Research Article

Diet Quality, Protein Quality, and Micronutrient Adequacy of Myanmar Vegans and Lacto-Ovo-Vegetarians

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ABSTRACT

This study evaluated dietary quality, protein quality, and micronutrient adequacy among vegans, lacto-ovo-vegetarians (LOVs), and omnivores in Myanmar using the Healthy Eating Index-2015 (HEI-2015), the digestible indispensable amino acid score (DIAAS), as well as probability of adequacy (PA) and mean PA (MPA) for vital nutrients like proteins, vitamin B12, calcium, iron, and zinc. A purposive sample of 97 participants (34 vegans, 32 LOVs, 31 omnivores) provided three-day food records. Results showed that HEI scores were not significantly different between groups (omnivores: 58.6 ± 9.8, vegans: 56.9 ± 11.1, LOVs: 55.0 ± 12.2; p = 0.441). Omnivores exhibited the highest DIAAS, PA, and MPA scores in addition to achieving excellent protein quality (DIAAS > 100%), while vegans and LOVs achieved good quality (75-99%) or poor quality protein (< 75%). Median PAs for calcium among all groups were uniformly 0%. Omnivores had the highest median PAs for zinc (100%) and iron (85%), while vegans and LOVs had median PAs between 0-0.5% (p < 0.001). MPA for micronutrients was 57.7 (41.7, 65.3) % for omnivores, compared to 0.2 (0.1, 0.9) % for LOVs and 0.2 (0.1, 0.8) % for vegans (p < 0.001). This study underscores the need for Myanmar vegans and LOVs to diversify protein sources and include calcium, zinc, and iron-rich plant foods and supplements. For LOVs, increased dairy consumption can offer a viable calcium source. These findings provide essential insights for tailoring nutritional recommendations for diverse dietary patterns in Myanmar.

Key words: Vegan; Lacto-ovo-vegetarian; Diet quality; Protein quality; Micronutrient adequacy

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INTRODUCTION

Non-communicable diseases (NCDs) pose a significant global health challenge in the 21st century and are responsible for a substantial portion of worldwide mortality. Based on the latest World Health Organization data, NCDs accounted for 71% of global deaths in 2016, with cardiovascular diseases (CVDs) being the leading cause, followed by cancer, diabetes, and respiratory diseases. Alarmingly, a large percentage of NCD-related deaths occur in low- and middle-income countries (LMICs) where they pose a significant public health burden[1]. Like many LMICs, Myanmar grapples with a heavy NCD burden with CVDs being the leading cause of death. Despite a lack of up-to-date research, a study conducted by Burmese researchers between 2012 and 2017 found that hospitalization rates in Myanmar due to major NCDs increased considerably, especially for CVDs, chronic respiratory diseases, cancers, and diabetes[2].

Efforts to mitigate the global NCD burden have led to recommendations for dietary and lifestyle changes, such as reduced salt consumption, limiting saturated fats, and the elimination of trans-fats from the diet. A well-planned plant-based diet comprising low amounts of saturated fats and trans-fats has been associated with numerous health benefits, including a reduced risk of CVDs, lower incidence of type 2 diabetes, and better management of metabolic syndrome[1,3]. As rates of NCDs increase, many people in Myanmar, a country rich in ethnic and religious diversity[4], are turning to plant-based diets for health, ethical, religious, and economic reasons. Although data on the vegetarian population are limited, advancements in communication technologies and social media have heightened health and ethical awareness among the Burmese people. Consequently, even strict diets like veganism, which excludes eggs and dairy, are gaining in popularity.

While plant-based diets offer substantial health advantages, concerns regarding dietary quality and nutrient adequacy persist, particularly regarding vital nutrients like proteins, calcium, vitamin D, iron, and vitamin B12[5–10]. Evaluating dietary quality requires a comprehensive approach, with dietary quality indices proving more insightful than a single-nutrient focus[11]. The Healthy Eating Index (HEI) assesses adherence to the United States Dietary Guidelines for Americans (DGAs) and monitors dietary pattern changes[12–14]. HEI has been used globally to assess dietary quality in various countries[15]. Among the various HEI versions, HEI-2015 is well-suited for vegetarian diets, with its improved allocation of legumes as a protein source[15]. Protein quality in plant-based diets has garnered attention, with concerns about digestibility and amino acid content in available protein from plant sources[16–18]. The Digestible Indispensable Amino Acid Score (DIAAS) offers a more nuanced evaluation of protein quality, considering differences in amino acid absorption[17]. According to the position of the Academy of Nutrition and Dietetics and previous literature, micronutrient adequacy is a critical aspect of a high-quality diet for vegans and vegetarians, especially in terms of iodine, iron, zinc, calcium, vitamin D, and vitamin B12 content[19,20].

This study’s rationale rests on the premise that while a growing number of Myanmar people are starting to embrace a plant-based lifestyle, the nature of a plant-based diet in this country is still an under-researched issue. Although much cross-country evidence exists showing vegans and vegetarians score better in terms of dietary quality, to our knowledge no studies have yet attempted to assess dietary quality, protein quality, or micronutrient adequacy among Myanmar vegans and vegetarians compared to omnivores. Hence, this study's objective was to compare dietary quality, protein quality, and micronutrient adequacy of Myanmar vegans and lacto-ovo-vegetarians (LOVs) with those of omnivores using HEI-2015, DIAAS, probability of adequacy (PA) for key nutrients, and their mean PAs (MPA).

METHODS

Study design

A cross-sectional online survey of a purposive sample of Myanmar vegans, LOVs, and omnivores was conducted from September 2021-July 2022. To recruit participants, the study was advertised on social media platforms, such as vegetarian groups on Facebook and vegetarian Instagram pages. Participants completed an online screening form that inquired about dietary pattern, age, sex, pregnancy status, education level, occupation, household income, number of family members, current residence, height, weight, and contact information. Thereafter, potential participants were categorized based on reported dietary pattern, namely vegans (those who avoided all animal products including meat, fish, egg, and dairy), LOVs (those who consumed egg and dairy but avoided meat and fish)[18], and omnivores (those who consumed all types of animal products), but only if they had been following the same dietary pattern for at least one month. The inclusion criteria were healthy Myanmar vegans, vegetarians, and omnivores, aged 19-50 years who used social media and who were fluent in speaking and reading Burmese. Pregnant women and those with diabetes, hypertension, heart disease and stroke were excluded from the study. Ethical approval for this study was obtained from the Mahidol University Central Institutional Review Board, Thailand (COE No. MU-CIRB 2021/262.1910). The protocol was under exemption category research involving the use of survey procedures.

Data collection

Following the initial screening, participants completed an online questionnaire covering demographics, education, income, occupation, residence, height, weight, dietary patterns, and duration of adherence to their respective diets. Subsequently, participants viewed an instructional video demonstrating methods for estimating food portion sizes and seasoning amounts using standard household utensils commonly found in Burmese households. Video calls were conducted to confirm participants' comprehension, followed by the recording of dietary intake through a 3-day estimated food record that covered two non-consecutive weekdays and one weekend day. To enhance accuracy and minimize memory-related errors, participants recorded their consumption in real-time using a Google form on their mobile phones. Additionally, they included a photo of the food they consumed to prevent over- or under-reporting. Participants submitted their required data and dietary records through the Google form after watching the instructional video via a provided link. Further video calls were scheduled on recording days to discuss detailed information and food photos. Participants were then categorized into vegan, vegetarian, or omnivorous groups based on recorded diets, disregarding self-proclaimed dietary patterns.

Nutrient intake calculation

Nutrient intakes from the food records were processed using the INMUCAL-Nutrients V.4.0 software program (database version NB.4) from the Institute of Nutrition, Mahidol University, Thailand. This program facilitated the determination of each participant's daily intake values for energy, sugar, sodium, saturated fatty acid, protein (plant and animal), vitamin B12, zinc, calcium, and iron. Polyunsaturated and monounsaturated fatty acid (PUFA and MUFA) values were sourced from Fatty Acids Composition and Cholesterol in Thai Foods[21] and Indian Food Composition Tables[22]. To calculate the average daily intake from 3 days of a 24-hr food record, the average nutrient intake from the 2 weekdays was multiplied by 5, the value was then added to the intake on one weekend day, which was multiplied by 2, and the total value was divided by 7.

HEI calculation

Following the method of Krebs-Smith et al., the HEI calculation process involved several steps[23]. Firstly, food intake data were categorized into relevant food groups using the USDA's Food Patterns Equivalent Database (FPED)[24]. Secondly, quantities of dietary constituents were determined and converted to cup or ounce equivalents, with legumes converted based on categorization and equivalent measures from the FPED. Thirdly, ratios were derived and scores calculated for each HEI component using established standards. This process included summing food group components, constructing ratios, generating scores based on HEI standards, and calculating means across the three days for each participant. Finally, group average scores were then computed to represent mean diet quality.

DIAAS calculation

For this study, protein sources encompassed dairy, eggs, meat, legumes, nuts and seeds, grains, whey protein concentrate, and soy protein isolate. Exclusion criteria applied to fruits, vegetables, sugars, and oils due to limited protein content and minimal data on true ileal amino acid digestibility[18,25]. For DIAAS calculation, protein amounts and indispensable amino acid (IAA) composition from the various sources were determined using the Indian Food Composition Tables[22] and the Amino Acid Content of Thai Foods database[26]. True ileal IAA digestibility data were obtained from the Report of a Sub-Committee of the 2011 FAO Consultation on Protein Quality Evaluation in Human Nutrition[25]. Missing values were obtained from relevant references. DIAA reference ratios for lysine, sulfur amino acids (methionine + cysteine), threonine, and tryptophan were calculated as mg of dietary DIAA in 1 g protein which was then divided by mg of the same dietary DIAA in 1 g of the reference protein, then multiplied by 100, and the lowest value was the DIAAS[17]. The mean 3-day DIAAS for each individual was calculated, followed by the computation of weighted averages for group values.

PA and MPA calculation

The PA for key vitamins and minerals (i.e., iron, zinc, calcium, and vitamin B12) were calculated in this study based on information from Melina et al.[19]. Although they might be nutrients of concern, iodine and vitamin D were excluded, since the Universal Salt Iodization program has been executed nationwide in Myanmar since 1997 to combat iodine deficiency[27], while serum vitamin D level is more a matter of accessibility to sun exposure rather than a dietary issue[28]. PA was computed using CVs of 10% (calcium and vitamin B12) and 25% (zinc) based on the Institute of Medicine (IOM) and FAO/WHO recommendations[29,30]. Adjustments for zinc bioavailability were made, considering dietary influences, such as phytates and animal proteins. Estimated Average Requirement (EAR) values for men (1.4 mg/d) and women (1 mg/d) were adjusted for bioavailability (high [50%], moderate [30%] or low [15%])[30]. SPSS with the CDF.NORMAL function assessed PA using intake values, EAR, and SD. For iron, since the requirement distribution was skewed and EAR could not be used, PA was directly calculated from data in the IOM iron requirements for adult men and women[29]. From intake values at 18% bioavailability for the general diet, intakes for 10% and 5% bioavailability corresponding to vegetarian and vegan diets were derived[31]. To obtain MPA, individual PA values for calcium, iron, and zinc were averaged. Vitamin B12 was excluded from the MPA due to low database completeness in the INMUCAL software program (approximately 20%). Group MPAs were derived by averaging individual MPAs.

Statistical analysis

Sample size was determined using the G*Power 3.1 software (Department of Psychology at Heinrich-Heine-Universität Düsseldorf, Germany). The HEI scores reported by Clarys et al.[32] were employed, showing means of 65.4 (SD 8.3) for vegans, 58.7 (SD 8.9) for vegetarians, and 54.2 (SD 9) for omnivores, resulting in an effect size of 0.35. A sample size of 84 was calculated to achieve 80% power using a one-way ANOVA test. For the DIAAS, the sample size was based on scores from vegetarian and non-vegetarian endurance athletes, which were 89.9 (SD 10.5) and 99.9 (SD 0.8), respectively[18], resulting in a required sample of 21 participants. Consequently, a total of 84 participants was selected, with a 15% adjustment for potential dropouts, yielding a final sample size of 99 participants (33 per group).

Statistical analyses were conducted using the IBM SPSS Statistics version 19.0 (IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed with the Kolmogorov-Smirnov test. Means and standard deviations (SD) were calculated for normally distributed data, while median and interquartile range (P25, P75) were computed for non-normally distributed data. Group comparisons for HEI, DIAAS, PA, and MPA were performed using ANOVA or Kruskal-Wallis test, followed by Tukey's post-hoc test or Mann-Whitney U test with Bonferroni correction (p = 0.05/3 pairs = 0.017) for pairwise comparisons. Chi-square tests were applied for sociodemographic characteristics. A significance level of 5% was used for all comparisons, except for Mann-

Whitney U test (0.017 was used, as mentioned above).

RESULTS

Characteristics and nutritional status of participants

This study included 97 Myanmar adults comprising 31 omnivores, 32 LOVs, and 34 vegans. **Table 1** presents the participants' characteristics. The sample contained more females than males in each group (omnivore 58.1 vs. 41.9%; LOVs 75.0 vs. 25.0%; and vegan 64.7 vs. 35.3%). No significant differences in age, height, weight, and BMI as per Asian-Pacific cutoff points[33] were observed among groups ($p > 0.05$), but nutritional status differed significantly ($p < 0.001$). Omnivores had higher proportions of overweight (12.9%) and obesity (41.9%) compared to LOVs and vegans. LOVs showed a mix of normal BMI (34.4%), overweight (25.0%), and obesity (28.1%), while vegans had lower proportions of overweight (11.8%) and obesity (20.6%).

Regarding dietary patterns, 47.4% maintained lifelong dietary habits. All omnivores had maintained the same dietary pattern for many years, while only 25.0% and 20.6% were lifelong vegetarians and vegans, respectively. Most participants (43.8% for LOVs, 44.1% for vegans) adopted plant-based diets for less than 1 year. In terms of education, 52.5% had a bachelor's degree, while 12.4% were high-school graduates or without degrees. Omnivores had higher educational levels than LOVs and vegans. Occupationally, 48.4% of omnivores held white-collar jobs, while LOVs and vegans showed more unemployment or housewife status. The business capital, Yangon, housed the majority of omnivores (61.3%) and vegans (52.9%), while LOVs were more dispersed. Regarding income, 38.7% of omnivores earned <175 USD/month, with 41.9% earning >350 USD. LOVs and vegans had varying income levels, with 41.2% of vegans earning <175 USD, and 40.6% of LOVs and 32.4% of vegans earning >350 USD.

Nutrient intakes

Table 2 presents the median (P25, P75) daily nutrient intakes for the three dietary patterns. No significant differences were observed in energy and carbohydrate intakes ($p > 0.05$). Omnivores had the highest protein intake (63.8 [46.1, 87.8] g), sourced predominantly from animals (42.0 [28.7, 58.7] g). Vegans had the highest plant protein intake (28.6 [22.1, 36.2] g). Iron intake followed a similar pattern, with omnivores obtaining more from animal sources (3.5 [2.0, 6.4] mg) and vegans from plants (6.9 [5.0, 8.3] mg). Total fat, saturated fat, mono- and poly-unsaturated fats, and sugar intakes showed no significant differences ($p > 0.017$). Vegans had the highest dietary fiber intake (28.3 [21.7, 43.5] g).

The percent caloric distribution of macronutrients revealed significant differences. Vegans had the highest carbohydrate intake (56.9 ± 8.5%), while omnivores had the highest protein distribution (16.6 ± 4.7%). LOVs had the highest fat distribution (38.6 ± 8.1%), which surpassed vegans (32.7 ± 8.4%) but not omnivores (36.0 ± 7.8%). Saturated fat contributed more to LOV energy intake (10.4 ± 3.4%) than vegans (7.8 ± 4.1%). The contribution of mono- and poly-unsaturated fats did not significantly differ among groups.

Calcium intake did not significantly differ based on Bonferroni adjusted p-value of 0.017, with omnivores having the highest zinc and vitamin B12 intake. Vitamin B12 intake for vegans was low (0.0 [0.0, 0.2] mcg), possibly underestimated due to limited database completeness (20%). Omnivores had the highest sodium intake (1924.8 [1715.5, 2644.2] mg).

HEI scores

Table 3 gives the total and component scores of HEI-2015 for different dietary patterns, with omnivores scoring 58.6 ± 9.8, LOVs 55.0 ± 12.2, and vegans 56.9 ± 11.1, though differences were not statistically significant. The score for the category of greens and beans was significantly higher for vegans (p = 0.005), while the total vegetables score was significantly higher for vegans compared to omnivores (p < 0.001). Vegans had lower scores in terms of dairy and total protein foods compared to LOVs and omnivores.

DIAAS

DIAAS and its classifications are presented in **Table 3**. Omnivores had the highest DIAAS among the groups (p < 0.001), with all omnivores scoring ≥100%, mean and SD of 136.0 ± 12.5%. For LOVs, the mean DIAAS was 91.6 ± 21.0%, with 25% consuming high-quality protein (DIAAS ≥ 100%), 59.4% consuming good quality protein (DIAAS 75-99%), and 15.6% having low-quality protein (DIAAS < 75). Vegans had a mean DIAAS of 82.6 ± 8.7%, with only one vegan (2.9%) having a high-quality protein intake, while 76.5% and 20.6% had good and low-quality protein intakes.

PA and MPA of selected vitamin and minerals

PA and MPA PA for calcium and vitamin B12 was 0.0 (0.0, 0.0) % for all groups. The vitamin B12 database was only 20% complete, possibly leading to underestimation (**Table 3**). Zinc and iron PAs differed significantly; omnivores had the highest, with zinc at 100.0 (98.8, 100.0) % and iron at 85.0 (25.0, 100.0) %. LOVs and vegans scored 0.5 (0.2, 1.2) % and 0.4 (0.2, 1.3) % for zinc, respectively, and 0.0 (0.0, 0.0) % for iron. MPA for the four micronutrients was significantly highest for omnivores at 57.7 (41.7, 65.3) %, while LOVs exhibited 0.2 (0.1, 0.9) %, and vegans had 0.2 (0.1, 0.8) % after excluding vitamin B12 due to incomplete data.

DISCUSSION

Using purposive sampling targeting vegetarians and vegans, this study demonstrates that dietary quality (based on HEI score) was not significantly different between omnivores, LOVs, and vegans. However, protein quality (DIAAS) was highest among omnivores, followed by LOVs and vegans, while micronutrient adequacy (PA and MPA) was also highest among omnivores. The implications of these findings are discussed further below.

Nutritional status and nutrient intakes

Based on this study's results, the vegan group exhibited the highest prevalence of underweight participants and the lowest prevalence of overweight and obese individuals. Conversely, the omnivore group had the highest proportion of obese participants (42%) and the lowest prevalence of underweight individuals (10%). These findings align with previous research which demonstrated that vegetarians and vegans tend to have lower BMI compared to omnivores. For instance, studies such as India's third National Family Health Survey and the Adventist Health Study-2 have consistently shown lower BMI in pesco-vegetarians and vegans compared to other dietary patterns[34,35], suggesting that adherence to vegetarian diets may mitigate the risk of obesity.

Table 1. Characteristics and nutritional status of participants

Characteristics	Total (n = 97)	Omnivore (n = 31)	LOV (n = 32)	Vegan (n = 34)	*p*-value*†
Age[1] (years)	30.0 (26.0, 37.0)	28.0 (26.0, 31.0)	33.5 (26.3, 44.5)	31.5 (24.0, 37.3)	0.132
Gender[2] (Male: Female)	34.0:66.0	41.9:58.1	25.0:75.0	35.3:64.7	0.002
BMI (kg/m^2)	22.3 (19.8, 25.8)	23.8 (20.2, 26.6)	23.8 (20.0, 25.9)	22.0 (19.0, 24.8)	0.278
Nutritional status[3]					<0.001
Underweight (< 18.5 kg/m^2)	14.4	9.7	12.5	20.6	
Overweight (23-24.9 kg/m^2)	17.5	12.9	25.0	11.8	
Obese (≥ 25 kg/m^2)	29.9	41.9	28.1	20.6	
Duration of the current diet pattern					< 0.001
<1 year	29.9	0.0	43.8	44.1	
1 – 5 years	16.5	0.0	25.0	23.5	
> 5 – 10 years	6.2	0.0	6.3	11.8	
>10 years/lifelong	47.4	100.0	25.0	20.6	
Education					<0.001
High-school or diploma	12.4	3.2	12.5	20.6	
Bachelor's degree	51.5	54.8	62.5	38.2	
Master's degree or higher	36.1	41.9	25.0	41.2	
Occupation					<0.001
Unemployed/Housewives	30.9	22.6	40.6	29.4	
Elementary occupation‡	5.2	0.0	0.0	14.7	
Clerk and skilled agricultural worker§	27.8	29.0	25.0	29.4	
Manager and professional‖	36.1	48.4	34.4	26.5	
Area of residence					0.761
Business capital (Yangon)	51.5	61.3	40.6	52.9	
Other cities	48.5	38.7	59.4	47.1	
Monthly Household Income					0.198
<175 USD¶	37.1	38.7	31.3	41.2	
175 – 350 USD	24.7	19.4	28.1	26.5	
>350 USD	38.1	41.9	40.6	32.4	

[1] Presented as median (P25, P75) (all such values)

[2] Presented as % (all such values) [3] Asia-Pacific BMI Classification

* Chi-square test for discrete data; † ANOVA or Kruskal-Wallis test for continuous data

‡ Plant and machine operator or assembler; § Clerical support worker, services or sales worker, skilled agricultural, forestry, or fishery worker, craft and related trades worker; ‖ Manager and professional, technician or associate professional; ¶ 1 USD = 1 USD = 2860 MMK (actual selling price in Myanmar on 18.4.2023)

BMI, body mass index; LOV, Lacto-ovo-vegetarian

Table 2. Average nutrient intake of different dietary patterns

Nutrients	Omnivore		LOV		Vegan		*p*-Value[*]
	Median	P25, P75	Median	P25, P75	Media	P25, P75	
Total energy (kcal)	1457.9	1288.8, 2123.6	1424.8	1150.1, 1822.9	1506.9	1142.1, 1779.2	0.362
Carbohydrate (g)	180.3	164.0, 243.6	182.3	132.5, 221.6	218.4	153.4, 247.5	0.300
Protein (g)	63.8[a]	46.1, 87.8	36.6[b]	27.6, 43.7	36.4[b]	28.3, 49.6	<0.001
Protein intake (g/kg)	1.1 ± 0.5[1, a]		0.6 ± 0.3[b]		0.7 ± 0.3[b]		<0.001[†]
Protein, animal (g)	42.0[a]	28.7, 58.7	6.3[b]	3.2, 9.8	0.1[c]	0.0, 0.6	<0.001
Protein, plant (g)	16.6[a]	14.4, 22.6	22.3[b]	15.0, 28.3	28.6[c]	22.1, 36.2	<0.001
Total fat (g)	59.9	42.8, 89.0	61.5	48.8, 77.4	52.1	40.5, 68.2	0.149
Saturated fat (g)	16.2[a]	10.9, 23.9	13.9[a]	11.8, 20.5	12.8[b]	8.1, 16.2	0.039
Mono-unsaturated fat (g)	20.1	12.3, 36.6	20.3	14.7, 25.4	16.5	11.4, 22.7	0.269
Poly-unsaturated fat (g)	14.6	8.1, 21.3	15.6	9.6, 22.3	11.3	6.9, 21.1	0.433
Dietary fiber (g)	8.9	7.1, 11.1	11.7	9.4, 16.5	16.2	7.5, 18.9	0.009
Sugar (g)	31.0	18.8, 48.4	28.8	14.6, 40.4	28.3	21.7, 43.5	0.460
Calcium (mg)	275.2[a]	217.0, 512.1	303.1[a,c]	183.3, 373.5	224.2[b,]	167.3, 270.1	0.018
Iron (mg)	10.0	5.8, 14.5	7.5	4.9, 9.6	8.4	7.0, 10.9	0.093
Iron, animal (mg)	3.5[a]	2.0, 6.4	0.5[b]	0.2, 0.9	0.0[c]	0.0, 0.1	<0.001
Iron, plant (mg)	3.6[a]	2.7, 5.0	5.8[b]	3.9, 7.6	6.9[b]	5.0, 8.3	<0.001
Zinc (mg)	5.2[a]	3.5, 6.7	3.6[b]	2.7, 4.5	4.7[b]	3.2, 5.9	0.008
Vitamin B12 (mcg)	0.6[a]	0.3, 2.2	0.3[b]	0.1, 0.8	0.0[c]	0.0, 0.2	<0.001
Sodium (mg)	1924.8[a]	1715.5, 2644.2	1552.3[b]	1281.5, 2216.2	1549.4	1163.8, 1809.5	0.002
Percentage of energy intake	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value[†]**
Carbohydrate (%)	47.6[a]	10.0	51.1[a]	8.4	56.9[b]	8.5	<0.001
Protein (%)	16.6[a]	4.7	10.3[b]	1.7	10.4[c]	2.7	<0.001
Total fat (%)	36.0[a,b]	7.8	38.6[a]	8.1	32.7[b]	8.4	0.017
Saturated fat (%)	9.4[a,b]	3.0	10.4[a]	3.4	7.8[b]	4.1	0.013
Mono-unsaturated fat (%)	12.1	4.9	13.0	4.0	10.8	4.6	0.140
Poly-unsaturated fat (%)	8.4	4.7	10.3	4.7	8.5	4.8	0.215

[1] Presented as mean (SD)

[*] Kruskal-Wallis test for non-normally distributed data, pairwise comparison with Mann-Whitney U test and Bonferroni adjustment

[†] ANOVA for normally distributed data with Tukey post-hoc test

[a,b,c] Values in a row with different letters differ

LOV, Lacto-ovo-vegetarian

Table 3. Total and component scores of HEI-2015, DIAAS, PA, and MPA of 4 micronutrients across different dietary patterns[*]

Adequacy components	Omnivore		LOV		Vegan		
	Scores of HEI-2015						
	Mean	SD	Mean	SD	Mean	SD	*p*-Value[†]
Whole fruits	2.1	1.8	1.4	1.4	1.7	1.5	0.140
Total fruits	1.5	1.5	1.2	1.3	1.2	1.1	0.561
Greens and beans	3.1[a]	1.7	3.4[a]	1.4	4.2[b]	0.9	0.005
Total vegetables	3.1[a]	1.3	3.9[b]	0.9	4.3[b]	0.9	<0.001
Whole grains	1.5	2.4	1.3	2.2	1.0	1.8	0.601
Dairy	1.0[a,b]	1.6	1.7[a]	1.6	0.7[b]	1.4	0.040
Seafood and plant proteins	4.1	1.1	3.6	1.1	3.7	1.1	0.093
Total protein	4.8[a]	0.4	3.3[b]	1.0	3.1[b]	1.2	<0.001
Fatty acids	9.0	1.5	8.3	2.0	8.5	1.9	0.361
Moderation components							
Refined grains	4.6	2.7	4.6	3.0	3.9	2.5	0.501
Added sugars	9.6	0.7	8.9	1.8	9.0	1.6	0.114
Saturated fats	7.3	2.5	6.4	2.7	7.7	2.8	0.128
Sodium	6.7	2.4	7.1	2.4	7.7	2.3	0.220
Total scores	58.6	9.8	55.0	12.2	56.9	11.1	0.441
				DIAAS			
	Mean	SD	Mean	SD	Mean	SD	*p*-Value[†]
DIAAS, %	136.0[a]	12.5	91.6[b]	21.0	82.6[c]	8.7	<0.001
DIAAS classification	n	%	n	%	n	%	*p*-Value[‡]
≥100% (Excellent/high)	31	100.0	8	25.0	1	2.9	<0.001[‡]
75-99% (Good)	0	0	19	59.4	26	76.5	
<75% (Low)	0	0	5	15.6	7	20.6	
	Probability of adequacy (PA) and mean probability of adequacy (MPA)						
PA, %	Median	P25, P75	Median	P25, P75	Median	P25, P75	*p*-Value[§]
Calcium	0.0	0.0, 0.0	0.0	0.0, 0.0	0.0	0.0, 0.0	NA[‖]
Iron	85.0[a]	25.0, 100.0	0.0[b]	0.0, 0.0	0.0[b]	0.0, 0.0	<0.001[§]
Zinc	100.0[a]	98.8, 100.0	0.5[b]	0.2, 1.2	0.4[b]	0.2, 1.3	<0.001[§]
Vitamin B12	0.0[a]	0.0, 0.0	0.0[b]	0.0, 0.0	0.0[c]	0.0, 0.0	NA[‖]
MPA, % [¶]							
	57.7	41.7, 65.3	0.2	0.1, 0.9	0.2	0.1, 0.8	<0.001

* HEI-2015, Healthy Eating Index 2015; DIAAS, Digestible indispensable amino acid score; PA, Probability of adequacy; MPA, Mean probability of adequacy

[†] ANOVA with Tukey post-hoc test; [‡] Chi-square test; [§] Kruskal-Wallis test, pairwise comparison with Mann-Whitney U test and Bonferroni adjustment

[‖] P-value cannot be calculated because all PA values are 0.0

[¶] MPA of calcium, iron, and zinc were calculated; PA of vitamin B2 was excluded due to low percentage (20%) of data completeness

[a,b,c]: values in a row with different letters differ

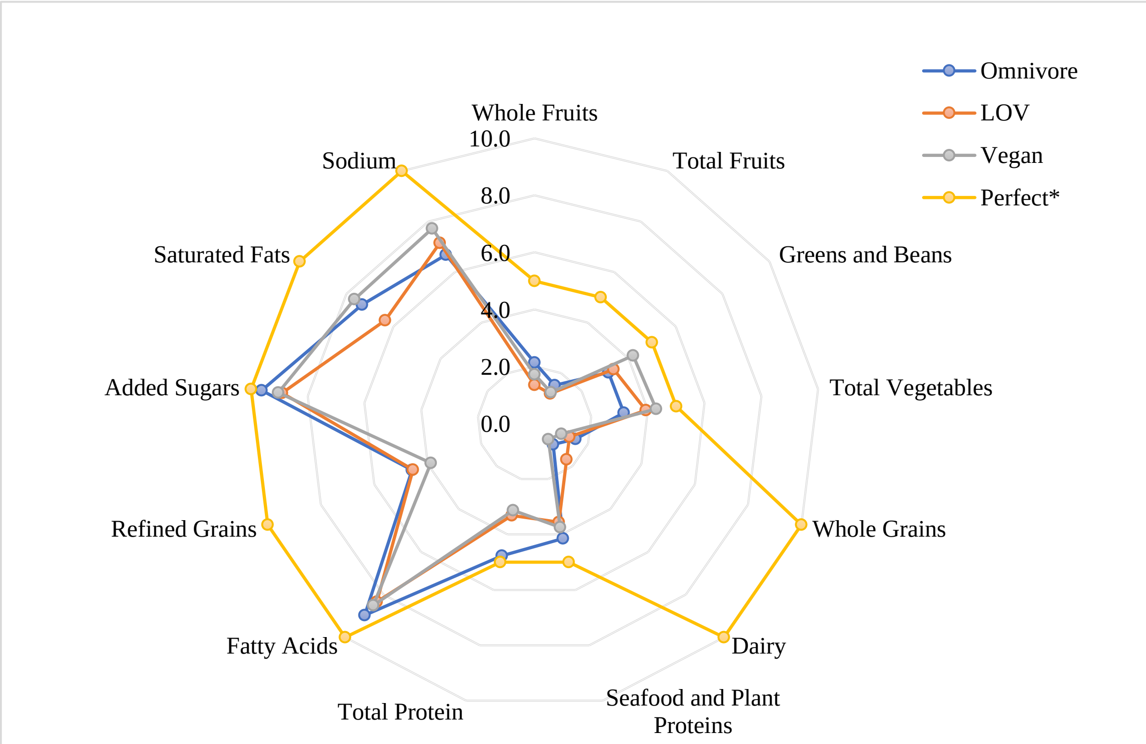

Figure 1. Radar chart depicting a perfect HEI score (100 points) and the HEI scores of omnivores, lacto-ovo-vegetarians, and vegans

*Perfect means HEI-2015 score of 100

The lower protein intake among vegans in this study may contribute to their lower BMI. Both vegans and LOVs consumed less protein compared to omnivores, with vegans consuming the lowest amount of animal protein but the highest amount of plant protein. Additionally, vegans had the highest dietary fiber intake, followed by LOVs and omnivores. These nutrient intake patterns are consistent with those reported by previous research studies, such as among Belgian vegans and Flemish vegetarians who had higher carbohydrate and fiber intake but lower protein consumption compared to omnivores[9,32,36].

Dietary quality

Contrary to results reported in previous literature, our study found no significant difference in the total Healthy Eating Index (HEI) score among the three groups. Previous research, such as two studies in Belgium conducted by the same group of researchers and another comparing German vegetarians and omnivores, reported higher HEI scores for vegans and vegetarians compared to omnivores[32,36–37]. However, in our study component scores for certain aspects (e.g., whole grains, total protein, seafood and plant proteins, and refined grains) were lower for vegans, potentially due to their higher consumption of white rice and potatoes as primary energy sources. Despite this, vegans scored the highest in HEI components like greens and beans and total vegetables that may contribute to their higher dietary fiber intake. The radar graph shown in **Figure 1** displays the HEI component scores and total scores of the three dietary patterns, which gives a better understanding of the trends.

Protein quality

According to DIAAS, only 25% of LOVs and 2.9% of vegans consumed excellent quality protein, compared to 100% of omnivores. LOVs and vegans had lower protein intake (0.63 and 0.67 g/kg body weight [BW]/day, respectively) than the recommended daily allowance (RDA) (0.8 g/kg BW/day)[29], which was obtained mostly from low-quality plant sources like white rice and potatoes. Considering their protein intake and DIAAS, LOVs should consume 0.87 g/kg BW/day (0.24 g/kg BW more) and vegans should consume 0.94 g/kg BW/day (0.27 g/kg BW more) to reach the recommended RDA of protein for the general population and avoid potential negative impacts on muscle mass and performance[38,39]. Complementary protein pairing[29,40], such as mixing different plant protein sources, can improve protein quality for vegans. Consequently, a diverse intake of plant proteins throughout the day is essential for meeting amino acid requirements in plant-based diets[19].

Micronutrient adequacy

All three dietary groups demonstrated a 0% PA for calcium. As noted above, the PA of vitamin B12 may be underestimated due to data incompleteness. However, the PA for zinc and iron was notably low for LOVs and vegans, resulting in very low MPA scores. Omnivores had the highest intakes of iron from animal food sources, zinc, and vitamin B12, whereas vegans had the lowest. In addition, it is interesting to note that the intakes of calcium and vitamin B12 among all three groups were remarkably below the EARs (800 mg and 2 mcg, respectively), while the iron intakes of LOVs and vegans were below the EAR. This finding is in agreement with previous literature. For instance, a cross-sectional analysis of 689 British male participants (226 omnivores, 231 vegetarians, and 232 vegans) from the EPIC-Oxford cohort[(10)] found that half the vegan participants were vitamin B12 deficient, whereas only 7% of LOVs and one omnivore fell in that category.

In terms of micronutrient adequacy, not only LOVs and vegans but also omnivores in Myanmar need to consume more low-oxalate, high-calcium vegetables, such as kale, broccoli, bok choy, and other Chinese vegetables (except Chinese spinach)[41]. For omnivores and LOVs, dairy products should be consumed in higher amounts. For vegans, it is also advisable to take low-dose calcium supplements if the dietary supply is inadequate. With regards to vitamin B12, apart from seaweed and algae, supplementation would be a reliable source since vitamin B12 comes from animal sources.

A practical recommendation for vegetarians to increase their iron absorption is to pair high-non-heme iron foods with vitamin C rich foods and fermented foods to enhance absorption. They should also limit their intakes of phenolic compounds, such as tea, coffee, betel leaves, pickled tea leaves (laphat) with meals, as well as avoid eating high-calcium and high-iron foods together in a meal[30]. A pragmatic approach for vegetarians to increase the dietary zinc bioavailability include germination of legumes followed by soaking at ambient temperature for

12-24 hours, and the fermentation of dough can increase phytase activity which destroys phytate, which is zinc absorption inhibitor[30]. Since the Burmese people typically incorporate pulses and legumes into their daily side dishes, alongside wheat-based products like buns, paratha, and you-tiao (Chinese churros) as breakfast items, these methods can be easily integrated into their diet. However, such nutrition knowledge is not readily available to the general public in the Burmese language. Hence, this lack of nutrition knowledge could be manifested in terms of lower DIAAS and PA scores for these two groups compared to their omnivore counterparts. Consequently, accessibility to reliable nutrition information, especially in the Myanmar language, is crucial to bridge these knowledge gaps and improve dietary quality among those who are consuming plant-based diets.

Limitations and strengths of the study

This study has certain limitations, however. The non-representative sample, primarily comprising individuals from urban areas with higher education levels, may have introduced recruitment biases and limited the generalizability of the findings to the entire Myanmar population. In addition, for reasons noted above, the exclusion of iodine and vitamin D, which are considered as at-risk nutrients for non-meat eaters, may have affected the study's completeness. Additionally, the nutrient database limitations of the INMUCAL program required the substitution of some foods, potentially impacting on the accuracy of nutrient assessments. Moreover, the three-day food records collected may not fully represent long-term dietary patterns, and online data collection could introduce inaccuracies. The study also did not account for micronutrient supplementation, potentially influencing PA and MPA estimations.

Despite these limitations, the study boasts notable strengths. The use of an extensive DIAAS database, incorporating various plant protein sources, enhances the assessment of protein quality. The study's comprehensive approach compares three indices, i.e., HEI, DIAAS, as well as PA and MPA, across vegan, LOV, and omnivorous dietary patterns. This comparison allows for a detailed examination not only of dietary and protein qualities but also the micronutrient adequacy of vegetarian and vegan diets. The study's strengths contribute to a more nuanced understanding of the nutritional profiles associated with different dietary patterns in Myanmar.

CONCLUSION

Plant-based diets are understudied in Myanmar despite the growing number of vegans and vegetarians. This research assessed protein quality and micronutrient adequacy in vegan, LOV, and omnivorous diets using HEI, DIAAS, and PA and MPA calculations. HEI scores showed no significant differences among the groups. DIAAS revealed omnivores consumed excellent quality protein, while vegans and LOVs had mixed qualities, emphasizing the need for diverse plant protein sources. Micronutrient PA, especially for calcium, vitamin B12, iron, and zinc, was subpar for all groups, with LOVs and vegans being notably low. Overall, this study lays the groundwork for dietary guidelines and educational programs. Recommendations include increasing plant sources and considering supplementation for these nutrients, as well as highlighting the necessity of nutrition knowledge before dietary changes.

In terms of future research, studies should focus on plant-based dieters across various regions of Myanmar, using the same three indices to provide a more representative sample of both rural and urban populations. Additionally, examining the diet and protein quality of prudent diets, such as semi-vegetarian and pesco-vegetarian diets, offers another area for exploration. Further studies employing biochemical assessments are also needed to confirm the relationship between dietary quality and micronutrient status. Lastly, developing comprehensive plant-based dietary guidelines would be a logical next step.

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