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RESEARCH ARTICLE

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Are Peruvians moving toward healthier diets with lower environmental burden?

Household consumption trends for the period 2008–2021

Joan Sanchez-Matos | Ian Vázquez-Rowe | Ramzy Kahhat

Peruvian LCA & Industrial Ecology Network (PELCAN), Department of Engineering, Pontificia Universidad Católica del Perú, Lima, Peru

Correspondence
Joan Sanchez-Matos, Peruvian LCA & Industrial Ecology Network (PELCAN), Department of Engineering, Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel 15088, Lima, Peru.
Email: sanchez.joan@pucp.edu.pe

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Abstract

Peru is one of the most diverse countries in the world in terms of food production, but also suffers a wide range of food security challenges, including malnutrition, the impact of natural hazards, and rising food prices. People living in poverty conditions are the main victims of these problems, which trigger undernutrition, obesity, and diet-related non-transmittable diseases. Despite these challenges, Peru lacks historical food intake data. Therefore, in the current study, we assess the diet quality evolution in the period 2008–2021 based on apparent household purchases extracted from the National Household Survey. The results reveal significant variations in the consumption of certain food items and groups, and the consequences of these changes are discussed in environmental and human health terms. The consumption of lower environmental impact animal protein, such as chicken, eggs, and marine fish, has increased by 37%, 69%, and 29%, respectively; whereas the consumption of high environmental impact foods, such as beef and other red meat, has decreased. Moreover, consumption of less processed carbohydrate sources (e.g., legumes, fruits, and vegetables) has risen, while refined sugar and sugar-sweetened beverages have decreased significantly (almost 45%). Regional differences were also visible; hence, cities on the Northern coast and the Amazon basin had similar consumption habits, whereas Central/Southern coastal and Andean cities had closer consumption patterns. On average, this improvement was reflected in the increase in calories (9.9%) and macronutrient intake (up to 15%), but at the socioeconomic level, food inequality persists, with consumption of many food groups below minimum thresholds in lower socioeconomic strata. This article met the requirements for a gold/gold *JIE* data openness badge described at http://jie.click/badges.

KEYWORDS
diet quality, energy intake, industrial ecology, Latin America, nutrients, Peru

1 INTRODUCTION

Poor diets are responsible for a wide range of health complications, including obesity, diabetes, and cancers (Liu et al., 2020). Recurrent unhealthy food intake is associated with limited life expectancies and increased morbidity (Willett et al., 2019). In Latin America, adult and childhood obesity has increased since the 1980s (Popkin & Reardon, 2018). According to Popkin and Reardon (2018), Latin America is the second low-income and middle-income region with the highest levels of obesity in the world, after the Middle East and North Africa. Some of the main problems identified in Latin American nations are linked to the increased and excessive consumption of added-sugar and salt products (Fisberg et al., 2021), refined carbohydrates, or savory snacks (Matos et al., 2021), whereas the consumption of fruits (Vázquez-Rowe et al., 2017), nuts, and especially vegetables remains low (Kovalskys et al., 2019). Legumes, which were once staples in the region, now represent a very low proportion of daily food intake (Leterme & Carmenza Muñoz, 2002). However, despite the aforementioned general trends at the Latin American level, marked differences have been well documented at a subnational level (Kovalskys et al., 2019).

In Peru, according to the Peruvian Institute of Statistics (INEI), only 10.5% of the population fulfilled its daily intake of fruits and vegetables in 2021 (INEI, 2022a). Similarly, food insecurity has risen considerably, from 37.2% of the national population exposed to moderate or severe food insecurity in 2014–2016 to 50.5% in the period 2019–2021, and obesity in adults has increased from 18.1% in 2012 to 19.7% in 2016 (FAO, 2022). In contrast, additional data also show a brighter side toward healthy diets in Peru (FAO, 2022). More specifically, the amount of people who cannot afford a healthy diet has decreased from 23.7% in 2017 to 20.5% in 2020. Similarly, undernourishment has gone down sharply from 18.8% in 2004–2006 to 8.3% in 2019–2021. Despite the dietary flaws that remain in national diets, profound changes have been linked to agri-food systems in the country since the early 1990s. One such change has been the still ongoing agro-exports boom, initiated in the mid-90s (Williams & Murray, 2019), through which Peru has become a worldwide agricultural hub for products like green asparagus, blueberry, avocado, or table grapes (Esteve-Llorens et al., 2022), but has also experienced new environmental challenges, especially along the hyper-arid coast (Damonte & Boelens, 2019).

Most studies conducted in Peru to date have focused on child and adolescent food intake and/or insecurity (Pradeilles et al., 2022; Westgard et al., 2021), vulnerable groups (Ramirez-Hernandez et al., 2020), or environmental metrics related to food intake (Larrea-Gallegos & Vázquez-Rowe, 2020; Vázquez-Rowe et al., 2017), but fewer studies, as far as we were able to ascertain, have performed a national analysis on food consumption trends. The main data that have been collected and published regarding food intake are linked to the Latin American Study of Nutrition and Health (ELANS, using its acronym in Spanish), in which a comparative study of urban population food intake was performed for a set of Latin American nations, including Peru (Gómez et al., 2019; Kovalskys et al., 2018).

In parallel, the INEI has annually carried out, since 1995, the National Household Survey (ENAHO, using its acronym in Spanish) to monitor indicators of living conditions in Peruvian urban and rural areas (INEI, 2022b). ENAHO provides statistical, demographic, social, and economic information from households in the 24 regions of Peru (INEI, 2022c) and allows an understanding of the evolution of monetary poverty throughout the country (PNDA, 2022).

Therefore, the main goal of this study was to comprehensively analyze the evolution in diet quality in Peru in the period 2008–2021 based on apparent household purchases extracted from the ENAHO. Furthermore, this study identified patterns in the temporal and spatial variability of food consumption, differences in consumption based on poverty levels, and gaps in achieving consumption levels of macronutrients and calories recommended by international nutritional authorities. Our main hypothesis is that a set of converging situations in Peru, including economic growth, the progressive and steady reduction of poverty levels, the expansion of the gastronomic sector, and a growing consciousness regarding healthy and sustainable diets has led to an improvement in mean dietary habits and patterns. The novelty of the study is related to the fact that this is the first study that provides an extensive assessment of changes in diet patterns in Peru over a significant timeframe.

2 MATERIALS AND METHODS

2.1 Data collection and processing

ENAHO is carried out nationally on a quarterly basis to track well-being conditions in Peru, poverty, and food consumption patterns and provide relevant data for public and private institutions (PNDA, 2022). The type of sample considered in ENAHO is probabilistic and stratified, with 95% confidence (PNDA, 2022). The survey is carried out through face-to-face interviews every year by INEI, except for 2020 and 2021, which were carried out both by telephone and in person, due to COVID-19-related restrictions. The results are presented as a national average, for each of the main 26 Peruvian cities (see Figure S1 in the Supporting Information S1) and level of poverty. In terms of cities, the capital city of each region was considered, as well as Chimbote and Tarapoto. The data and results for Lima include the 42 districts of the province of Lima.

2.1.1 | Food consumption data collection

The raw data were collected from module 601 "food and drink expenditures" of the database (INEI, 2023). It contains food and beverage expenditures in annualized monetary and mass values, since 2004. Data on household consumption from 2008 to 2021 were considered to compare the results reported for the 2008–2009 period (Vázquez-Rowe et al., 2017) with those in the current study and identify trends in the last 14 years.

Module 601 of the ENAHO survey is composed of five questions, which are asked to the head of the household or the housewife/househusband, as follows:

1. In the last 15 days, have you and/or any member of this household obtained, consumed, purchased, or received any of the following products?
2. How did you obtain the product?
3. How often did you purchase the product, what was the amount purchased, and where did you purchase it in that period?
4. How much was the total amount of the purchase?
5. How often did you get the product and what was the amount consumed during that period?

With the responses to these questions, the types of products, frequency, and amount consumed by households are obtained. Thereafter, ENAHO estimates and discloses the yearly values of food and beverages consumed per household and per capita. Hence, consumption data from 93 food and beverage products were gathered (Table 1), considering the main products consumed by Peruvian citizens reported by INEI (2012a) and adding products with important participation in current Peruvian diets. Sample sizes for each year analyzed are presented in Table S1 of the Supporting Information S1.

2.1.2 | Macronutrient and energy consumption estimation

Macronutrients (i.e., carbohydrates, fats, and proteins) and caloric intake were estimated based on Equations (1) and (2):

$$\mathrm{MI} = \sum_{i=1}^{n} \mathrm{FC}_i * \mathrm{MC}_i, \tag{1}$$

$$\mathrm{CI} = \sum_{i=1}^{n} \mathrm{FC}_i * \mathrm{CC}_i, \tag{2}$$

where MI and CI are macronutrient (g/kg or g/L) and caloric intake, respectively. The daily per capita food consumption (FC, kg/person/day or L/person/day) of a given food or beverage was calculated based on ENAHO (PNDA, 2022). Macronutrients (MC, g/kg or g/L) and caloric content (CC, g/kg or g/L) of food and beverages were collected from the Peruvian tables of food composition (INS, 2017). Given the wide variety of types or species per product considered and to simplify the analysis, a representative product item was selected for each food and beverage product, based on data availability (see Table S2 in the Supporting Information S1).

2.1.3 | Determination of monetary poverty levels

The monetary poverty level is declared by ENAHO for each household each year. These values divide households into three categories: no poverty, poverty, and extreme poverty. The level of monetary poverty is estimated accordingly (INEI, 2012b). This method assumes that expenditures are a well-being indicator; therefore, it establishes a "poverty line" (Feres & León, 1990), which is the price of the basic basket (BB) composed of food and non-food components. According to INEI (2022d), the non-food component is made up of the value of the basket of goods and services that a person requires to satisfy their needs related to clothing, footwear, housing rental, fuel use, furniture, household goods, health care, and transportation, among others. The food component (i.e., the basic food basket—BFB) is made up of the 110 most consumed products obtained from the ENAHO survey carried out in 2010. For example, the BB total value in 2021 was 378 Peruvian soles (PEN), and the BFB added up to 201 PEN. Thus, households with monthly per capita expenditures higher than the price of the BB are classified as nonpoor, while households with lower monthly per

TABLE 1 List of main products consumed by Peruvian citizens considered in the present study.

Category	Food and beverages
Cereals	Rice, maize, wheat, oat, barley, rye, and other cereals[a]
Flours	Wheat flour, legume flour, tuber flour, and other cereals flour[b]
Bakery	Bread, cookies, and cakes
Pasta	Dried noodles
Meats	Lamb, pork, beef, poultry, hen, chicken, wild animal meat, ham, poultry offal, other meats,[c] and other offal[d]
Fish and seafood	Freshwater fish (fresh), freshwater fish (dried), marine fish (fresh), marine fish (dried), other fresh fish,[e] other dried fish,[f] canned fish, and seafood[g]
Dairy products	Evaporated milk, fresh milk, milk powder, other milk,[h] yogurt, and fresh cheese
Eggs	Poultry eggs and fish eggs
Fats	Vegetable oil, margarine, and butter
Fruits	Blueberries, peach, strawberry, lime, mandarin orange, orange, mango, apple, avocado, papaya, banana, watermelon, and grapes
Vegetables	Celery, garlic, onion, Italian pumpkin, cabbage, asparagus, Peruvian corn grain, lettuce, tomato, carrots, pumpkin, algae, and pepper
Legumes	Beans, peas, fava beans, peanuts, lima beans, soya beans, lentils, and chickpeas
Tubers	Sweet potato, potato, cassava, *olluco*,[i] *chuño*,[j] and other tubers
Sugar	Refined sugar
Condiments	Peppers
Beverages	Soda, mineral water, and soy milk
Minerals	Salt
Other	Coffee and tea

[a]This includes quinoa (*Chenopodium quinoa*), cañigua (*Chenopodium pallidicaule*), and other cereals.
[b]This includes flour of barley, kiwicha (*Amaranthus caudatus*), corn, quinoa, seven seeds, cooked corn meal, and other cereals.
[c]This includes fresh and dried meat of llama, alpaca, goat, rabbit, guinea pig, deer, and other meats.
[d]This includes offal of cattle, pork, sheep, llama, alpaca, goat, rabbit, guinea pig, deer, and other.
[e]This includes non-identified fresh fish.
[f]This includes non-identified dried fish.
[g]This includes cephalopods, crustaceans, and bivalves.
[h]This includes malted and chocolate milk.
[i]*Olluco* is a species of Andean tuber (*Ullucus tuberosus*).
[j]*Chuño* is a freeze-dried potato traditionally consumed by Andean populations.

capita expenditures are considered poor. Furthermore, when the value of a household's per capita expenditure is less than the BFB, it is considered extremely poor (see Figure S2 in the Supporting Information S1).

2.1.4 | Data analysis

Measures of central tendency from the data were calculated using Pandas Python's library (Mckinney, 2012). To extrapolate the results from the sample to the entire Peruvian population, expansion factors provided by INEI (2023) for each household and year were considered. Moreover, to identify similar consumption patterns between cities, Ward's hierarchical clustering analysis method (Ward, 1963) was performed using SciPy Python's library (Virtanen et al., 2020). The analyses aforementioned were carried out with the open-source computational interface Jupyter notebook (Jupyter Team, 2015). Statistical data for each food item, including standard deviation, median, or quintiles are available in Table SM1 of the Supporting Information S2. Furthermore, different maps were constructed using QGIS 3.22.10 (QGIS Development Team, 2023) to visualize the spatial distribution of food consumption patterns throughout Peruvian cities.

2.2 | Limitations of the study

The main limitations of the study are related to the inability to delve into food-away-from-home (FAFH) and food loss and waste (FLW), which are not included in the survey. While the amount of monetary expenditure in households linked to FAFH is known, it lacks a level of detail that allows determining the actual food items purchased by Peruvians in restaurants or canteens. Vázquez-Rowe et al. (2017) made an estimation of the importance of FAFH on the food basket in Peru, determining that approximately 15% of greenhouse gas (GHG) emissions linked to food intake were related to FAFH. However, regional variabilities were identified between cities and socioeconomic groups. Moreover, it is plausible to assume that draconian measures in Peru in response to the pandemic, which implied that restaurants were completely shut for nearly 2 months after the lockdown and were then exposed to important capacity limitations indoors, are influencing the food values reported in this study for years 2020 and 2021. In terms of FLW, previous studies suggest that annual organic waste in Peruvian households could be as high as 29 kg/person/year (Vázquez-Rowe et al., 2021), implying that a certain proportion of purchased food items are not directly consumed (FLW in post-consumer phase) by dwellers in the households surveyed, which could influence the real macronutrient and caloric intake. Furthermore, FLW generated in the pre-consumer phase could have implications for environmental burdens, as previously reported by Vázquez-Rowe et al. (2017, 2021).

An important limitation is linked to the high number of outliers that were identified when analyzing some of the most common products in the food basket. Products such as rice, chicken, or potatoes showed a higher number of outliers that could lead to interpreting these values as misreporting by interviewees or poor codification by surveyors. However, it should be noted that Peru has a highly informal economy, with >80% of the workforce developing some sort of informal job (Ñopo, 2023). Hence, it is common, as in other countries in the Global South (Hansen et al., 2014), for households to run informal vending of food, either directly in the household, through street food sales, or delivery services (the latter gained popularity during the pandemic) (Tirado-Kulieva et al., 2022), accounting for much higher food purchase rates than those consumed by family members or wasted due to regular food waste behaviors.

3 | RESULTS AND DISCUSSION

3.1 | Purchase trends of sources of carbohydrates

Results reveal an increasing trend in some of the most consumed sources of carbohydrates (e.g., dried noodles or wheat flour) in the period assessed (see Figure 1). Cereals represent the group with the highest level of per capita consumption, led by rice, which ranged from 42.8 to 43.3 kg per year, with a slight rise toward 45.7 kg in 2020, probably linked to higher household consumption due to the pandemic restrictions. Increases in oat (from 3.2 to 4.8 kg/year) and maize (from 9.2 to 9.8 kg/year) consumption were also observed between 2008 and 2021.

Tubers also constitute an important alternative for carbohydrate intake. This group, represented mainly by potatoes, has shown a steady increase in consumption, from 63.7 to 68.6 kg/year. Other Andean tubers, such as sweet potato (from 4.6 to 8.4 kg/year), *olluco* (from 2.2 to 3.5 kg/year), and *chuño* (from 2.0 to 2.8 kg/year), also showed significant increases in the period analyzed. In this regard, high tuber consumption in Peru is widely documented, especially in Andean areas, where they provide important support for food security (de Haan et al., 2019). Tubers constitute an ancestral source of energy, proteins, minerals, vitamins, antioxidants, and other bioactive components (Leidi et al., 2018). However, it is consumed more in rural than urban areas, due to tuber prices (i.e., potatoes) being higher than that of cereals (e.g., rice) in urban areas, while rural consumers are self-sufficient (Rose et al., 2009). This rural–urban dichotomy also explains the high participation of rice in the carbohydrate supply in urban Peruvian diets.

Legume consumption, which has numerous health benefits (Miller et al., 2017) thanks to its provision of protein intake, fibers, and essential oils (Polak et al., 2015), has shown steady declines in consumption throughout Latin America in the 20th century (Bermudez & Tucker, 2003). However, legume intake in Latin America is still highest in emerging and developing regions of the world (Semba et al., 2021), although Peru's average consumption is within the lower range within the region (Kovalskys et al., 2019). The decreasing tendency seems to have inverted timidly in Peru in the period assessed. For instance, consumption of peas increased from 4.3 to 6.0 kg/person/year, whereas lentils showed increases from 2.8 kg to 4.3 kg/person/year. However, other legumes seem to have no noticeable changes (e.g., beans, soybean, etc.). Anyhow, total legume consumption has increased by approximately 26% (Fig. S3 in Supporting Information S1), from an average value of 39 g/person/day in the period 2008–2010 to 49 g/person/day in the period 2018–2021 (excluding the year 2020). Nevertheless, nonpoor households showed an increase in their consumption (+115%) to 56.0 g/person/day in 2021 compared with 26.6 g/person/day in 2008, while poor and extremely poor Peruvians consumed less legumes in 2021 compared with 2008. More specifically, people in poverty consumed 34.3 g/day in 2021, 5.5% less than in 2008, whereas legume consumption by extremely poor people was 21.4 g/day in 2021, 20% lower than in 2008 (Figure S4 in Supporting Information S1).

More processed wheat-based carbohydrate sources were consumed in 2021 than in 2008. Dried noodles, for instance, showed increased consumption from 10.6 to 13.3 kg/person/day, and wheat flour from 0.3 to 0.5 kg/person/day. Conversely, bread consumption has dwindled in the timeframe assessed.

Sugar-sweetened beverages (SSBs) and refined sugar are two important food items that are acquired in households. In both cases, the amount consumed per capita has decreased, significantly in the case of ready-to-drink SSBs (approximately 45% from 15.0 to 8.2 L/year in the period 2008–2021), and steadily in the case of sugar (<10%). However, as shown in Table SM4 in Supporting Information S2, the reduction in ready-to-drink SSB consumption is almost entirely due to sharp reductions in nonpoor households (over 50%) and, to a lesser extent, in poor households (approx. 45%), whereas changes in these drinks are minimal in extremely poor dwellings. Although taxation of SSB drinks and warning labels were

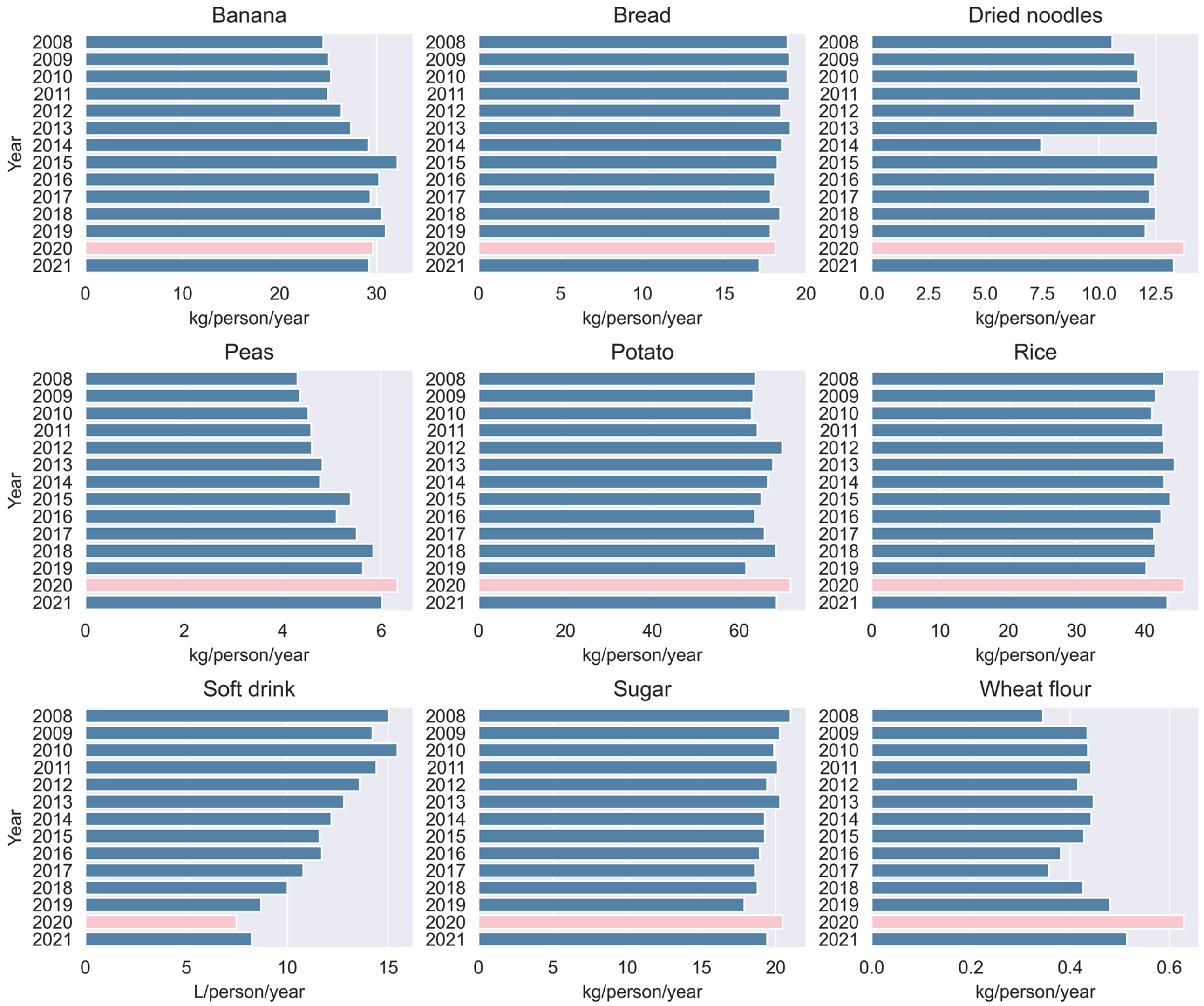

FIGURE 1 Trends in per capita consumption of the main sources of carbohydrates in Peru in the period 2008–2021. The pink bar indicates the year of the pandemic (2020). Underlying data for this figure are available in Table SM2 of Supporting Information S2.

implemented in 2018 (MEF, 2019, 2018), reductions in consumption appear steady throughout the period assessed (Lowery et al., 2022). Hence, with the data available, we were not able to correlate these policies with the reductions observed, but we should not rule out that they have had an effect in further reducing their consumption. On another note, a study by Guzman-Vilca et al. (2022) highlighted that Peruvian households consume twofold more homemade SSBs (e.g., *chicha* or *emoliente*) than ready-to-drink SSBs, which may indicate that reductions in soda consumption are far lower than apparent from the ENAHO data. Access to safe drinking water may also be influencing the amount of homemade and ready-to-drink SSBs across different groups (Al-Kassab-Córdova et al., 2023). Similar trends can be observed in other Latin American countries. For instance, Kovalskys et al. (2020) identified that lower socioeconomic groups in Argentina consume more SSBs and bakery products. In parallel, in Colombia, on average, SSB consumption seems to have dwindled in recent years (Herrán et al., 2020).

Considering the glycemic index (GI) as an indicator of carbohydrate quality (Wibawa et al., 2023), which represents the potential of a carbohydrate food to increase blood glucose (Kaur et al., 2016), the consumption behavior seems to show an increase in the best quality carbohydrate sources and a decrease in the lowest quality ones. For instance, raw sugar, bread, and SSBs, which have the highest level of GI (>70) (Wibawa et al., 2023), were consumed less in 2021 as compared to 2008. In parallel, fruits, vegetables, and legumes, usually linked to low values in GI, showed increases in the same period (see Fig. S3 in Supporting Information S1). However, other sources of carbohydrates (i.e., rice and potatoes), with a high GI (Kaur et al., 2016; Sagili et al., 2022), remain almost unchanged in Peruvian diets. In general terms, this trend appears to be positive in nutritional and health terms due to the relation between sugar and ultra-processed foods with the prevalence of obesity, type 2 diabetes (Veit et al., 2022), and caries (Giacaman, 2018).

Downscaling the analysis, Peru shows different carbohydrate consumption patterns across its main cities (see Figure 2). First, the high contribution of cereals, especially rice, to the average carbohydrate intake considering the main sources (e.g., bakery products, fruits, cereals, flours,

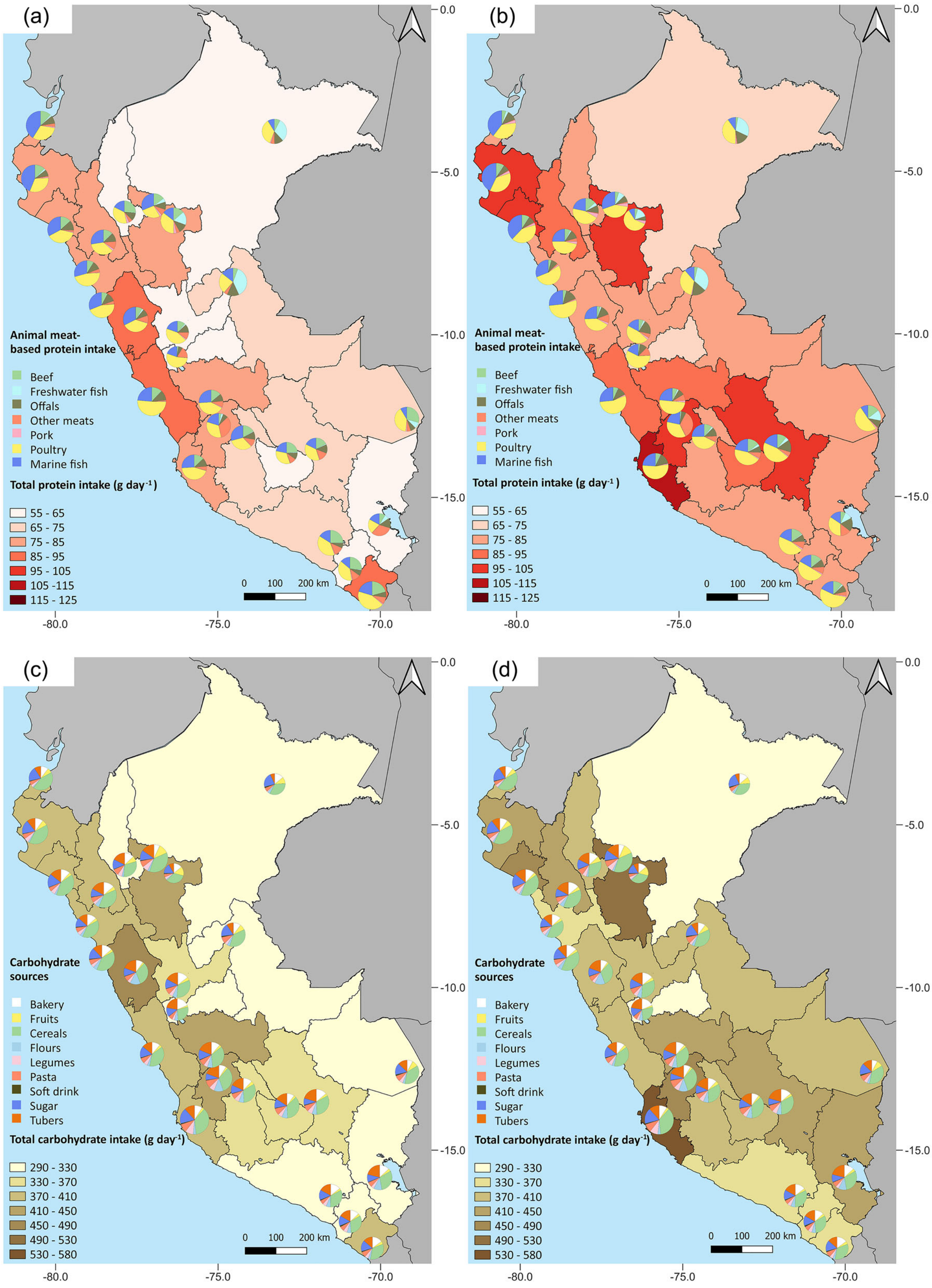

FIGURE 2 Spatial and temporal variability of the per capita consumption of main carbohydrate and protein sources by Peruvian citizens, where (a) represents the trends in protein consumption in the year 2008, (b) represents the trends in protein consumption in the year 2021, (c) represents the trends in carbohydrate consumption in the year 2008, and (d) represents the trends in carbohydrate consumption in the year 2021. The red gradient color for departments (a and b maps) represents the animal meat-based protein (AMBP) consumption in its capital city. The brown gradient color for departments (c and d maps) represents the total carbohydrate consumption in its capital city.

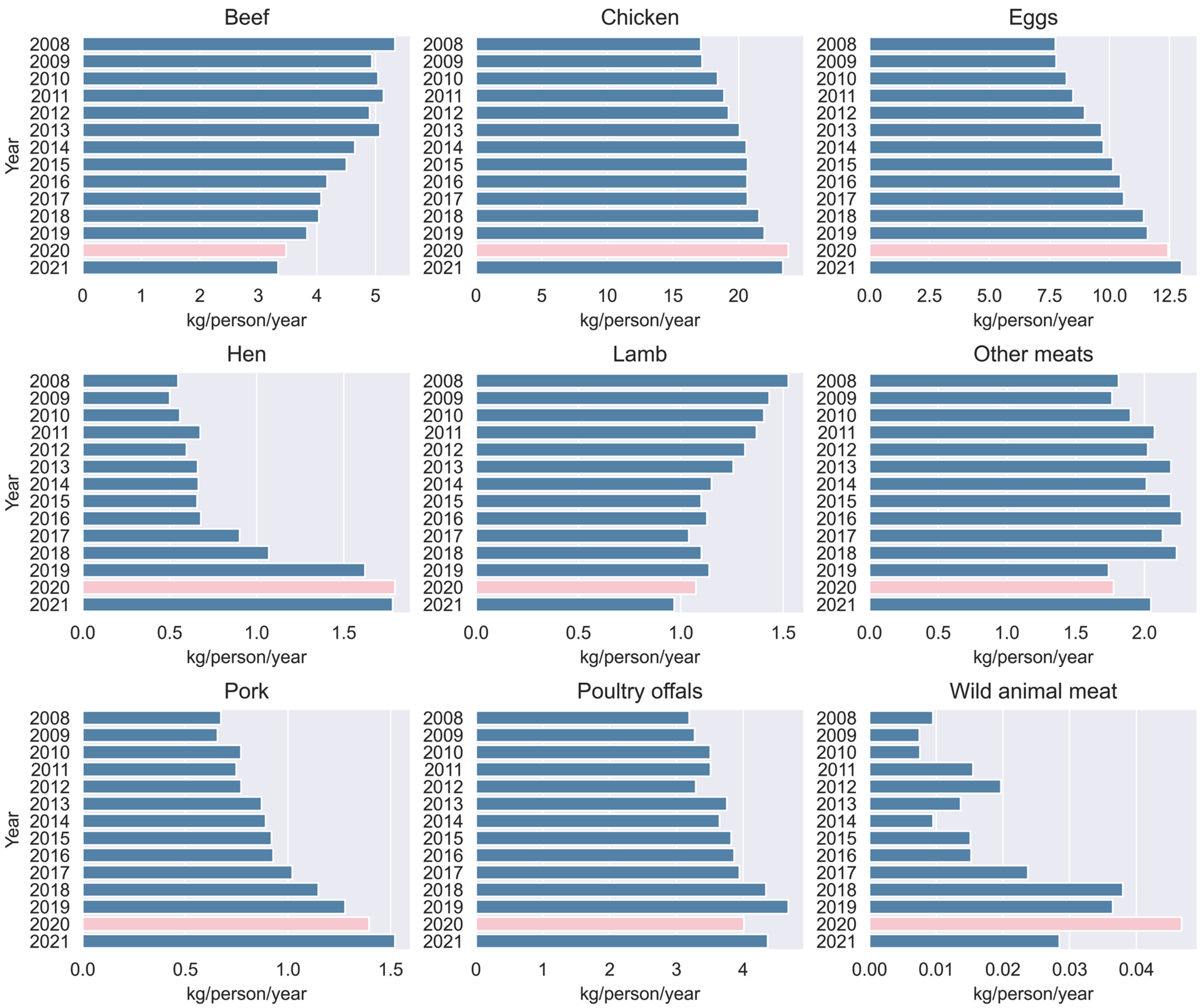

FIGURE 3 Trends in per capita consumption of the main animal-based protein sources in Peru in the period 2008–2021. The pink bar indicates the year of the pandemic (2020). Underlying data for this figure are available in Table SM2 of Supporting Information S2.

legumes, soft drinks, refined sugar, and tubers) is evident throughout the country. More specifically, in 2021, cereal contribution ranged from 28% to 44% of the carbohydrate intake, with the city Ica showing the highest consumption (187 g/person/day), whereas Tarapoto showed the lowest amount (79.3 g/person/day). Second, two main carbohydrate sources seem to be important in visualizing regional consumption habits. On the one hand, tubers, mainly potatoes, contribute widely to carbohydrate intake in Andean cities, ranging between 16% and 22%. For instance, Huancavelica presented the highest consumption of tuber-based carbohydrates (82.5 g/person/day), whereas the contribution of this carbohydrate source was lowest in Iquitos (18.6 g/person/day) in 2021. On the other hand, fruits contributed to a range of 7% to 15% of the carbohydrate intake in Amazon cities and Northern coastal cities, mainly due to banana consumption, while in the remaining cities, on average, the percentage of fruit-based carbohydrates ranged from 2% to 5%. Unlike the Andean region, in the Amazon, bananas fulfill an important part of the carbohydrate supply, mainly due to the strong indigenous population influence on the eating habits of this region, who have bananas and cassava as their main sources of energy (Ohashi, 2023). Bananas are mainly consumed as a side dish, and depending on their preparation (cooked, smoked, or fried), they contribute significantly to achieving the minimum required calories (Molina Recio et al., 2016).

3.2 Animal protein and dwindling beef consumption

Despite the general tendency of increased purchase of the main products in the food basket, a remarkable outlier is beef consumption, which has decreased from 5.3 kg per capita in 2008 to 3.3 kg in 2021 (Figure 3), a reduction of approximately 38% that has been relatively steady and constant

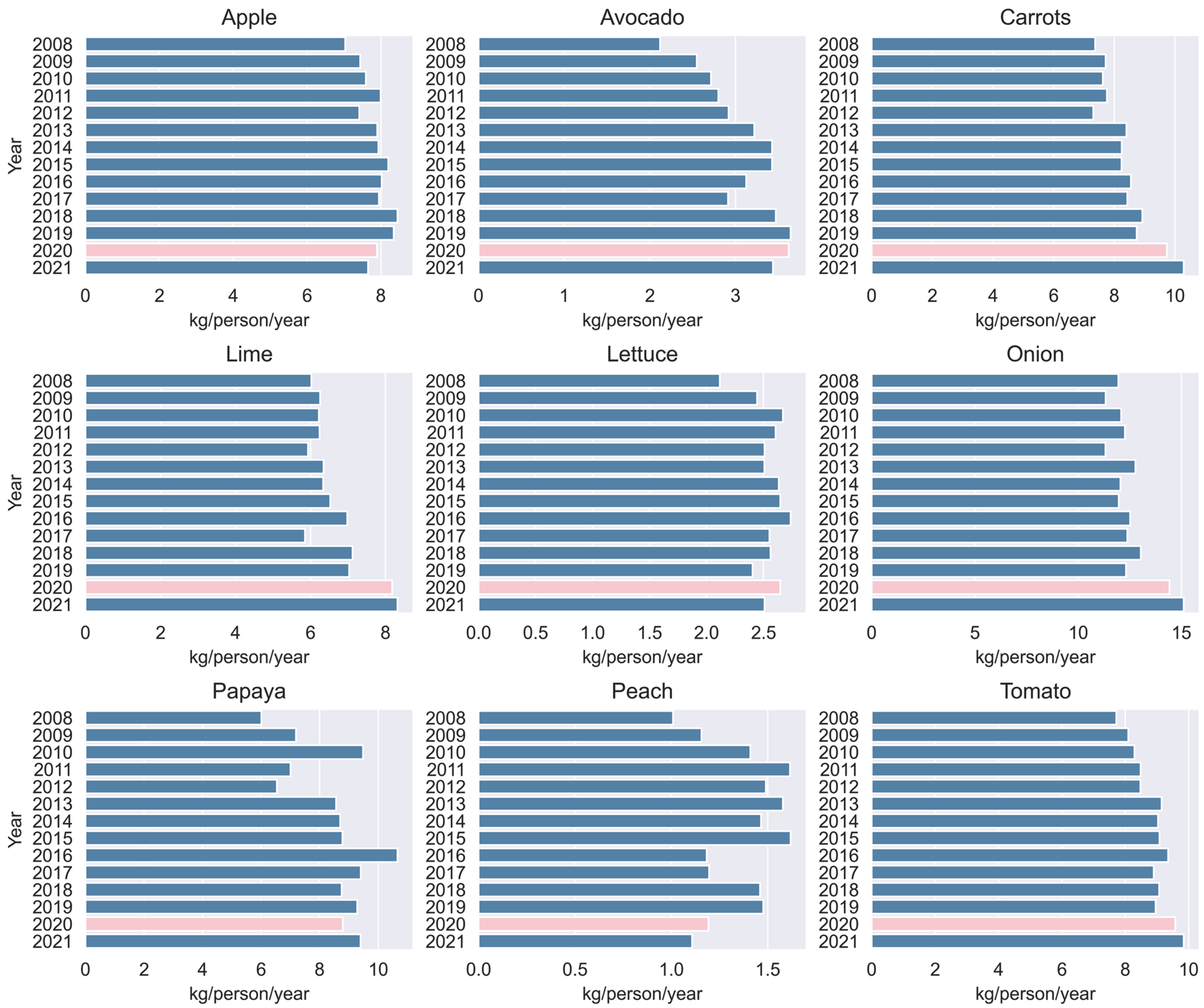

FIGURE 4 Trends on per capita consumption of main fruits and vegetables in Peru, 2008–2021. The pink bar indicates the year of the pandemic (2020). Underlying data for this figure are available in Table SM2 of Supporting Information S2.

throughout the entire period. This reduction has occurred across all socioeconomic groups and in most cities, including those in the Andes, in which beef consumption is highest (e.g., Cusco or Arequipa). At much lower consumption rates, lamb has also experienced a similar decline, from 1.5 to 1 kg per capita in the period assessed. Furthermore, dairy products also experienced decreasing per capita consumption. Hence, all types of milk (evaporated, powder, fresh, and other) and yogurt were less consumed in 2021 than 2008. All these products have shown a steady reduction ranging from 15% to 20% in the period assessed. However, per capita consumption of fresh cheese increased from 2.6 to 3.3 kg in the period studied.

In contrast, most animal meat consumption has increased in the period analyzed (Figure 4). For instance, chicken consumption has risen from 17.1 kg per capita in 2008 to over 23.4 kg in 2021. This increase is more evident in households in extreme poverty, where the increase has been fourfold, from 0.9 kg per capita in 2008 to 4.7 kg in 2021. Egg consumption shows a similar trend, increasing from 7.7 to 13.0 kg. Other animal meat, such as pork, poultry offal, and, to a lesser extent, wild animal meat and meats defined as “other,” which are consumed mainly in Amazon and Andean cities, have also shown slight increases. According to Herrán et al. (2020), similar trends have been documented in Colombia, where adults and children showed a decreasing trend in red meat and milk consumption, combined with slight increases in poultry consumption. However, the substitution of animal meat-based protein (AMBP) sources was not equivalent in terms of protein intake. In contrast, Argentinians showed no significant differences in red meat consumption between different socioeconomic groups (Kovalskys et al., 2020).

The increase in consumer preference for chicken as the main source of protein is a consequence of economic trends, political strategies, technology development, and social behaviors in the past 50 years. Some of the main triggering factors for the growth of chicken production and consumption in Peru include the policies adopted in the 1970s to restrict the sales of imported beef (Llaque-Ramos, 2009), the intensification and concentration of the chicken industry, the strategic location of production centers in arid and semi-arid areas with favorable climatic conditions for the broiler industry (Shimizu & Scott, 2014), the avoidance of major avian disease outbreaks and improved genetics of imported chicks (Scott & Vigo, 2023), the gastronomic and economic boom beginning in the late 1990s (Morales & Cordova, 2019), and the increase in restaurants exclusively selling roasted chicken (i.e., *pollerías*) (Scott & Zelada, 2011).

Increasing poultry and egg consumption has some interesting nutritional and environmental benefits, but also shortcomings. On the one hand, they are considered a healthier option to source protein and micronutrients than red meats (Scherer et al., 2019), as their link to increased cardiovascular diseases and all-cause mortality (Zhong et al., 2020) is lower. In parallel, GHG emissions from beef-based protein can be up to 10-fold higher than those from poultry- and egg-based proteins (Poore & Nemecek, 2018), and water use can be up to 3-fold as compared to chicken production (Mekonnen & Gerbens-Leenes, 2020). Based on the food consumption data from 2008–2009 period, Vázquez-Rowe et al. (2017) estimated that red meat represents 39% of total GHG emissions from the Peruvian diet, despite having a low contribution to total protein intake (Figure 2a). In this regard, previous studies have revealed that shifting dietary choices from red meat to poultry and eggs can reduce up to 50% of total dietary GHG emissions (Gaillac & Marbach, 2021). On the other hand, however, the intensification of poultry production in broilers has been related to antibiotic resistance (Yang et al., 2019), residual antibiotics intake (Ma et al., 2022), particulate matter formation (Gržinić et al., 2023), and the release of endocrine-disrupting compounds (Powers & Angel, 2008), amongst others.

Increased chicken consumption may be substituting other types of animal protein, such as freshwater fish in the Peruvian Amazon, limiting the intake of iron and essential fatty acids and increasing the carbon footprint of Amazon diets (Heilpern et al., 2021). However, when analyzing the data from Amazon cities, decreasing freshwater fish consumption was not identified, so the substitution of fish by chicken does not seem to be occurring. However, the region has experienced an important decrease in wild freshwater fish landings, while aquaculture production in the last decade has augmented significantly (PRODUCE, 2021). This could imply increasing freshwater fish supply from aquaculture and, consequently, lower concentrations of polyunsaturated fatty acids (Heilpern et al., 2021). Although this scenario poses nutritional problems, it could be positive in terms of food safety, due to lower risks of toxic metal ingestion (e.g., mercury) through the consumption of contaminated wild freshwater fish in Amazonian rivers (Feingold et al., 2020; Ferreira da Silva & de Oliveira Lima, 2020).

Peru shows heterogeneous consumption patterns not only due to the diversity of food accessibility linked with its different biomes but also poverty and development in each city. This is reflected in the amount of total protein consumed, despite the increase in protein consumption experienced throughout the entire Peruvian territory and across socioeconomic strata. For instance, cities with lower human development index—HDI (INEI, 2022d)—recurrently consume lower levels of protein (e.g., Pasco, Iquitos, Puno, and Huánuco) during the period evaluated, whereas industrial and agricultural hubs, such as Piura, Chiclayo, Ica, or Cusco, showed the highest protein intake (Seminario et al., 2020), with notable increases in the period evaluated (see Figure S9 in the Supporting Information S1).

AMBP is a fundamental protein source in Peru, providing 31%–51% of the total protein intake in 2021, a slightly different distribution to that in 2008 (30%–48%). Poultry is a critical contributor to AMBP in all Peruvian cities, augmenting from a 21%–54% range in 2008 to 34%–60% in 2021. In contrast, freshwater and marine fish and other meats seem to have a territorial consumption pattern. Hence, northern coastal cities (Chiclayo, Piura, and Tumbes), where fishing activities are intense, have the highest per capita marine fish protein consumption (e.g., 43% in Piura). Similarly, freshwater fish is the main AMBP source in Amazon cities (e.g., Pucallpa, Iquitos, or Tarapoto), contributing to almost 33% of the AMBP intake (e.g., Pucallpa). Andean cities (e.g., Huancavelica, Puno, or Arequipa) showed high consumption levels of other meats (e.g., alpaca, goat, rabbit, guinea pig, and others) representing up to 35% of AMBP intake (e.g., Huancavelica). This trend can be noticed even when we compare cities within the same region. For instance, Chimbote, a coastal city, showed higher per capita consumption of marine fish (10.3 kg) than Huaraz (7.6 kg) in 2021. However, Huaraz, an Andean city, had higher per capita consumption of other meats (3.4 kg) than Chimbote (0.3 kg) in 2021.

3.3 | Closing the gap in vegetable and fruit consumption

The consumption of most fruits and vegetables has increased from 2008 to 2021 (Figure 4 and Figure S3), although many citizens are still unable to complete the required daily portions for these food items (INEI, 2022a). For instance, avocado consumption per capita increased from 2.1 to 3.4 kg/person/year, watermelon from 2.1 to 2.5 kg/person/year, and papaya from 6.0 to 9.4 kg/person/year. In contrast, peach consumption presents an erratic trend through the period assessed, partly due to the foreign dependence on imports to cover domestic demand (e.g., Peru imports all its canned peach from abroad) and a lower level of industrialization and mechanization of local orchards as compared to other fruits (La Cruz et al., 2021). Other fruits, such as apples and mangos, do not experience a clear trend.

Increases in the intake of citric fruits were common to all this group. These were led by lime, which augmented from 6.0 to 8.2 kg/person/year, and mandarin orange, from 7.0 to 10.6 kg/person/year. In the case of orange consumption, increases were lower, from 9.3 to 9.9 kg/person/year.

Vegetables also showed an increasing trend. Onions and tomatoes (+27%) from 11.9 to 15.1 and 7.7 to 9.8 kg/person/day, respectively, carrots (+38%) from 7.4 to 10.2 kg/person/year, and Italian pumpkin (+43%) from 4.7 to 6.7 kg/person/year are those that show highest absolute consumption. Other vegetables consumed in lower quantities, such as celery (+47%), pumpkin (+125%), or cabbage (+13%), also showed significant increases.

Overall, total fruit consumption has increased by 25%, from 192.6 g/person/day in 2008 to 241.2 g/person/day in 2021. Similarly, vegetable consumption was 32% higher in 2021 (162.8 g/person/day) than in 2008 (123.3 g/person/day). Consumption of both food categories increased regardless of the monetary poverty level (see Figures S5 and S6 in Supporting Information S1). WHO (2023) recommends at least 400 g per day of vegetable and fruit consumption for 10-year-olds or older. On average, Peruvian citizens consumed 404 g/person/day in 2021 meeting the WHO recommendation; however, this is not reflected in all socioeconomic levels. For instance, people living in poverty and extreme poverty barely consumed 56% and 37% of the value recommended by WHO, respectively. Meanwhile, nonpoor Peruvians consumed 449 g per day in 2021.

No evident patterns were found in terms of spatial variability of vegetable and fruit consumption. However, some cities showed the highest consumption of these products. For instance, Huancavelica topped the ranking in 2021 for celery (8.1 kg/person/year), apple (16.0 kg/person/year), grapes (10.6 kg/person/year), carrots (20.5 kg/person/year), and Italian pumpkin (18.2 kg/person/year), duplicating the average national consumption of these products. Huaraz consumed high amounts of peach (4.6 kg/person/year) and mandarin orange (16.7 kg/person/year). Regarding coastal cities, Tacna showed the highest consumption of tomato (16.3 kg/person/year), whereas Chimbote consumed higher amount of strawberries (5.9 kg/person/year), Moquegua showed high level of consumption of lettuce (6.7 kg/person/year) and avocado (6.9 kg/person/year), and Ica had the major consumption on asparagus (258 g/person/year), lime (12.1 kg/person/year), and mango (6.1 kg/person/year). Regarding Amazon cities, Moyobamba was the leader in the consumption of cabbage (6.8 kg/person/year), and Tarapoto consumed more orange (24.7 kg/person/year), papaya (20.3 kg/person/year), and watermelon (7.5 kg/person/year) than other Peruvian cities.

In many cases, a correlation was found between high consumption and the fruit or vegetable being vastly produced in the surrounding area, although this trend was not homogeneous. Interestingly, in coastal cities, newly incorporated agro-export products, such as asparagus, strawberries, or blueberries, have become part of the local diet as the land destined to produce these products has augmented (see Figures S7 and S8 in the Supporting Information S1). However, none of these products have become part of the diet throughout the country.

Iquitos and Pasco showed the lowest values of vegetable and fruit consumption. On the one hand, Iquitos has no terrestrial connection with the rest of Peruvian cities, so most commodities are imported by air or through the Amazonian river network (Coomes et al., 2021). This leads to increases in the price of perishable foods produced outside Iquitos, due to airfreighting costs and the dependence on boat transport, which can be slow and expensive (Ambikapathi et al., 2021). Iquitos shows the lowest consumption across Peruvian cities of imported fruits (e.g., apples and peaches) and agro-export products (e.g., blueberries and grapes). However, the Peruvian Amazon is a countless source of native fruits (up to 193 have been inventoried) that are collected in many cases informally and sold in local markets but are not widely traded in other areas of the country (Gonzales-Coral, 2007). It is plausible to consider that there is a modest consumption of fruits that remain unaccounted for in the official statistics in Iquitos and, to a lesser extent, in other Amazonian cities. On the other hand, the city of Pasco, despite having a terrestrial connection with the rest of Peru, had the lowest levels of consumption of avocado, lime, papaya, tomato, and watermelon. This could be related to the low purchasing power of its citizens, as it has high poverty levels (INEI, 2022d) and one of the lowest HDI values in the country.

3.4 | Regional patterns and food intake homogenization

We identified a tendency for homogenization throughout the food basket in the period assessed. In other words, products such as chicken (Figure S20), milk (Figure S22), bread (Figure S16), eggs (Figure S50), refined sugar (Figure S52), tomato (Figure S60), or vegetable oil (Figure S62) are now being consumed at higher rates, but also in a more uniform manner across the country, with lower differences across cities and regions. Despite this trend, certain food products are still highly characteristic of certain regions of the country. The results of the hierarchical clustering analysis revealed two well-defined groups according to their food consumption habits (Figure 5).

The first group is composed of northern coastal (Piura and Tumbes) and Amazon (e.g., Iquitos or Tarapoto) cities. This group is characterized by having the highest consumption rates of freshwater (Figure S26) or marine fish (Figure S32), rice (Figure S54), pork (Figure S44), poultry (Figure S48), and banana (Figure S12). In contrast, Andean and the remaining coastal cities, which make up the second group, showed the highest level of consumption of beef (Figure S14), other meats (Figure S40), lamb (Figure S30), potatoes, and tubers (Figure S46). A second differentiation can be made within the second group, in which coastal cities tend to be grouped, whereas most Andean cities are also clustered based on more similar diets. Interestingly, however, the results presented in Figure 5 suggest a certain level of homogenization within each group between 2008 and 2019, whereas the Euclidean distance between the two groups rose steadily in the period assessed.

3.5 | Spatial and social variability of calories and macronutrients consumption

In general terms, Peruvian citizens consumed more calories and macronutrients across the period assessed. However, results must be interpreted with care, since years 2020 and, to a lesser extent, 2021, were dominated by higher household food purchases due to intermittent lockdowns to tackle the surge of the pandemic. Thus, in 2021, Peruvians consumed 9.9% (2315 kcal/person/day), 17.3% (86.2 g/person/day), 15.4% (46.5 g/person/day), and 8% (418.2 g/person/day) more calories, protein, fats, and carbohydrates, respectively, than those consumed in 2008

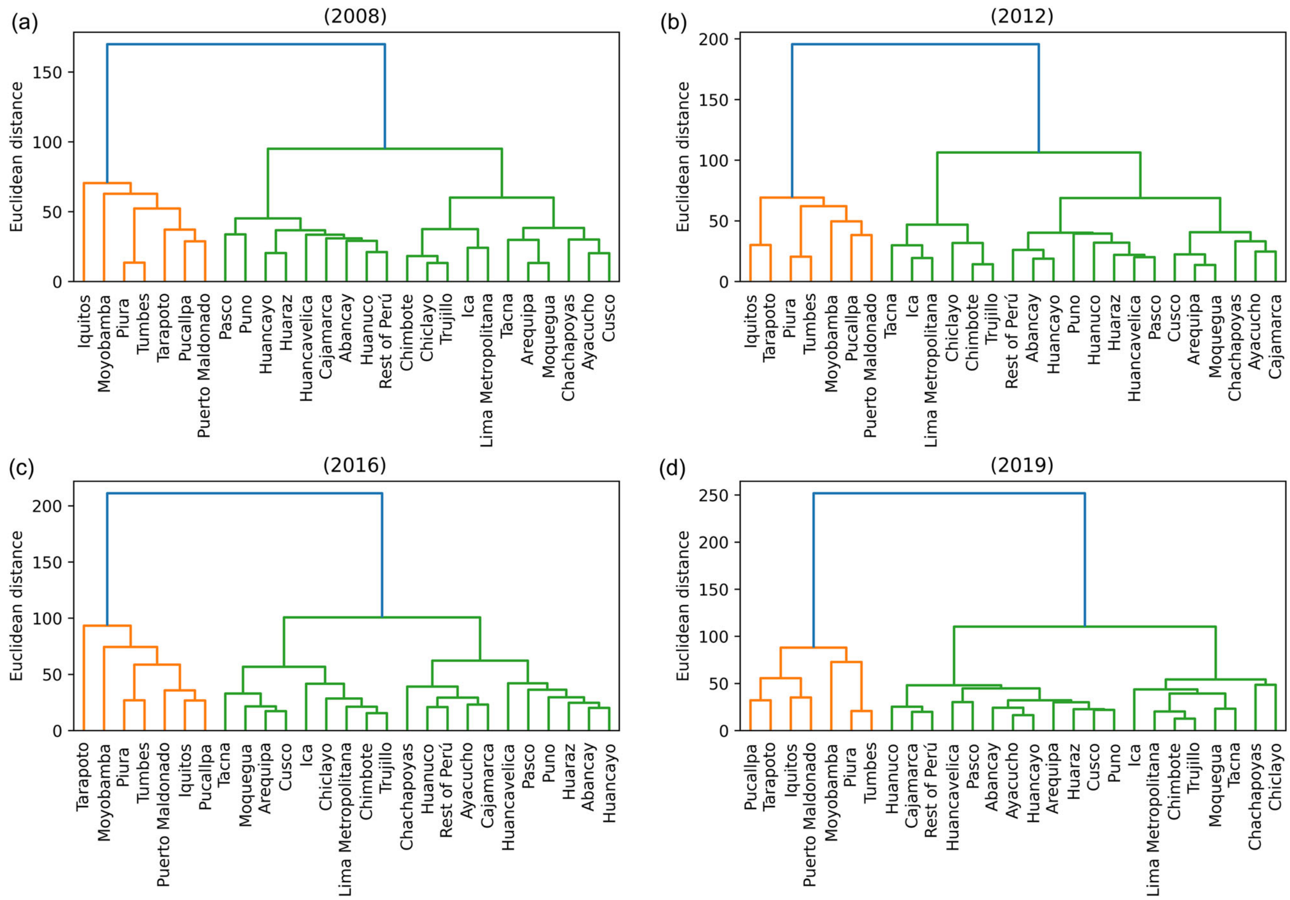

FIGURE 5 Hierarchical clustering map on dietary patterns of the main Peruvian cities (2019). The year of reference was considered to avoid the influence of the pandemic on dietary patterns linked with geographical location. Euclidean distance is a parameter that represents the dissimilarity between two patterns in the case of a numerical data set (Vijaya et al., 2004). The underlying data for obtaining the dendrograms in this figure are available in Table SM3 of Supporting Information S2.

(Figure 6). However, if 2019 is used as a reference year, only fats and proteins increased in the period 2008–2019, whereas caloric intake and carbohydrate consumption decreased.

When these results are analyzed across social strata, important disparities can be observed (see Table 2). In extremely poor households only fat consumption increased in the period 2008–2019 (11%), whereas carbohydrates (−9.1%) and overall caloric intake (−5%–4%) decreased considerably. In poor households, similar trends were found, although changes were less significant, with carbohydrate consumption reductions of −5.6%. In contrast, nonpoor households only showed relevant increases in total protein consumption (4.2%) in 2008–2019. However, the role of the pandemic in steering this group from FAFH is evident, as the changes in the period 2008–2021 are above 7% for the caloric intake and the macronutrients evaluated.

According to FAO (2023), the average dietary energy requirement (ADER[1]) in 2021 for Peru was 2035 kcal/person/day, a value that an average Peruvian citizen meets with household consumption alone. Notwithstanding, in terms of socioeconomic level, only nonpoor people satisfy their caloric requirements with household food purchase, while poor and extremely poor people only complete 75% and 51% of the ADER, respectively. Hence, thorough studies on FAFH consumption are needed across monetary levels to understand to what extent that gap is closed through other food consumption pathways. A similar trend is found with protein intake. For instance, WHO (2007) recommends a safe daily protein intake for adults based on body weight (0.83 g/kg). Considering the average body weight of adult Peruvian citizens (i.e., 64 kg) (Pajuelo Ramírez et al., 2019), nonpoor and poor people would be consuming amounts within the recommended values (53 g for adult people). However, extremely poor households are consuming only 67% of the recommended consumption for a healthy diet.

A common tendency is that nonpoor households have widened the gap in terms of purchase as compared to poor and especially extremely poor households. For instance, caloric intake by nonpoor households was 1.82-fold higher than in extremely poor households in 2008–2010, but this number has gradually increased to 1.97 for years 2018–2019 and 2021. Regarding macronutrients, similar tendencies are repeated, with nonpoor households consuming almost 2 folds more carbohydrates (446.4 g/person/day), 2.4 folds more fats (50.6 g/person/day), and 2.6 folds more proteins (93.9 g/person/day) than those consumed by extremely poor people in 2021, in all cases with a steady increase in the period assessed.

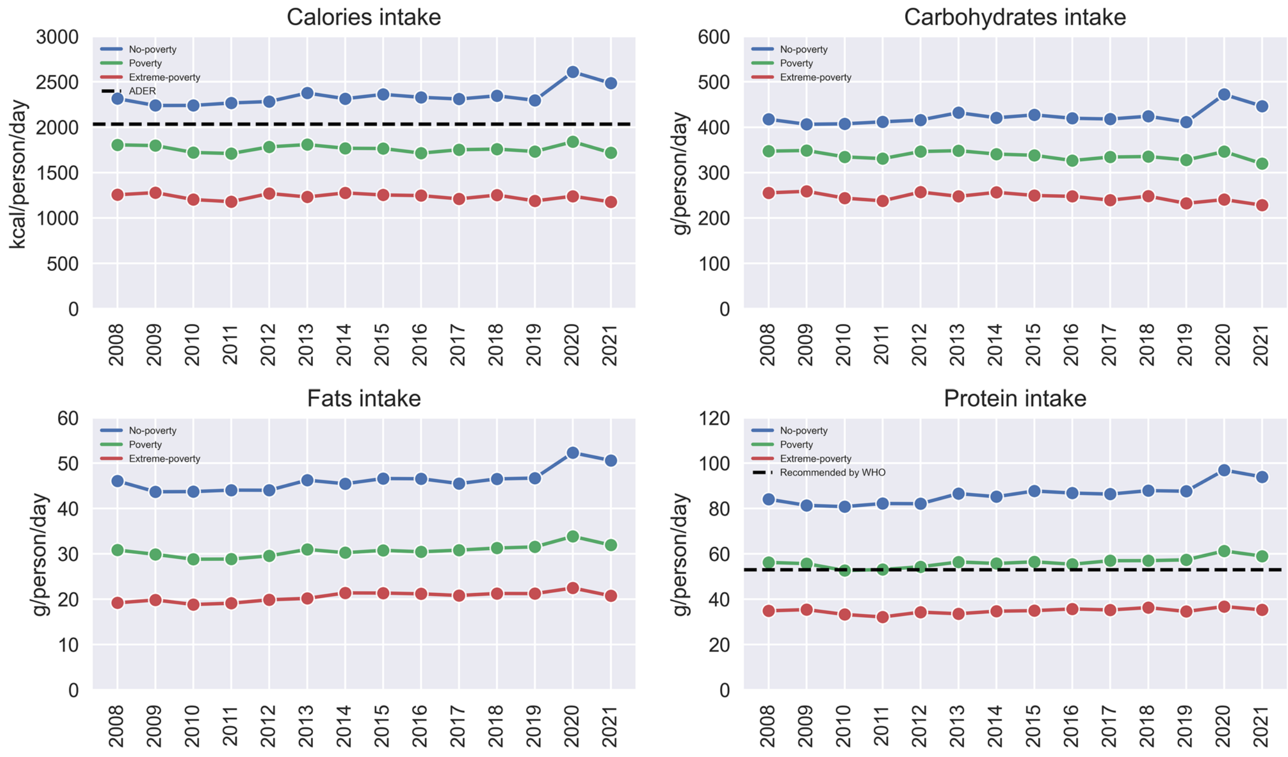

FIGURE 6 Evolution of per capita calories and macronutrient intake by Peruvian citizens during the period 2008–2021. Dotted lines in the "calories intake" and "protein intake" subplots represent the reference values of average dietary energy requirement (ADER) (FAO, 2023) and recommended protein intake (WHO, 2007). Underlying data for this figure are available in Table SM5 of Supporting Information S2.

TABLE 2 Changes in caloric intake and macronutrient consumption in Peru throughout different time periods.

	Household monetary level	Caloric intake (kcal/person/day)	Protein consumption (protein/person/day)	Fat consumption (fat/person/day)	Carbohydrate consumption (carbs/person/day)
A. Average consumption, 2008–2010	Nonpoor	2264.4	82.1	44.5	410.4
	Poor	1774.3 (0.78)	54.9 (0.67)	29.9 (0.67)	343.4 (0.84)
	Extremely poor	1245.1 (0.55)	34.5 (0.42)	19.3 (0.43)	252.5 (0.62)
B. Average consumption, 2017–2019	Nonpoor	2317.5	87.3	46.2	417.8
	Poor	1747.2 (0.75)	57.1 (0.65)	31.2 (0.68)	332.4 (0.80)
	Extremely poor	1216.2 (0.52)	35.4 (0.41)	21.1 (0.46)	239.7 (0.57)
C. Average consumption, 2018–2019 and 2021	Nonpoor	2375.6	89.8	47.9	427.2
	Poor	1736.1 (0.73)	57.8 (0.64)	31.6 (0.66)	327.5 (0.77)
	Extremely poor	1204.9 (0.51)	35.4 (0.39)	21.1 (0.44)	236.0 (0.55)

Note: Numbers in brackets for poor and extremely poor households represent the consumption proportion as compared to nonpoor households.

We hypothesize that rapid growth of the Peruvian economy in recent years (Seminario et al., 2020) can be a carrying factor for increasing caloric intake and other macronutrients. However, the results suggest that these increases are mainly due to an expansion of the middle class and a reduction in the poverty level from above 40% in 2008 to 20.2% in 2019 (INEI, 2021, 2022d), whereas poor and extremely poor households have shown dwindling trends, especially in terms of caloric intake and carbohydrates.

At a geographical level, most Peruvian cities experienced increases in caloric intake per capita (Fig S10). Ica was the city with the highest caloric intake in 2021, with 3039 kcal/person/day (+43% compared with 2008), followed by Moyobamba (2726 kcal/ person/day), Chiclayo (2621 kcal/person/day), and Piura (2504 kcal/person/day). Conversely, citizens from Huaraz reduced their caloric intake by 17% (2147 kcal/person/day) compared with 2008. The lowest caloric intake values were found in Tarapoto (1617 kcal/person/day), Iquitos (1756 kcal/person/day), and Pasco (1798 kcal/person/day).

3.6 | Outliers: What are they telling us?

A recurrent observation of extreme values of food consumption was identified in the raw data (see Table SM1). These values were not excluded from the statistical analysis based on the assumption that they are linked to expenditures in informal street vendors, food stores, neighborhood associations (e.g., *ollas comunes*), and restaurants. In fact, according to INEI (2022e), 77% of Peruvians work in informal jobs, a scenario that was exacerbated due to the draconian restrictions during the pandemic (Cueva et al., 2021). This suggests that there is a network that links people within the neighborhood through food trade, fostering food security. For instance, o*llas comunes* are community kitchens located in the poorest neighborhoods, where organized families collaborate to buy and prepare food to decrease costs (Desmaison et al., 2022). This collective structure of food supply could be hiding or distorting real consumption, especially in households whose food provision is based on these social systems, which would lead to a greater dependence on informal FAFH, not accounted for in this study.

4 | CONCLUSIONS

Results suggest that, on average, a set of promising trends can be observed in dietary patterns in Peru. The deficit of legume, fruit, and vegetable consumption has closed significantly, but asymmetrically and not sufficiently, in the period assessed. In addition, the number of households that are considered poor or extremely poor according to national statistics has decreased significantly despite a final increase in 2020–2021 due to the pandemic. Dietary patterns, however, have not improved significantly between those households that are still categorized as poor or extremely poor.

The reduction in red meat (i.e., beef and lamb) consumption per capita is a remarkable trend that has important implications in terms of mitigating GHG emissions, water scarcity, and reducing all-cause mortality. The main substitutes, chicken and eggs, also pose important health (e.g., residual antibiotics consumption) and environmental (e.g., particulate matter formation) risks if not managed correctly. Furthermore, food consumption shows a geographical distribution, with similar dietary patterns grouped in two main clusters: (a) northern coast and Amazon basin cities, and (b) Peruvian coast and Andean cities, a disposition that could be used for the sake of region-specific food policies.

Despite the limitations, in addition to the inclusion of outliers, our findings suggest the need to develop policies aimed at improving access to foods with high nutritional value, especially in the lower-income socioeconomic strata. Moreover, although we explore the potential environmental impacts of the consumption of certain food products and the promising decreases in consumption of high environmental burden foods (e.g., beef), future research could be oriented toward analyzing the potential trade-offs of these changes on the Peruvian diet, including the spatial variability of these choices, as well as accounting for certain food consumption behavior pathways, such as FAFH and FLW, to obtain a more complete picture of food intake in Peru.

AUTHOR CONTRIBUTIONS

Joan Sanchez-Matos: Conceptualization; investigation; formal analysis; resources; writing (original draft). **Ian Vázquez-Rowe**: Conceptualization; validation; formal analysis; resources; writing (original draft); supervision; project administration; funding acquisition. **Ramzy Kahhat**: Conceptualization; validation; formal analysis; writing (review and editing); supervision; funding acquisition.

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CONFLICT OF INTEREST STATEMENT

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

DATA AVAILABILITY STATEMENT

The complete dataset developed in this study has been deposited in the Zenodo database under the access code: https://doi.org/10.5281/zenodo.11049824. In this link, there are three datasets. First, "dataset1.csv" contains the input data of food and beverage consumption per capita by the household from each National Household Survey from 2008 to 2021. Second, "dataset2.csv" contains input data regarding the caloric and macronutrient content of each food and beverage item studied. Finally, "dataset3.csv" contains the detailed results of caloric and macronutrient consumption per capita in households from each National Household Survey from 2008 to 2021.

ORCID

Joan Sanchez-Matos https://orcid.org/0000-0003-1006-6209
Ian Vázquez-Rowe https://orcid.org/0000-0002-7469-2033
Ramzy Kahhat https://orcid.org/0000-0001-7321-2256

ENDNOTES

[1] ADER is the reference value of the average calorie intake requirements of an average person, considering different factors such as demographics and levels of physical activity (Tallard et al. 2022).

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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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