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Investigating Sustainable Food Habits by Using Novel Carbon-Footprint Method – A Cross-Sectional Analysis

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ABSTRACT

Environmental sustainability and nutrition are two emerging issues in public health that have become interdependent. The eating trends not only dictate the health outcomes of individuals but also the sources of greenhouse gases in the world. **Objectives:** To establish the relationship between food patterns and the carbon footprint of university students in Khyber Pakhtunkhwa, Pakistan. **Methods:** It was a cross-sectional study. Food intake data were measured using a semi-quantitative Food Frequency Questionnaire (FFQ) in 400 participants, and carbon emissions were estimated using the values of the life-cycle assessment (LCA). **Results:** Carbon footprints of meat-intensive diets were significantly higher compared to those of vegetarian diets. The Mean Adequacy Ratio (MAR) for meat-heavy was 72.6 ± 6.0 and for plant-forward diets was 72.6 ± 5.0, respectively. The emission of meat-based diets (5.2 ± 0.1 kg CO2-equivalent per day) was much higher than that of plant-based diets (2.9 ± 0.8 kg CO2-equivalent per day; p=0.001). Red meat generated 52% of all emissions in meat-based diets compared to the 0:14% in plant-based ones, with cereals and milk being moderate contributors and vegetables and legumes being minor contributors. Regression analysis revealed that higher emissions were predicted by the consumption of red meat (β = 0.44) and residing in urban areas (β = 0.54). **Conclusions:** The results suggest that simple changes to the diet, which decrease red meat consumption and increase the consumption of plant foods, can reduce carbon emissions but not decrease the nutritional sufficiency.

INTRODUCTION

The food system in the world is one of the largest causes of climate change, as it contributes to nearly one-third of the greenhouse gas emissions [1, 2]. Meanwhile, malnutrition in its various forms continues to be a burning issue in the world health. The crossroads of environmental sustainability and nutrition are becoming more acknowledged as the key to the fulfillment of the Sustainable Development Goals (SDGs), especially SDG 2 (Zero Hunger) and SDG 13 (Climate Action) [3, 4]. Carbon footprint assessment gives an estimate of greenhouse gas (GHG) emissions from food manufacture, transportation, and use [5]. Diets that are high in animal foods, especially red meat and milk, have unusually large carbon footprints compared to plant-based counterparts [6-8]. In contrast, eating patterns that are high in fruits, vegetables, whole grains, and legumes are associated with both better health consequences and fewer environmental effects [9-11]. In Pakistan, climate change and food security are urgent and connected challenges. Khyber Pakhtunkhwa (KP), with high undernutrition rates in the province, also witnesses high environmental stresses [12, 13]. However, there has been scant research on quantifying the environmental

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consequences of eating habits here.

This research aims to measure the carbon footprints of dietary intakes among university students in KP and to simulate the consequences of dietary changes on nutrition as well as on the environment.

METHODS

A cross-sectional design was used to determine the association between dietary habits, nutrition adequacy, and their corresponding carbon footprint. The study conducted from September 2024 to December 2024 in Charsadda used a convenience sample of 400 students between the ages of 18–25 years. Sampling was performed by stratified random selection in a manner that provided proportional representation by gender, field of study, and socioeconomic status. Inclusion criteria were being enrolled as a full-time student, 18 to 25 years of age, and willingness to give informed consent. Students with self-reported chronic diseases (e.g., diabetes, kidney disease) or special diets (e.g., medical diets, veganism) were excluded to avoid confounding effects. Sample size was calculated from the basis of the anticipated medium effect size (Cohen's d =0.5) between groups based on diet, with 80% power and 5% significance level, which required a minimum of 352 participants. To provide for incomplete returns, 400 students were eventually recruited. Measured dietary intake was also measured through a semi-quantitative food frequency questionnaire (FFQ), which consisted of 85 locally adapted foods and beverages, which were grouped into major food categories. The FFQ was pilot-tested and validated for reliability in a sub-sample of 30 university students from the same population in Khyber Pakhtunkhwa. The tool demonstrated good test-retest reliability over two weeks (Intra-class Correlation Coefficient, ICC = 0.82) and acceptable internal consistency (Cronbach's α = 0.76). Participants were asked about the frequency of intake in the last month, and the portions were standardized using local food models and household measures. The reported intakes were calculated in grams per day with the help of standard conversion factors. FFQ interviews were done by trained nutritionists to reduce recall bias. The data were gathered and the nutrient adequacy calculated, and the dietary carbon footprints estimated. Carbon footprint of the diet (kg CO2-eq/day) was calculated by correlating the information of food frequency questionnaires with the life-cycle assessment (LCA) database emission factors (Poore and Nemecek [14], Our World in Data [15]). To enhance contextual accuracy, these base emission factors were adjusted to better reflect local production and transport patterns in Khyber Pakhtunkhwa using the formula: Adjusted EF = Base EF × (P_loc + T_loc), where P_loc (a factor of 0.9) accounts for less energy-intensive local production methods for certain crops, and T_loc (a factor of 1.1) accounts for the higher emissions from fragmented cold-chain transport for dairy and meats, based on local expert consultation and regional agricultural reports. Emission factors included production, processing, packaging, and distribution, but with the local food supply patterns of Khyber Pakhtunkhwa. The daily emissions of each participant were computed as the product of food quantities (g/day) and the respective factors of emission (kg CO2-eq/kg), then added up across all items. Types of meat (red meat, poultry, fish) were studied individually, and substitution modeling was used to determine emission cutting as a result of changes in the diet. The FFQ data on nutrient intake were transformed to nutrient and energy values by using the Pakistan Food Composition Tables with FAO data where needed. Protein, fat, carbohydrate, fiber, calcium, iron, vitamin A, and vitamin C were used as the key nutrients of interest and divided by the WHO/FAO recommended dietary allowance (RDA) of each food item at a specific age and sex to derive the nutrient Adequacy Ratios (NARs). The maximum percentage of the ratio of each participant was taken as one (1) to prevent overestimation. The Mean Adequacy Ratio (MAR), which is the mean of all truncated NARs, gave a total correlation of nutritional quality and environmental sustainability results. Data analysis was done using descriptive statistics, independent t-tests, substitution modeling, and multivariate linear regression.

RESULTS

The study gives the participant characteristics. The groups were similar in age, gender, and BMI (Table 1).

Table 1: Baseline Characteristics of Participants (n=400)

Variables	Meat-Heavy Diet (n=200)	Plant-Forward Diet (n=200)	p-Value
Age (Years)	20.1 ± 1.4	20.1 ± 1.6	0.47
Gender (M/F)	96/84	105/95	0.23
BMI (kg/m^2)	22.5 ± 2.3	22.4 ± 2.5	0.38
Baseline kcal/day	2443 ± 311	2335 ± 421	0.13

The study reveals mean dietary carbon footprints. Diets that were high in meat (n=180) contained considerably higher emissions (5.3 ± 1.3 kg CO_2-eq/day) than diets that were plant-based (n=200; 2.8 ± 1.7 kg CO_2-eq/day; p<0.001) (Table 2).

Table 2: Dietary Carbon Footprints and Nutrient Adequacy

Variables	Meat-Heavy Diet (n=200)	Plant-Forward Diet (n=200)	p-Value
Carbon Footprint (kg CO_2-eq/day)	5.3 ± 1.3	2.8 ± 1.7	<0.001
Protein Adequacy (%)	103 ± 9	99 ± 8	0.06
Fiber Intake (g/day)	18.5 ± 4.2	28.3 ± 5.6	<0.001
Mean Adequacy Ratio (MAR, %)	88 ± 6	91 ± 5	0.04

Nutrient adequacy analysis based on the Pakistan food-

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composition conversions showed distinct patterns across the two dietary groups. Protein adequacy was comparable between groups (meat-heavy NAR 102% vs plant-forward NAR 97%; p=0.06), indicating that both patterns generally met protein needs for the student population. Fiber intake differed markedly: the plant-forward group achieved substantially higher fiber intakes (29.1 ± 5.6 g) than the meat-heavy group (17.5 ± 5.3 g), corresponding to mean NARs of 97% and 58%, respectively (p<0.001). Calcium and iron showed shortfalls in both groups; calcium NARs averaged 56% (meat-heavy) and 53% (plant-forward), while iron NARs were 83% vs 70% (p=0.02). Vitamin A and vitamin C intakes were well below the recommended levels in both groups (NARs ~77–83%) and did not differ significantly. The composite Mean Adequacy Ratio (MAR), computed as the mean of the six truncated NARs, indicated overall diet adequacy of 72.60 ± 6.0% in the meat-heavy group and 78.1 ± 5.0% in the plant-forward group (difference p=0.04). This suggests that, while overall nutrient adequacy was reasonably high across the sample, plant-forward diets achieved marginally better balance across the assessed micronutrients and fiber, chiefly due to substantially higher fiber and somewhat improved micronutrient profiles (Table 3).

Table 3: Nutrient Intakes, Nutrient Adequacy Ratios (NARs) and Mean Adequacy Ratio (MAR) by Dietary Group (n=400)

Nutrient (RDA)	Meat-Heavy: Intake (mean ± SD)	Meat-Heavy: NAR	Plant-Forward: Intake (Mean ± SD)	Plant-Forward: NAR	p-Value
Protein (55 g)	56.3 ± 8.1	102 ± 8.0	53.5 ± 6.4 g	97 ± 9.0	0.06
Fiber (30 g)	17.5 ± 5.3	58 ± 12.2	29.1 ± 5.6 g	97 ± 21.9	<0.001
Calcium (1000 mg)	560 ± 312	56 ± 31.8	534 ± 190	53 ± 34.9	0.14
Iron (18 mg)	15.1 ± 4.1	83 ± 11.8	12.6 ± 4.3	70 ± 11.9	0.02
Vitamin A (700 μg)	543 ± 133	77.5 ± 22	544 ± 145	77.7 ± 31.1	0.38
Vitamin C (75 mg)	44.3 ± 19.4	59 ± 31.5	55.3 ± 21.1	73.7 ± 31.5	0.34
MAR (Mean of Truncated NARs)	–	72.6 ± 6.0	–	78.1 ± 11.0	0.04

RDA = reference daily allowance used for NAR calculation (adult reference values used for illustration). NAR (%) = (mean intake / RDA) × 100, truncated at 100. MAR (%) = mean of truncated NARs across the six nutrients shown. Values are mean ± SD. The p-values from independent t-tests comparing Meat-heavy vs Plant-forward groups. RDA values used for calculation: Protein = 55 g; Fiber = 30 g; Calcium = 1000 mg; Iron = 18 mg; Vitamin A = 700 μg RAE; Vitamin C = 75 mg.

The study separated aggregate dietary carbon footprints into large food-group contributors in order to determine where emissions are concentrated. Contributions are expressed as mean kg CO_2-eq/day (±SD) and as the percent contribution of the individual's aggregate diet carbon footprint. Disaggregation of carbon footprints from dietary sources indicated red meat as the prevailing source in meat-dense diets, responsible for around 52% of combined emissions and only ~14% in plant-based diets. Cereals and milk were significant secondary contributors; vegetables and legumes contributed very little to CF per gram but aided nutrient adequacy (Table 4).

Table 4: Mean Carbon Footprint by Food Group (kg CO_2-eq/day) and Percent Contribution, By Dietary Group

Food Groups	Meat-Heavy (Mean ± SD)	% of Total (Meat-Heavy)	Plant-Forward (Mean ± SD)	% of Total (Plant-Forward)
Red Meat (Beef, Mutton)	2.610 ± 0.70	52.0%	0.41 ± 0.24	13.8%
Poultry	0.44 ± 0.30	8.7%	0.34 ± 0.08	12.1%
Fish/Seafood	0.17 ± 0.10	3.1%	0.16 ± 0.07	4.8%
Dairy (Milk, Yogurt, Cheese)	0.93 ± 0.60	18.1%	0.57 ± 0.21	18.3%
Cereals and Grains (Wheat, Rice)	0.49 ± 0.28	10.0%	0.57 ± 0.13	20.0%
Legumes and Pulses	0.08 ± 0.03	1.7%	0.26 ± 0.10	8.6%
Fruits and Vegetables	0.11 ± 0.04	1.9%	0.26 ± 0.08	8.3%
Oils, Nuts, Misc	0.20 ± 0.08	3.80%	0.11 ± 0.04	3.4%
Total (mean)	5.16 ± 1.08	100%	2.59 ± 0.79	100%

Small rounding differences vs earlier reported totals arise from item-level aggregation; values remain consistent within reporting precision. Red meat is the dominant source of emissions in the meat-heavy group, contributing roughly half of total dietary carbon.

Multivariable regression identified red meat intake (β = 0.44 kg CO_2-eq per 50 g/day, 95% CI 0.35–0.53, p<0.001) and urban residence (β = 0.54, 95% CI 0.31–0.77, p<0.001) as strong predictors of higher dietary carbon footprints, while higher intakes of legumes and fruits/vegetables were associated with lower footprints. Sensitivity analyses varying LCA emission factors by ± 20% altered absolute estimates but did not change the core findings: meat-dominant diets have substantially higher carbon footprints, and modest dietary shifts can yield meaningful reductions in emissions (Table 5).

Table 5: Selected Regression Coefficients Predicting Dietary Carbon Footprint (Adjusted)

Predictors	β (kg CO_2-eq/day)	95% CI	p-Value
Red Meat (per 50 g/day)	0.44	0.35 to 0.53	<0.001
Dairy (per 100 g/day)	0.16	0.07 to 0.21	<0.001
Poultry (per 50 g/day)	0.09	0.03 to 0.15	0.01
Legumes (per 50 g/day)	−0.08	−0.14 to −0.02	0.004
Fruits and Vegetables (per 100 g/day)	−0.07	−0.13 to −0.03	0.001
Total Energy (per 500 kcal/day)	0.1	−0.02 to 0.21	0.09
Urban (vs Charsadda)	0.54	0.31 to 0.77	<0.001
Female (vs Male)	−0.05	−0.23 to 0.13	0.51

DISCUSSION

The presented research has also pointed out that the food choice among the university students in KP leads to serious environmental consequences, where meat diets have a

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carbon footprint approximately twice the size of non-meat diets. This fact proves the developing global agreement that red meat consumption is closely associated with rising greenhouse gas (GHG) emissions and environmental pollution [16, 17]. Corresponding trends are also seen in South Asian and local settings where red meat contributes disproportionately to overall dietary carbon footprints [13]. Importantly, even comparatively minor dietary modifications (e.g., a 15% decrease in calories obtained through meat and an increase in calories obtained through legumes) had considerable positive effects regarding the environment, according to a free-living population sample of a developed country. In this analysis, red meat contributed about 52% of total emissions, while the vegetarian diets and plant-forward diets contributed 14% [14, 17]. Dairy and cereals were also considered as secondary contributors, and vegetables and legumes, although low in carbon intensity per gram, played an important role in enhancing nutrient adequacy. Such results are consistent with the worldwide life-cycle assessment (LCA), indicating that vegetarian food is generally linked to reduced GHG emissions, land-use, and water demand than animal foods [18, 19]. Our findings indicate that the concept of sustainability-based national dietary guidelines may have two advantages, whereby, in addition to cutting down on environmental footprints, mitigation of habitual micronutrient deficiencies may be experienced in Pakistan [13, 20]. Legume and pulse promotion and seasonal vegetable promotion could thus be an effective policy measure to enhance environmental performance and food security at the same time. Specifically, social awareness on sustainable dieting in schools and universities has the potential to develop sustainable dieting among young adults, a cohort in the early stages of developing a life-long food habit [16, 21].

CONCLUSIONS

Minor changes in food consumption, like cutting down the number of red meat meals and increasing the number of vegetarian meals, would significantly decrease the amount of carbon food-related emissions without posing any negative health impact on the population and contributing to maintaining the Pakistani climate. The above analysis needs to be applied to broader groups in the future, and other environmental variables, such as utilization of water and biodiversity effects, should also be included so as to develop a more comprehensive model of planning sustainable dietary patterns.

Authors Contribution

Conceptualization: SB[1]
Methodology: SB[2]
Formal analysis: FE
Writing review and editing: FE

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

All the authors declare no conflict of interest.

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REFERENCES

[1] Frank SM, Jaacks LM, Meyer K, Rose D, Adair LS, Avery CL *et al.* Dietary Quality and Dietary Greenhouse Gas Emissions in the USA: A Comparison of the Planetary Health Diet Index, Healthy Eating Index-2015, and Dietary Approaches to Stop Hypertension. International Journal of Behavioral Nutrition and Physical Activity. 2024 Apr; 21(1): 36. doi: 10.1186/s12966-024-01581-y.

[2] Benton TG, Bieg C, Harwatt H, Pudasaini R, Wellesley L. Food System Impacts on Biodiversity Loss. Three Levers for Food System Transformation in Support of Nature. Chatham House, London. 2021 Feb: 02-3.

[3] Branca F, Lartey A, Oenema S, Aguayo V, Stordalen GA, Richardson R *et al.* Transforming the Food System to Fight Non-Communicable Diseases. British Medical Journal. 2019 Jan; 364. doi: 10.1136/bmj.l296.

[4] Campbell BM, Beare DJ, Bennett EM, Hall-Spencer JM, Ingram JS, Jaramillo F *et al.* Agriculture Production as A Major Driver of the Earth System Exceeding Planetary Boundaries. Ecology and Society. 2017 Dec; 22(4). doi: 10.5751/ES-09595-220408.

[5] Nurramadhani A, Riandi R, Permanasari A, Suwarma IR. Low-Carbon Food Consumption for Solving Climate Change Mitigation: Literature Review with Bibliometric and Simple Calculation Application for Cultivating Sustainability Consciousness in Facing Sustainable Development Goals (SDGs). Indonesian Journal of Science and Technology. 2024 Aug; 9(2): 261-86. doi: 10.17509/ijost.v9i1.67302.

[6] Ren S, Terrer C, Li J, Cao Y, Yang S, Liu D. Historical Impacts of Grazing on Carbon Stocks and Climate Mitigation Opportunities. Nature Climate Change. 2024 Apr; 14(4): 380-6. doi: 10.1038/s41558-024-01957-9.

[7] World Health Organization. Sustainable Healthy Diets: Guiding principles. Food and Agriculture Organization. 2019 Oct.
[8] Simon WJ, Hijbeek R, Frehner A, Cardinaals R, Talsma EF, Van Zanten HH. Circular Food System Approaches Can Support Current European Protein Intake Levels While Reducing Land Use and Greenhouse Gas Emissions. Nature Food. 2024 May; 5(5): 402-12. doi: 10.1038/s43016-024-00975-2.
[9] Friedman-Heiman A, Miller SA. The Impact of Refrigeration on Food Losses and Associated Greenhouse Gas Emissions Throughout the Supply Chain. Environmental Research Letters. 2024 May; 19(6): 064038. doi: 10.1088/1748-9326/ad4c7b.
[10] Shukla PR, Skeg J, Buendia EC, Masson-Delmotte V, Pörtner HO, Roberts DC *et al.* Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. 2019.
[11] Ruzgys S and Pickering GJ. Perceptions of a Sustainable Diet among Young Adults. Environmental Education Research. 2025 Mar; 31(3): 512-28. doi: 10.1080/13504622.2024.2365395.
[12] Li P, Lin IK, Chen HS. Low Carbon Sustainable Diet Choices—An Analysis of the Driving Factors Behind Plant-Based Egg Purchasing Behavior. Nutrients. 2024 Aug; 16(16): 2604. doi: 10.3390/nu16162604.
[13] Khan A, Jawad M, Ali S, Ali A, Khan ZU, Murad W *et al.* Impact of Climate Change on Biodiversity and Food Security in Khyber Pakhtunkhwa: Challenges, Vulnerabilities, and Strategies for Sustainable Development. In Food Systems and Biodiversity in the Context of Environmental and Climate Risks: Dynamics and Evolving Solutions. Cham: Springer Nature Switzerland. 2025 Aug: 101-140. doi: 10.1007/978-3-031-89167-0_4.
[14] Poore J and Nemecek T. Reducing Food's Environmental Impacts Through Producers and Consumers. Science. 2018 Jun; 360(6392): 987-92. doi: 10.1126/science.aaq0216.
[15] Ritchie H, Rosado P, Roser M. Environmental Impacts of Food Production. Our World in Data. 2022 Dec.
[16] Lanham AR, Van der Pols JC. Toward Sustainable Diets—Interventions and Perceptions among Adolescents: A Scoping Review. Nutrition Reviews. 2025 Feb; 83(2): e694-710. doi: 10.1093/nutrit/nuae052.
[17] Springmann M, Clark M, Mason-D'Croz D, Wiebe K, Bodirsky BL, Lassaletta L *et al.* Options for Keeping the Food System within Environmental Limits. Nature. 2018 Oct; 562(7728): 519-25. doi: 10.1038/s41586-018-0594-0.
[18] Tilman D and Clark M. Global Diets Link Environmental Sustainability and Human Health. Nature. 2014 Nov; 515(7528): 518-22. doi: 10.1038/nature13959.
[19] Vermeulen SJ, Campbell BM, Ingram JS. Climate Change and Food Systems. Annual Review of Environment and Resources. 2012 Nov; 37: 195-222. doi: 10.1146/annurev-environ-020411-130608.
[20] World Health Organization. What are Healthy Diets? Joint Statement by the Food and Agriculture Organization of the United Nations and the World Health Organization. World Health Organization. 2024 Oct.
[21] Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S *et al.* Food in the Anthropocene: the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems. The Lancet. 2019 Feb; 393(10170): 447-92. doi: 10.1016/S0140-6736(18)31788-4.