fortification within plant-based meat analogues was determined as the proportion of products within the category that were fortified with either iron, vitamin B_{12} or zinc. The mean (SD) amount of each micronutrient for fortified products was

TABLE 2 Comparison of the mean (SD) energy and nutrient content between plant-based meat analogues and meat equivalents

	Energy (kJ/100 g)	*p*-value	Protein (g/100 g)	*p*-value	Saturated fat (g/100 g)	*p*-value	Sodium (mg/100 g)	*p*-value	Total sugar (g/100 g)	*p*-value
Total										
Meat ($n = 658$)	882 (227)	0.052	13.8 (4.2)	0.748	4.8 (3.1)	**<0.001**	587 (301)	**<0.001**	1.6 (1.6)	**<0.001**
Plant-based ($n = 132$)	841 (223)		13.6 (7.9)		2.4 (3.0)		454 (186)		2.3 (2.1)	
Bacon										
Meat ($n = 91$)	970 (320)	0.726	16.1 (3.1)	0.135	7.1 (3.3)	**0.003**	1104 (235)	**<0.001**	1.2 (0.6)	**<0.001**
Plant-based ($n = 4$)	1027 (76)		18.6 (6.9)		2.0 (1.2)		601 (233)		3.0 (2.2)	
Burgers										
Meat ($n = 43$)	838 (196)	0.598	14.9 (2.5)	**<0.001**	4.8 (3.4)	**<0.001**	458 (160)	0.549	1.4 (1.0)	**<0.001**
Plant-based ($n = 48$)	815 (220)		11.2 (5.2)		2.0 (3.3)		439 (145)		3.0 (2.8)	
Coated poultry										
Meat ($n = 169$)	868 (155)	0.409	14.0 (3.1)	0.262	2.2 (1.5)	0.335	479 (165)	0.155	2.4 (2.3)	0.295
Plant-based ($n = 18$)	899 (109)		13.1 (3.7)		1.8 (1.5)		537 (143)		1.8 (1.0)	
Meatballs										
Meat ($n = 12$)	861 (177)	0.601	15.8 (1.8)	0.932	6.0 (2.7)	0.164	511 (216)	0.229	1.1 (1.1)	0.744
Plant-based ($n = 5$)	812 (162)		15.6 (4.6)		3.5 (4.3)		366 (224)		1.3 (0.5)	
Meat with pastry										
Meat ($n = 142$)	990 (144)	0.577	8.5 (2.0)	0.759	6.0 (1.5)	0.860	441 (111)	0.847	1.6 (1.0)	0.280
Plant-based ($n = 4$)	1031 (145)		8.2 (2.4)		5.8 (1.3)		452 (98)		2.1 (0.7)	
Mince										
Meat ($n = 17$)	770 (194)	0.747	19.0 (3.0)	0.671	5.4 (3.0)	**0.040**	98 (121)	**0.037**	0.8 (0.4)	**0.005**
Plant-based ($n = 15$)	802 (349)		20.4 (13.7)		2.9 (3.5)		226 (203)		2.5 (2.2)	
Plain poultry										
Meat ($n = 55$)	588 (186)	**0.033**	19.1 (3.4)	0.221	1.6 (1.2)	0.520	522 (181)	0.120	1.6 (1.7)	0.394
Plant-based ($n = 12$)	719 (204)		21.0 (9.0)		1.3 (1.6)		435 (132)		1.1 (0.6)	

(Continues)

TABLE 2 (Continued)

	Energy (kJ/100 g)	*p*-value	Protein (g/100 g)	*p*-value	Saturated fat (g/100 g)	*p*-value	Sodium (mg/100 g)	*p*-value	Total sugar (g/100 g)	*p*-value
Sausages										
Meat ($n = 129$)	879 (212)	0.895	14.1 (2.5)	**<0.001**	6.3 (2.8)	**<0.001**	663 (274)	0.069	0.9 (0.8)	**<0.001**
Plant-based ($n = 26$)	873 (208)		10.8 (6.1)		3.0 (3.1)		561 (167)		1.9 (1.1)	

calculated across each food category. The number and proportion (%) of products fortified with all three micronutrients was also calculated.

To explore the potential influence of the bacon category (a typically high sodium product category) on the overall sodium content of products, we conducted a sensitivity analysis that compared the overall sodium content between plant-based meat analogues and meat products with all bacon products excluded.

3 | RESULTS

A total of 132 plant-based meat analogues were included in the analysis, after excluding seafood style, dairy style, or other products not seeking to mimic meat (tofu, falafel, etc.) ($n = 104$), plant-based meat analogues that could not be categorised ($n = 16$) and product missing nutrient information ($n = 1$). For meat products, a total of 658 were included in the final analysis after excluding mixed dishes and variety packs ($n = 24$), products that could not be categorised into a relevant sub-category based on plant-based meat equivalents, for example some raw meats, canned meats, sliced luncheon meats, or cured meats such as salami, pancetta or chorizo ($n = 840$) and products missing nutrient information ($n = 48$) (Supplementary Figure 1). Of the products included in the analysis, 270 products (34%) displayed dietary fibre on pack, 97 being plant-based meat analogues and 173 meat products.

Overall and according to the HSR, plant-based meat analogues were found to have a healthier nutritional profile compared with equivalent meat products (percentage difference 43.8%, 95% CI: 41.7–46.0) **(**Figure 1**)**, which would equate to a mean difference in HSR of 1.2 stars (95% CI: 1.0–1.4 stars, $p < 0.001$) (Figure 2). Plant-based products had a higher HSR than meat equivalents across all food categories except for meat with pastry. The largest differences in the HSR across these products was found in the bacon (mean difference: 2.75 stars, 95% CI: 2.24–3.27 stars, $p < 0.001$), plain poultry (0.92 stars, 95% CI: 0.68–1.17 stars, $p < 0.001$) and mince (0.64 stars, 95% CI: 0.10–1.17 stars, $p = 0.02$) categories.

Overall, the energy content was marginally lower in plant-based meat analogues when compared to their equivalent meat products (percentage difference − 4.7%, 95% CI: −7.4 to −1.9) (Figure 1). In terms of individual categories, the mean energy content for meat analogues was significantly higher in plain poultry products when compared to meat equivalents (mean difference: 131 kJ/100 g, 95% CI: 11–251 kJ/100 g, $p = 0.03$) (Table 2).

Protein content was similar in both plant-based meat analogues and their equivalent meat products (percentage difference − 1.5%, 95% CI: −9.2 to 6.3) (Figure 1). The mean protein content was lower for meat analogues in the burger (−3.8 g/100 g, −5.5 to −2.0 g/100 g, $p < 0.001$) and sausage categories (−3.3 g/100 g, −4.7 to −1.8 g/100 g, $p < 0.001$) (Table 2).

Plant-based meat analogues had a significantly lower mean saturated fat content when compared against meat equivalents with a mean percentage difference of −50% (95% CI: −58.5 to −41.5) (Figure 1), equivalent to −2.4 g/100 g (95% CI: −2.9 to −1.8 g/100 g, $p < 0.001$) (Table 2). The mean saturated fat content was lower for meat analogues in the bacon (−5.1 g/100 g, −8.4 to −1.8 g/100 g, $p = 0.003$), burger (−2.7 g/100 g, −4.1 to −1.3 g/100 g, $p < 0.001$), mince (−2.5 g/100 g, −4.8 to −0.1 g/100 g, $p = 0.04$), and sausage categories (−3.3 g/100 g, −4.6 to −2.1 g/100 g, $p < 0.001$), all of which had almost half the mean saturated content of meat equivalents.

Plant-based meat analogues also had a significantly lower sodium content with a mean percentage difference of −22.7% (95% CI: −25.6 to −19.7) (Figure 1), equivalent to −132 mg/100 g, (−186 to −79 mg/100 g, $p < 0.001$) (Table 2). The mean sodium content was lower for meat analogues in the bacon category (−530 mg/100 g, −741 to −265 mg/100 g, $p < 0.001$) but found to be significantly higher in the mince category (127 mg/100 g, 8–247 mg/100 g, $p = 0.04$) where mean sodium content was twice that of meat equivalents.

Conversely, total sugar was found to be significantly higher in plant-based meat analogues (0.7 g/100 g, 0.4–1.1 g/100 g, $p < 0.001$) (Table 2). The mean total sugar content was significantly higher for meat analogues in the bacon (1.8 g/100 g, 1.1–2.5 g/100 g, $p < 0.001$), burger (1.7 g/100 g, 0.8–2.6 g/100 g, $p < 0.001$), mince (1.7 g/100 g, 0.5–2.8 g/100 g, $p = 0.005$) and sausage categories (1.0 g/100 g, 0.7–1.4 g/100 g, $p < 0.001$), approximately twice that of meat equivalents.

For the 34% of products displaying dietary fibre on pack, plant-based meat analogues had a higher overall dietary fibre content compared to meat equivalents (percentage difference 216.7%, 95% CI: 198.0–235.4) (Figure 1). The mean dietary fibre content was significantly higher for meat analogues in the burger (4.5 g/100 g, 2.6–6.3 g/100 g, $p < 0.001$), meatball (3.8 g/100 g, 0.5–7.0 g/100 g, $p = 0.03$), sausage (2.1 g/100 g, 0.9–3.3 g/100 g, $p = 0.001$), coated poultry (2.8 g/100 g, 2.3–3.4 g/100 g, $p < 0.001$) and plain poultry categories (4.7 g/100 g, 2.4–7.1 g/100 g, $p < 0.001$) when compared to meat equivalents (Supplementary Table 1).

Using the NOVA classification for level of processing as an indicator of healthiness, most plant-based meat analogues and meat products were considered ultra-processed at 84% and 89%, respectively. Of note, 100% of plant-based mince, coated poultry, and meat with pastry categories were classified as ultra-processed (Figure 3). In terms of meat products, categories with the highest proportion of ultra-processed products were meat with pastry (99%), sausages (97%) and bacon (96%).

Of the 132 plant-based meat analogues analysed, 16 (12.1%) were fortified with all three micronutrients—iron, vitamin B_{12} and zinc, with similar numbers of products fortified with each of the three (20%, 20% and 16%, respectively) (Table 3). The mean level of fortification for each nutrient was reasonably similar across all food categories, with amounts ranging from 3.0 to 3.6 mg/100 g for iron, 1.5 to 2.1 μg/100 g for vitamin B_{12} and 4.0 to 4.5 mg/100 g for zinc.

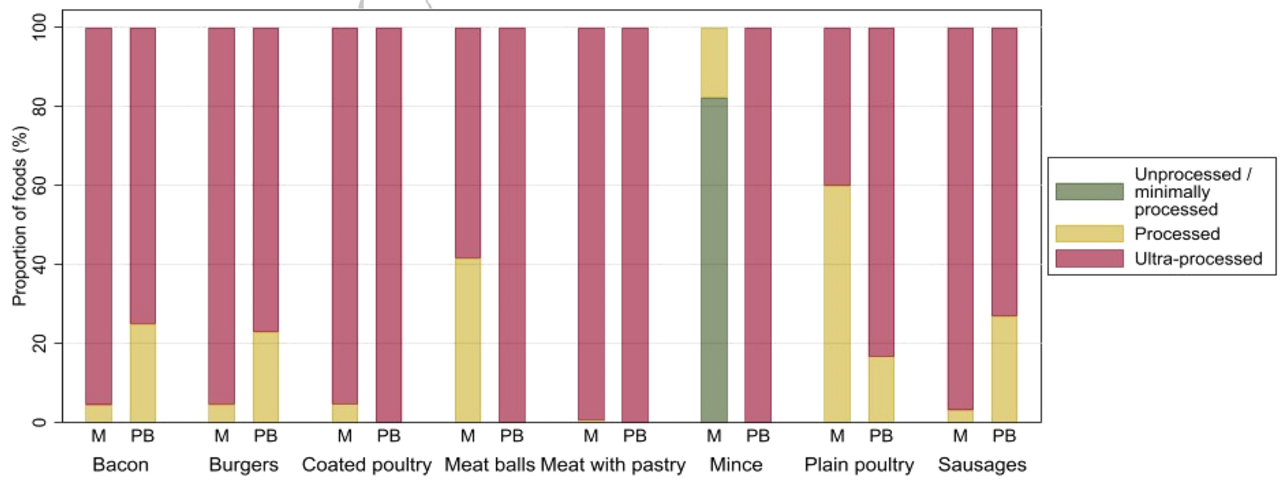

FIGURE 3 Comparison of level of processing (NOVA) across plant-based meat analogues and meat products. M, meat products; PB, plant-based meat analogues

TABLE 3 Prevalence and level of fortification across plant-based meat analogues

Plant-based meat analogues	Prevalence and level of fortification: Iron – Number (%) of fortified products within sub-category	Iron – Mean (SD) amount (mg/100 g)	Vitamin B_{12} – Number (%) of fortified products within sub-category	Vitamin B_{12} – Mean (SD) amount (μg/100 g)	Zinc – Number (%) of fortified products within sub-category	Zinc – Mean (SD) amount (mg/100 g)	Number (%) of products fortified with iron, B_{12} and zinc within sub-category
Total ($n = 132$)	20 (15.2)	3.4 (0.5)	20 (15.2)	1.9 (0.4)	16 (12.1)	4.4 (0.5)	16 (12.1)
Bacon ($n = 4$)	1 (25.0)	3.5 (.)	1 (25.0)	2.0 (.)	1 (25.0)	4.4 (.)	1 (25.0)
Burgers ($n = 48$)	6 (12.5)	3.6 (0.6)	6 (12.5)	2.1 (0.4)	6 (12.5)	4.5 (0.8)	6 (12.5)
Coated poultry ($n = 18$)	1 (5.6)	3.5 (.)	1 (5.6)	2.0 (.)	1 (5.6)	4.4 (.)	1 (5.6)
Meat balls ($n = 5$)	2 (13.3)	3.5 (0.0)	2 (13.3)	2.0 (0.0)	1 (6.7)	4.4 (.)	1 (6.7)
Meat with pastry ($n = 4$)	0 (0.0)	–	0 (0.0)	–	0 (0.0)	–	0 (0.0)
Mince ($n = 15$)	3 (20.0)	3.5 (0.0)	3 (20.0)	2.0 (0.0)	3 (20.0)	4.4 (0.0)	3 (20.0)
Plain poultry ($n = 12$)	2 (16.7)	3.5 (0.0)	2 (16.7)	2.0 (0.0)	1 (8.3)	4.4 (.)	1 (8.3)
Sausages ($n = 26$)	5 (19.2)	3.0 (0.7)	5 (19.2)	1.5 (0.7)	3 (11.5)	4.0 (0.7)	3 (11.5)

Results from the sensitivity analysis demonstrated that excluding bacon products from the analysis did not appreciably change the overall sodium content results. When all bacon products were removed, the overall mean sodium content for plant-based meat analogues remained significantly lower than the sodium content for meat equivalents (−53 mg/100 g, 95% CI: −94 to −13 mg/100 g, $p = 0.009$).

4 | DISCUSSION

This study of 132 plant-based meat analogues available for sale in the Australian marketplace provides a comprehensive evaluation of the nutritional content and overall healthiness of these products compared with equivalent meat products. Overall, plant-based meats were found to have a higher HSR and dietary fibre content, as well as a lower saturated fat and sodium content. However, the healthiness of these plant-based meat analogues did vary by food category, and few were fortified with key micronutrients commonly found in meat products. This may put consumers of these products at nutritional risk if they consume these products exclusively as meat replacements in the absence of a healthy balanced diet.[31,32] Importantly, the majority of both plant-based meat analogues and meat products were ultra-processed, which raises concerns about how both of these foods may fit into a healthy diet.

A key finding from the analysis is that across most food categories, plant-based meat analogues had lower saturated fat, a higher HSR and a higher level of dietary fibre compared to their corresponding meat products. Using a larger and more comprehensive sample of products than previous studies,[33–35] these findings are consistent with prior observations. For example, a cross-sectional study of plant-based meat analogues in the United Kingdom also found saturated fat to be significantly lower and dietary fibre significantly higher in meat analogues,[33] and a prior audit of Australian products found higher saturated fat levels in meat burgers and sausages.[34] As saturated fat intake is associated with increases in cardiovascular events,[36] and higher HSRs associated with lower risk of all-cause and cardiovascular disease (CVD) mortality,[37] switching from processed meat products to processed meat analogues may help to protect against some non-communicable diseases.

While there are many healthy options for consumers within the range of plant-based meat analogues available for purchase, this study also found that not all plant-based meat analogues rated highly when compared to meat products. For example, sodium content was found to be significantly higher for plant-based mince. Another example being that the mean total sugar content was higher for plant-based meat analogues across most food categories. Though the difference in the sugar content between plant-based meat analogues and meat products was relatively small and likely explained by the fact meat products naturally contain very little to no sugar, a modelling study from the United Kingdom exploring the potential nutritional impact of replacing meat products with plant-based equivalents estimated a projected rise in consumption of total sugar when making the switch to plant-based meats.[38] Moreover, the level of sugar in these products raises some potential concerns particularly for those who frequently consume plant-based meat analogues. However, as our findings have shown a wide variability in the total sugar content across plant-based meat analogues, this suggests that reformulation to reduce the level of sugar in plant-based meat analogues should be both technologically feasible and acceptable to consumers.

Most plant-based meat analogues and meat products assessed in this study, regardless of their overall nutritional quality, were classified as ultra-processed foods. Currently in Australia, ultra-processed foods contribute to 42% of total energy intakes[28] and there are concerns these products may have a negative impact on health.[28,39–46] The health effects of ultra-processed foods appear to be driven from a range of factors from reduced dietary quality, higher glycaemic load and reduced gut-brain satiety signalling.[28,44] While evidence is mounting for the potential negative health impact of ultra-processed foods, there is little research on the impact of plant-based meat analogues specifically. Our findings highlight the need to explore how the highly processed nature of plant-based meat analogues independently or synergistically with the nutritional composition of such products may impact health outcomes.

Despite the growing prevalence of plant-based meat analogues in the Australian food supply, there is currently no national guidance for how these products fit within a healthy diet. Plant-based meat products were not included in the most recent Australian Dietary Guidelines, which was released in 2013.[10] This is likely due to the fact that plant-based meat analogues were not highly prevalent in the food supply at the time and therefore it was unlikely that recommendations regarding their consumption were considered necessary. Given the Australian Dietary Guidelines are currently under review and that the availability and consumption of plant-based meat product is growing rapidly in Australia, this provides an opportunity for plant-based meat analogues to be included so that Australian consumers can be more informed about incorporating these products as part of a healthy, balanced diet.[47] Given the findings from this current paper have demonstrated the majority of plant-based meat products are ultra-processed, this suggests that these products should be consumed only in moderation as part of a balanced, healthy diet that incorporates plant-based sources of protein such as beans, legumes, tofu and vegetable-based patties as well as small amounts of animal protein including lean, unprocessed, unflavoured meats, fish and eggs.

The low rates of fortification of plant-based meat analogues could be a potential concern for consumers who frequently or exclusively choose these products as a direct replacement for meat and do not include other foods that provide vitamin B_{12}, such as milk, yoghurt, cheese or eggs.[48,49] Prior research suggests that more than half of consumers expect meat analogues to contain the same amount of iron and vitamin B_{12} that is found in red meat.[50] In Australia, there are currently no mandatory fortification requirements for plant-based meat analogues,[29] and mandatory fortification is generally restricted to issues where evidence of harm is extensive and/or there is a population wide deficiency. However, given the rapid growth in the availability of meat alternative products and our finding that few products are fortified with key micronutrients, there may be public health gains through setting fortification standards to achieve similar levels already observed in about 20% of such products as found in our study.

This study had several strengths. First, it utilises the largest and most comprehensive sample of plant-based meat analogues and meat products available for sale in Australia to date.[34] Second, the study utilised a contemporary nutrition composition dataset that has a periodic and standardised method for obtaining nutrition information from products available in Australian supermarkets, allowing for future replication of analyses, and the assessment of changes in plant-based meat analogues over time. Lastly, while some research has used the NOVA classification to investigate the level of processing in plant-based meat analogues,[51] to the best of our knowledge this is the first study to conduct this investigation in Australia—adding important evidence about the prevalence of ultra-processed products within this growing sector of the food supply.

Some limitations need to be acknowledged. Nutritional data were collected from four major stores and therefore it is unlikely to have complete coverage of products, although the four retailers likely cover the majority of plant-based meat analogues available in Australia. While ingredients most indicative of ultra-processed foods were flagged using individual ingredients and lists from similar applications,[26–28] the accuracy of the NOVA classification assignment was limited by how ingredients are listed on pack (e.g., use alternate scientific names of ingredients may have been missed) and any miss-spellings in the FoodSwitch database. Furthermore, the assignment of the NOVA classification to a broad set of food products, though an informative addition to nutrient profiling, has been criticised as producing subjective and inconsistent results.[52] This research was conducted using products available in the Australian marketplace and therefore the results may not be generalisable to other countries.

This study found that compared to meat equivalents, plant-based meat analogues available for sale in Australia generally had a higher HSR, higher dietary fibre and lower levels of saturated fat and sodium. However, plant-based meat analogues also had a higher total sugar content overall and the healthiness of these products varied according to the food category. Moreover, the vast majority were ultra-processed, which raises concerns about how these plant-based meat analogues fit into a healthy diet, and only a small proportion were fortified with nutrients commonly found in meat, such as vitamin B_{12}, zinc or iron. More research is needed to understand the health impact of plant-based meat analogues and future dietary guidelines in Australia should provide recommendations for how these products can be consumed as part of a healthy, balanced diet.

AUTHOR CONTRIBUTIONS

HM, DHC and ER designed the research. HM conducted the research and MS performed the data and statistical analysis with contributions from JHYW and DHC. HM, MS and DHC wrote the first draft with contributions from AG, BLM and RA. All authors reviewed and provided critical feedback on subsequent drafts of the manuscript and approved the final manuscript.

CONFLICT OF INTEREST

None to declare.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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