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Understanding foodscapes for sustainable diets in rural localities in Tunisia: Integrating multiple methods and tools in a mixed-methods design

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ABSTRACT

Background: Understanding foodscapes is essential for developing effective interventions to support nutritional health. However, resource limitations often hinder comprehensive foodscape assessments linked to dietary outcomes. This study aimed to examine the foodscapes in the context of sustainable diets within a food systems framework in rural farming communities in Tunisia.

Methods: A mixed-methods approach using the following tools and methods, was employed in a sample of four rural communities in Tunisia to explore food beliefs and dietary influencers: market observation combined with a food costing survey, a household survey including dietary data collection using Diet Quality Questionnaire, distance from market, meal decision influencers, anthropometric and demographics data, and focus group discussions.

Results: The participants' (n = 692) dietary quality and BMI were significantly associated with gender, age, distance from fresh markets, and education. Food price was significantly positively associated with dietary diversity and with both health-protective and health-risking food groups' consumption. Focus group discussions revealed religion and culture's embeddedness in food beliefs and behaviors. Participants placed animal-sourced foods and grain-based products among the top highly praised foods for health, with significantly more men than women believing meat was necessary for good health. Few respondents considered legumes as meat-alternatives.

Conclusion: This foodscapes study presented the application of farming household survey, food market and costing, and restaurant observation data, and focus group discussion in a convergent parallel mixed methods design to efficiently assess foodscapes in rural Tunisia. The tools enabled the identification of eco-socio-cultural factors that can guide the designing of interventions for sustainable diets.

1. Introduction

Food security, a globally critical issue, reflected in the Zero Hunger Goal (SDG 2) for sustainable development, remains unachieved (FAO et al., 2024). Tackling the triple burden of malnutrition (Global Nutrition Report [Internet], 2021) requires effective nutrition interventions, which require a good understanding of foodscapes at a locality level (Downs et al., 2024), including both the physical and social interactions within a geographic location. Foodscapes refer not only to food environment elements external to individuals but also to socially and politically shaped landscapes, where culture and personal experience are critical to understanding how food systems impact people (Vonthron et al., 2020). Foodscape studies have been approached from any of the four broad perspectives, namely spatial, sociocultural, behavioral, and systemic (Vonthron et al., 2020). Each of these approaches is based on the objective of the study and necessitates the selection of methods and data collection tools that best fit the approach and the objective within a given context.

The spatial perspective concerns the environment where food is made available to consumers, where methods such as the number of food retail stores, restaurants, and markets would compose the data used to assess the foodscape (Clary et al., 2017; Méjean and Recchia, 2022). In a sociocultural approach to study foodscapes, attention is steered towards how the food environment, that is the spatial foodscape, is socially constructed (Vonthron et al., 2020; Johnston and Goodman, 2015). Topics like food politics and food culture are captured using this

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approach (Goodman, 2016; Morgan, 2014; Morley and Morgan, 2021). People's relationships with food as consumers, producers, processors, or politicians and citizens in foodscape studies have been generally explored from a constructivist paradigm (Goodman, 2016; Morley and Morgan, 2021; Miewald and McCann, 2014; Morgan, 2010). Park & Widyanta (Park and Widyanta, 2022) demonstrate this by showing how food tourism in Yogyakarta, Indonesia, attracts food tourists and how tourists in turn influence the foodscape concurrently. The constructivist paradigm used in this approach is evident. This approach was also termed *realised foodscapes* (Cervigni et al., 2022), highlighting the perception of those encountering the foodscape that played an active role in the construction of *their* foodscapes. One may justifiably argue that the constructions of foodscapes are not divorced from the elements of the food environment. This is where a behavioral approach comes into play.

In the *behavioral approach*, the encounter of consumers with the food environment and their experiences are studied (Vonthron et al., 2020). In this approach, the emphasis is put on the food behavior of agents with the foodscape being a physical, organisational, and socio-cultural space. Thus, the socio-cultural and spatial approaches, including both elements of the food environment and the interactions of the agents with these elements, are included. This approach can be placed within both a positivist and a constructivist approach. This is shown in the example of a study by Richmond et al. (2025) that showed gentrification's effect on foodscapes by mapping food outlets and by interviewing residents and observing descriptions of food outlets by social media influencers in Newburgh's foodscape in New York. Thus, multiple methods can be used within a single approach to studying foodscapes.

Another matter to consider in studying foodscapes is the lens through which foodscapes are viewed. The shift from achieving food security to establishing sustainable food security (Sonnino et al., 2014) calls for the assessment of foodscapes through a sustainability lens. This translates into studying foodscapes in the context of the effect of dietary practices of a locality's human, environmental, and social health in general, comprising the three aspects of sustainable diets. In their review, Vonthron et al. (2020) remarked how foodscape studies aimed to address the three main topics of public health, social justice, and sustainability. These are the same themes covered in the framework of sustainable diets (Jones et al., 2016), although foodscapes may cover a wider range of factors, or the aim may be an examination of the elements making up the foodscape rather than a comparison to what may be defined as sustainable. Nonetheless, the sustainable diets framework provides a focused direction for examining foodscape elements.

Reviews of sustainable diet studies show that a majority of studies were conducted in high-income countries and focused on nutrition and environmental health with poor coverage of socio-economic sustainability of diets (Jones et al., 2016; Rei et al., 2025; Harrison et al., 2022). In contrast, designing food-based interventions requires evaluating human factors like food beliefs and diet quality along with health and environmental variables such as diet quality, market availability, and accessibility. The current study responds to this gap by providing a case study of foodscapes in a low-moderate-income country setting and including socio-economic aspects of sustainable diets in a food systems framework.

In assessing the public health aspect of sustainable diets, nutritional health indicators for chronic nutritional status, such as body mass index (BMI) (Brauer et al., 2024) and dietary diversity (Arimond and Ruel, 2004), have often been used. Although BMI alone is limited for use in clinical settings (Sweatt et al., 2024a), its correlation with adiposity and ease-of-attainment favour its use in initial screening. The commonly used measure of dietary diversity, Minimum Dietary Diversity for Women (MDD-W) (FAO, 2021), has focused on the adequacy of nutrients without considering the consumption of high-calorie-low-nutrient-density (HC-LND) foods, whose consumption should be limited for optimum health. This is particularly important considering the increasing rate of obesity (Lim et al., 2020), which is associated with non-communicable diseases like hypertension and hypercholesterolemia (Khanna et al., 2022). Therefore, a tool that would collect both health-protecting and health-risking food data is desirable.

The socio-economic aspect of sustainable diets includes multiple concepts, such as gender, race, religion, equity, knowledge, food traditions, and political participation, which have been shown to influence dietary outcomes in a systematic review by Jones et al. (2016). These factors' effect on diets is modulated by one another and by the contextual factors in a particular food environment. For example, in comparison to high-income parents, low-income parents would buy more ultra-processed snacks for their children, not only because of the lower price of these snacks but also because of the social meaning, as in belonging to a group for teenagers and a treat or reward for children, attached to them (Hawkes et al., 2024; Gallagher-Squires et al., 2023)-thus, a cheap alternative for low-income parents to make their children happy. Similarly, gendered roles have been highlighted as a strong determinant of nutrition outcomes at the household and locality levels (Harris-Fry et al., 2017) and are essentially embedded within the structure of food systems (Njuki et al., 2021). Therefore, it is an important component in studying foodscapes.

The third component of sustainable diets is environmental health, which influences foodscapes. From an agricultural perspective, assessing the sustainability of foodscapes poses significant challenges. A widespread method for assessing the environmental impacts of food production and distribution is life cycle assessment (LCA), which quantifies the environmental impact of food from production to disposal. However, LCAs often focus on individual products rather than entire foodscapes, making it challenging to capture the complexity of food systems at a locality level. Practices such as the consumption of animal-source foods can serve as a proxy indicator of environmental health (Smetana et al., 2023), as may locally-produced foods' consumption (Stone et al., 2021).

Considering that studying foodscapes in the context of sustainable diets can require substantial time and resources, more efficient methods and tools are needed for research planning and strategy development. For example, taking a purely human behavioral approach would provide limited guidance on changing food environment elements to promote sustainable diets, while an exclusively spatial approach may lead to an intervention that could perpetuate social inequities or infringe upon cultural values. To this effect, a purely spatial approach in studying the effect of foodscape on diet (Clary et al., 2017) lacks accounting for personal variables that can modulate the effect of foodscapes on health and diet (Méjean and Recchia, 2022). To address this challenge, a study, undertaken in 2023, is presented in this paper to set an example of a practical foodscapes assessment in the context of sustainable diets at locality-level in Tunisia, a low-moderate-income country. In this study the relationship among a number of foodscape variables and nutrition outcome indicators was also empirically tested. Tunisia's main agricultural products include cereals, like wheat and barley, olives, dates, vegetables, and fruits (Ouessar et al., 2021). North Africa and the Middle East are foreseen to be most prone to the impact of climate change (IPCC, 2019), threatening their population's food security, health, and economy. The Tunisian population is experiencing a significant rise in overnutrition, with an estimated 37.2 % of women aged 18 and over and 22.1 % of men having obesity, which was higher than the regional average for the obesity prevalence (Global Nutrition Report [Internet], 2021). Additionally, deficiencies in micronutrients like vitamin A and iron (Doggui et al., 2020) may indicate poor dietary quality. Therefore, concerted efforts along the food chain are needed to achieve sustainable diets in Tunisia. High animal-based food consumption, unevenly distributed across the country (Perignon et al., 2019), has added environmental stress. In 2022, as part of an agroecological transition initiative in eight countries of the Global South, farmer organizations were approached to enable the implementation of agroecological principles specific to farms in the semi-arid area of Siliana and El-Kef governorates (CGIAR, 2023). As part of this initiative, a pilot nutrition intervention was to be planned to improve the dietary outcomes of the

farming households in the area. This plan gave impetus to the study of foodscapes in rural Tunisia. This article aims to demonstrate the selection of relevant elements, e.g., consumer behavior, and corresponding variables, e.g., dietary diversity, and the selection and application of tools and methods used to accomplish the initial step in developing evidence-based community nutritional health interventions. The findings can also contribute to policies supportive of health-promoting communities.

2. Framework for sustainable diets foodscapes

A conceptual framework for food systems (FAO, 2017) was adapted to guide this study. The modified framework included nutrition and dietary outcomes, elements from the food environment, such as restaurants, food advertisement, and fresh food markets, consumer behavior, and food supply chains. In assessing the foodscapes in rural farming communities in Tunisia, foodscapes were observed from the end user or consumer's point of view. Thus, variables like food price, gender roles, food beliefs, food advertising, and religio-cultural factors were considered imminent influencers of dietary choices (Chen and Antonelli, 2020). Particular attention was paid to gendered data collection to capture perspectives of women within the food systems' framework since women play a critical role in the transmission of culture and households' dietary practices (Kalansooriya and Chandrakumara, 2014). The HLPE framework (FAO, 2017) is well-suited for exploring foodscapes covering a range of factors while placing health and nutritional outcomes as indicators of diet quantity, quality, diversity, and safety, which are central to sustainable diets. A modified version of this framework (FAO, 2017) and sustainable diets' framework (de et al., 2019) was adapted, as shown in Fig. 1, to guide the selection of elements of foodscapes examined in this study.

Using this framework to guide the selection of indicators, methods, and tools used in the context of a low-moderate-income country situated among the most vulnerable to climate change is essential. It ensures that adaptation strategies are contextually relevant, evidence-based, and responsive to the unique challenges and resource constraints faced by such countries.

3. Materials and methods

For this study, four communities of Gaafour, Kesra, Makthar, and Sers in the governorates of El-kef and Siliana were involved in the agroecological transformation initiative that started in 2022 led by International Centre for Agricultural Research in Dry Areas (ICARDA). As per the food systems framework, Fig. 1, the type of data needed and the corresponding methods and tools required a four-step process: 1. Listing the type of data that help identify the specific needs for nutrition intervention(s) and to identify the barriers and facilitators to sustainable dietary behaviors in the targeted communities; 2. Identifying methods that could be applied to acquire the data; 3. Reviewing available tools that could be implemented in the given context, as in the availability of human, financial, technical, and time resources and the enviro-socio-political context of Tunisia. 4. Adapting the tools, if required, to match the need for data with attention to validity and reliability of the data and possible shortcomings.

A review of the literature revealed various methods and tools utilized in the study of food environments highlighting the need for further studies in Low- and middle-income countries (LMICs) and the

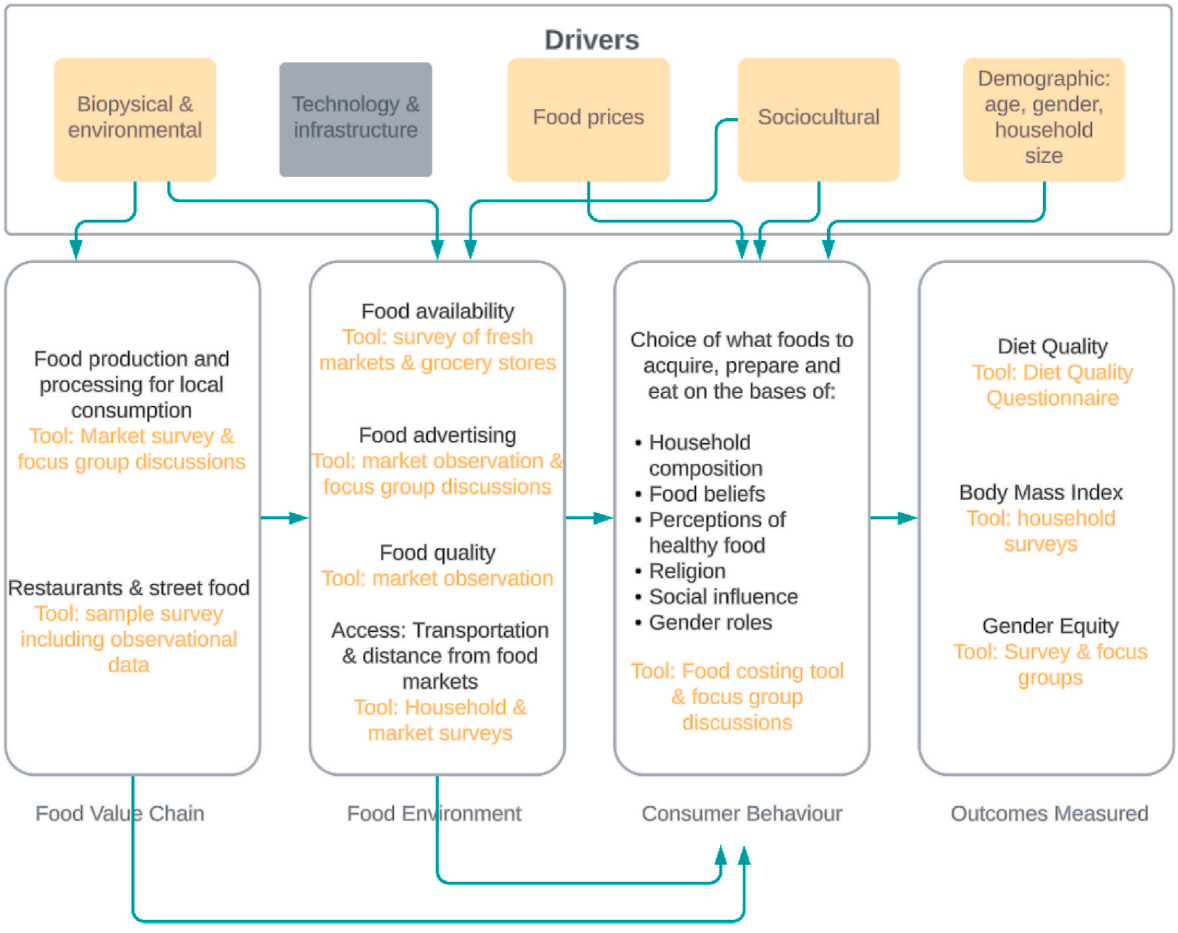

Fig. 1. Adapted food systems framework (FAO, 2017; de Brauw et al., 2019) guided the selection of indicators, tools, and methods to assess the foodscapes for sustainable diets; grey shaded element indicates the driver that was not actively included in the study.

shortcoming in studies exploring the socio-economic aspect of the food environment (Turner et al., 2018; Caspi et al., 2012). A convergent parallel mixed-methods design (Fetters et al., 2013) was implemented with a household survey, an environmental survey, and focus group discussions (FGDs) providing quantitative, quantitative and qualitative observational, and qualitative data, respectively. The different types of data were collected concurrently with the results complementing one another to understand the foodscapes in the selected communities.

As per Fig. 1, the kinds of data needed for the foodscape assessment were identified based on literature review of indicators for food environment and nutritional health. These included data on food consumption, health status, body weight and height, and an overview of the food environment including cost and availability of food, and social aspects, such as food beliefs and perceptions of sustainable foods, and barriers and facilitators to sustainable diets and dietary behaviors. Factors influencing consumption were included in the household survey and explored in FGDs. The study and data collection protocols were reviewed to assure compliance with the applicable Declaration of Helsinki ethical standards.

The tools used for the study are described below:

3.1. Household survey

Data from a household survey was collected to guide the design of a nutrition intervention for the targeted communities. Data from the demographics part of the survey, such as gender, household size, and distance from closest fresh market were relevant as influencers of diets. Other variables considered influential, like perceived health status and factors influencing meal decisions in a family, were added. The relevant variables are presented in Supplement 1. The Diet Quality Questionnaire (DQQ) validated for Tunisia was released in 2022 as part of a global survey of country-specific diet quality (Uyar et al., 2023). DQQ was added to the household questionnaire. DQQ is a global survey including sentinel foods common to diets in different countries, which combines several validated tools and dietary recommendations (Global Diet Quality Project). The food groups in the survey include both non-communicable-disease-protecting foods (NCD-Protect) and those that potentially increase humans' risk for non-communicable diseases (NCD-Risk). The combined NCD-Protect and NCD-Risk scores produce the Global Dietary Recommendations score from 0 to 18. A DQQ can be conducted in a short time (around 5 min) making it ideal for population-based surveys and for making the study findings comparable to other studies or to national DQQ survey findings. To determine intra-household gendered differences in BMIs, respondents were asked about their spouses' height and weight (n = 238). The household survey was implemented from January to February (n = 592) and from September to October (n = 100) in 2023 by Bureau d'étude, a research institute with established activities in the studied area. *Bureau d'étude* trained 24 enumerators originating from the studied zone and supervised by a team of four supervisors, one per locality. The enumerators conducted the survey in the local language and recorded the responses on tablets. The participating farming households were small and medium-sized farms with less than 20 ha area that carried out at least one agrarian activity: cultivation, arboriculture, or livestock. The sampling was based on the snowball approach (Goodman, 1961). The first households were identified by the local extension workers in the selected communities.

3.2. Environmental profile of a Community's health (EPOCH)

The EPOCH 1 (Chow et al., 2010) survey was developed to provide reliable data on environmental determinants of cardiovascular health. It showed fair-to-good and excellent inter-rater reliability when tested in 93 rural and urban communities in five countries including a LMIC. It provides guidance on surveying a marketplace, a sample grocery store and restaurant, and cardiovascular health-relevant locality characteristics. The latter relates to facilities like transportation, road condition, and healthcare services, which were available from local members of the researchers' team. The former three are described below. Locality in this study was defined as the area that a fresh market serves.

3.2.1. Marketplace survey

The market survey component of EPOCH was adapted to assess the availability and quality of foods and food advertisements in the fresh market, a centrally located supermarket, and a medium-scale restaurant close to the marketplace, which was also centrally located. Questions about cigarette-smoking were excluded as they were considered irrelevant to the study of foodscapes. The survey included questions about the number of street food carts and the availability of vegetables and fruits, which were listed and rated visually for their quality. The environment along a centrally located marketplace route, as per EPOCH 1, ranging in length from 340 to 750 m was observed by two researchers who recorded food availability and photographed food ads unless consent was not granted. In this case, a description of the advertisements and their quantities were noted. These notes were reconciled at the end of the observation walk and discrepancies were resolved by revisiting a store or place. The fresh market was selected as the most central place where the bulk of a family's weekly food is purchased, thus, providing data for food availability, advertising, quality and contributing to food access assessment as various components of the food environment. Food prices, a driver of dietary practices, were also obtained in the food market.

To examine the food value chain in the food systems model (Fig. 1), the economic and environmental aspects of sustainable diets, and to a limited extent food trade influencing food availability in the foodscape, the origin of foods listed was noted. The country-of-origin of the DQQ food items, excluding composite foods, and vegetable oil were noted by asking vendors or checking the packaged foods' labels.

3.2.2. Restaurant survey

The EPOCH survey contains a section that guides the assessment of restaurants, which was used to complete the assessment for at least one restaurant per locality, with a total of six. The medium-to-low-income sit-down restaurants visited in each locality were located close to the fresh market in each locality. These restaurants were selected as more consumers would be exposed to them as opposed to restaurants in other parts of the localities. Also, as per EPOCH a restaurant catering to middle-income families was selected, because it would represent a restaurant that would cater to an average-income consumer. The menu items and prices were noted and various items like *kefteji* (mix of roasted sweet pepper and hot pepper sauce, fries, olives, and tuna) sandwich, *tabouna* (a type of bread) with *tajin* (egg and chicken omelette), roasted chicken, and couscous with chicken and vegetables, from four out of the six restaurants visited were ordered. A nutritionist visually assessed the vegetable, meat, and grains portions as per portion sizes in the USDA Food Database (USDA. USDA FoodData Central) and fitting a generally balanced meal as per Planetary Health Diet recommendations(Willett et al., 2019).

3.3. Food costing survey

The price of items from the Diet Quality Questionnaire (DQQ) was surveyed to capture both nutritious and high-calorie-low-nutrient-density foods available in the local markets. The market survey in four communities was conducted in January 2023 within the same week. Out-of-season fruits and vegetables listed in the DQQ were excluded after their absence in the market was noticed in the first two markets visited. Olive oil and vegetable oil were added to the list.

A reference diet, in Supplement 2, was designed to meet the sustainable diets' requirements. Quantities of food groups were restricted by the upper limit ranges according to the Planetary Health Diet (Willett

et al., 2019). Some foods were assigned higher than average amounts to ensure micronutrient adequacy for common deficiencies, such as iron (Beal et al., 2023). The price of similar food items from DQQ was grouped and averaged. Sweets and fast foods were grouped separately. The origin of the foods in the food-cost list was recorded as a proxy indicator for the socio-economic aspect of dietary sustainability. Fresh market, supermarket, and restaurant surveys took on average 4 h per locality to complete.

3.4. Focus group discussions

One FGD per locality was conducted to explore participants' food beliefs about health-promoting foods and sustainable foods. Participants were recruited through local farmers' associations engaged in ICARDA's agri-ecological transformation initiative. After the organizations were provided information about the foodscapes study, they approached their members to invite them to the focus groups. Informed consent and demographics data were obtained from all participants. Considering that men, as heads of farming households, often represent a farm unit in agricultural organizations, special effort was made to request for women's participation in agricultural organizations by emphasising the focus of the study being related to food-acquisition and consumption rather than food-production. Furthermore, an agricultural cooperative with a high number of women's membership was successfully recruited to organize one of the FGDs.

Participants' perceptions of barriers and enablers to healthy eating for themselves and their families were explored. Discussions also covered factors influencing food behavior and ways to promote nutritional health. A modified force field mapping technique, used in healthcare, educational, and organizational settings as a simple and flexible tool (Salisi and Faller, 2024), visually engaged participants in identifying barriers and facilitators to healthy sustainable diets. The FGDs were conducted in three steps: 1. Participants listed foods they perceived to be health-promoting; This was written on a displayed paper visible to participants. 2. In force-field mapping activity, participants were asked to describe the barriers and facilitators to consuming health-promoting foods. A researcher wrote these in a table format visible to participants with facilitators in green and barriers in red color. 3. Using timeline mapping (Kolar et al., 2015) a researcher prompted participants to reflect on changes in production- and consumption-sustainability. Both force-field- and timeline-mapping techniques are visual ways of facilitating FGDs. With a researcher writing key words on the charts, the process facilitated participation of persons with different levels of formal education and required less time than when these procedures are drawn or indicated on a map by participants themselves.

3.5. Data analysis

Descriptive statistics included calculating means, standard deviations, and Wilcoxon and Student's T-Tests for not normally and normally distributed data, respectively, to test for differences between men and women in the variables measured. Household survey data provided information about respondents' and their spouses' BMI, respondents' Dietary Diversity Score (DDS), and NCD-Protect and NCD-Risk food groups' consumption. Holding these variables as potential outcomes, their association with age, gender, education, household size, share of children in the household, and price of NCD-Protect and NCD-Risk food groups was explored using linear regression for BMI and Poisson regression analyses for DDS, NCD-Protect, and NCD-Risk food intake, and GDR.

Regarding the household survey, a total of 692 questionnaires were completed in Chouarnia/Makthar (n = 140), Rahla/Gaafour (n = 151), Kesra (n = 179), and Sers (n = 222). Participants were asked about factors that influenced the choice of foods prepared. A total of 12 influencers were grouped under four dummy variables namely family's influence, personal factors, price, and food environment factors as potential predictor variables in the models. Variables that resulted in unacceptable levels of multicollinearity indicated by Variance Inflation Factor over five were removed. Health status, as a factor influencing diet and vice versa, was included as a potential predictor with "okay" health status placed as a reference with positive and negative health status ratings as two other variables. The square root of household size, being non-parametric, was used in the model.

Data from the market survey was used to describe and compare the food environment across the four communities. Food advertisements in markets, restaurants, and supermarkets were classified into broad healthy and unhealthy groups and counted; street food carts were counted and the food offered was descriptively included in the assessment of the foodscapes. Food items such as meat that can be nutritious when consumed in moderate amounts were counted as healthy unless the advertisements showed high-fat, high-salt preparations. Restaurant survey data was evaluated descriptively.

Differences in food group prices were tested across the four communities. To test this, one-way repeated measures ANOVA was conducted (Field, 2024). Furthermore, price data was used to calculate the cost of a hypothetical sustainable diet for the context of the study.

Thematic content analysis (Saldaña, 2009) was used for FGDs data using the pre-determined overarching themes of food beliefs of participants, factors they perceived influencing their dietary practices, and their perception of dietary sustainability. In-vivo coding (Saldaña, 2009) was used when appropriate. Data about dietary influencers were triangulated by comparing findings from FGDs and the household survey. These included data about actors that influenced decision-making about family meals from household survey and FGDs, food price from food costing survey, household survey, and FGDs, and beliefs about meat and alternatives from household survey and FGDs. This triangulation was used to gain a better understanding of the multifaceted factors shaping diets.

4. Results

The market observation showed adequate availability of NCD-Protect food in the fresh market to accommodate a sustainable diet. Relative to fruits, vegetables had lower prices in general. Food beliefs appeared to favour animal-sourced and grain-based foods rather than legumes, which was also reflected in restaurant menus. Sugar-price cap may have contributed to the observed consumption of sugar-sweetened food and drinks, which was not readily perceived as unhealthy. Women's engagement in the fresh market and supermarkets as laborers, although visible, appeared substantially lower than that of men's. Detailed results are presented below:

4.1. Food price

Food prices were averaged per DQQ food groups. These prices showed no significant differences ($F = 0.95$, $p = 0.43$) across the four localities (see Supplement 3). Out of the 116 food items listed in the DQQ, an average of 66.5 items were costed per locality, as not all items were in season and slight variations in availability were observed across the localities. This is explored further in 4.4.

4.2. Food markets and supermarkets

The markets offered sufficient variety of food to support health-promoting diets. Households primarily purchased food on fresh market days, held weekly in all surveyed communities. Fruits, vegetables, and legumes were commonly available in fresh markets, marked by temporarily placed carts on streets closed to traffic until noon. Grain products, dairy, eggs, fish, and meat were sold in butcheries, bakeries, and general stores. The figure in Supplement 4 presents fresh market observation data. There were more health-risking than health-

promoting food ads across all markets observed. All the communities visited, except Kesra, had the same chain store supermarkets. The supermarket carried plastic-containing-packaged products with many sugar-sweetened snacks and drinks, staples like couscous and legumes, and some vegetables not observed in the fresh markets. Only one supermarket sold bran couscous, costing over twice as much as the refined version. Refrigerated displays were available in supermarkets and convenience stores indicating technological access contributing to food safety even in convenient stores in Gaafour, which appeared to be the least developed locality.

Regarding the origin of food, only 30 % of the items' origin were identified across all communities, with a majority (86 %) of them produced and/or processed in Tunisia. This was taken as an end indicator of food value chains and an indicator of processing facilities existence.

Both genders shopped in large numbers, as per market observation data and FGDs. However, most sellers in the open market were men. Women sellers were present in small shops around the market and as assistants to male sellers in bigger stores. In supermarkets, most seated cashiers were women while men stocked shelves and supervised. Thus, women appeared to usually occupy positions with less authority and possibly lower pay, than those occupied by men. Marketplace observations showed shopping to be more of a chore than leisurely activity, as it was done in a fast-paced manner by mainly middle-aged women and men.

Overall, the food retail environments in the surveyed communities offered a foundational variety of foods to support health-promoting diets, but were also marked by limited food origin transparency, a high prevalence of unhealthy food advertising, gendered divisions of labor, and the growing presence of packaged and processed products, particularly in supermarkets.

4.3. Restaurants

Restaurants across the surveyed localities offered a narrow selection of foods, with menus largely centered on refined grains, animal proteins, and sugar-sweetened beverages. The most common food groups offered were white grains, chicken, eggs, and tuna and limited vegetables like cabbage and tomato. None of the restaurants offered whole grains, fruits, and legumes. Tunisian traditional salad was also available in most restaurants and displayed on menu boards. Dairy choices were only in the form of cheese in restaurants offering pizza. Options for up-sizing were limited to pizza. However, there were no downsizing options available for already high-caloric meals, either. The price for all meals ranged from 2 to 8 TND. The differences in the restaurant menus depended on the type of restaurant. Advertisements showed mostly high-calorie-low-nutrient-density foods like pizza, burgers, and soda. Across the communities, locally run restaurants offered simple, home-style meals, with Gaafour focusing on chicken dishes, Sers featuring traditional Tunisian fare, and Kesra providing home-cooked meals prepared and served by a woman. Choice of drinks, self-served refrigerated bottled soft drinks or water priced commonly at 1 TND, was similar across the restaurants visited in all locations. Thus, restaurant offerings were nutritionally limited, with few healthy options and minimal variation in the rural localities visited.

4.4. Exploring associations among various foodscapes factors and dietary outcomes

Table 3 shows the dietary status of the population reached via household surveys and their demographic characteristics descriptively. Differences in gender outcomes were considered valuable in the context of differential experience or outcomes of the foodscape.

Calculated BMIs, based on the reported height and weight data for respondents and their spouses ($n_{couples} = 238$), showed that wives' BMIs were significantly higher (p-value <0.05; CI = −1.88 -0.30) on average (mean difference: 1.09 kg/m^2), albeit with higher variation around the mean (mean BMI_{wives} = 26.62 ± 5.13, mean $BMI_{husbands}$ = 25.53 ± 3.75).

Table 3
Descriptive statistics based on survey of rural farming households in Tunisia.

Reported and calculated variables	Rural Farming Communities in Tunisia (Jan–Feb & Sep–Oct 2023)			National DQQ Survey (Global Diet Quality Project) (Aug 2022)
	Women (n = 185, 27 %) (n_{BMI} = 102) Mean, SD	Men (n = 507, 73 %), (n_{BMI} = 317) Mean, SD	Total (n = 692) (n_{BMI} = 419) Mean, SD	Total (n = 1000)
Global Dietary Recommendations (GDR)[w] (Score range from 0 to 18)	10.58 ± 1.74***	11.11 ± 1.80	10.97 ± 1.80	10.3
Distance from Fresh Market (km)[w]	9.83 ± 4.97	9.39 ± 5.94	9.54 ± 5.68	–
NCD-Protect (score range 0–9) [w]	2.23 ± 2.07***	3.14 ± 2.10	2.90 ± 2.13	3.7
NCD-Risk (score range 0–9) [w]	0.65 ± 1.19**	1.03 ± 1.68	0.93 ± 1.58	2.4
Dietary Diversity (score range 0–10)[s]	3.98 ± 2.39***	5.31 ± 2.36	4.96 ± 2.44	6.7
Body Mass Index (kg/m^2)[s]	26.07 ± 4.87**	25.07 ± 3.48	25.29 ± 3.91	–
BMI = <18.5 (underweight)	4 %	1 %	2 %	–
BMI = 18.5–24.9 (healthy weight)	45 %	55 %	52 %	–
BMI = 25–29.9 (overweight)	30 %	36 %	35 %	–
BMI = 30+ (obese)	21 %	8 %	11 %	–
Education (number of school years)[w]	3.49 ± 3.77***	4.85 ± 4.249	4.49 ± 4.16	–
Age[s] (years)	49.42 ± 12.92***	53.44 ± 15.06	52.36 ± 14.62	–
Household Size[w]	3.66 ± 1.66	3.53 ± 1.53	3.57 ± 1.56	–
Belief that meat is necessary for health[c]	[Yes (46 %), No (54 %)]***	[Yes (62 %), No (38 %)]	–	–
Access to healthy food in local market[c]	[Yes (37 %), No (63 %)]	[Yes (45 %), No (55 %)]	–	–

*Notes: *p < 0.1; **p < 0.05; ***p < 0.01; [w]Wilcoxon test, [s]Student's T-Test, [c]* Chi-square test of independence.

Regarding the food groups of interest as per Planetary Health Diet's recommendations (Willett et al., 2019; Beal et al., 2023), of the 692 completed surveys, 13 %, 20 %, 24 %, and 62 % reported having consumed whole grains, nuts and seeds, legumes, and red meat/chicken, respectively, the previous day. Regarding the consumption of sugar-sweetened beverages, 74 % of 692 respondents reported having had at least one the previous day while 12 % reported having fruit juice or fruit drink, soda, and sugar-sweetened tea, coffee, or chocolate drink altogether.

A regression analysis was conducted (Table 4), to examine the associations among measured foodscape variables, such as distance from markets, modifying variables, such as share of children in the household, and health outcome indicators, such as dietary diversity scores.

The regression models show that older age and being a woman were significantly and positively associated with BMI. The price of health-protective and health-risking food groups had a significant positive association with both food groups' consumption scores, GDR, and dietary diversity. Selecting price as a strong influencer of food choice indicated that respondents concerned about price more than other influencers had a higher intake of NCD-Risk foods and reduced intake of NCD-Protect

Table 4
Result of the regression analyses to measure the associations among foodscape and personal variables and health outcome indicators based on household survey data in four rural communities in Tunisia.

Type of Model	Dietary Diversity	NCD-Protect Foods Consumption	NCD-Risk Foods Consumption	Global Dietary Recommendation	Body Mass Index
	Poisson Regression	Poisson Regression	Poisson Regression	Poisson Regression	Linear Regression[e]
–	Coef. (SE)	Coef. (SE)	Coef. (SE)	Coef. (SE)	Coef. (SE)
Intercept	−0.225 (0.407)	−3.628*** (0.542)	−5.513*** (1.348)	1.727*** (0.259)	19.527*** (4.103)
Dietary Diversity Score (range from 0 to 10)	–	–	–	–	−0.046 (0.108)
Global Dietary Recommendation (range from 0 to 18)	–	–	–	–	−0.085 (0.13)
Dietary Education Received (yes OR no)	0.103* (0.053)	0.069 (0.069)	−0.128 (0.141)	0.029 (0.035)	0.575 (0.649)
Health Status Rated as Bad or Very Bad (compared to neutral)	−0.164*** (0.058)	−0.268*** (0.079)	−0.752*** (0.18)	−0.027 (0.037)	−1.177* (0.615)
Health Status Rated as Good or Very Good (compared to neutral)	−0.171*** (0.039)	−0.254*** (0.052)	−0.406*** (0.094)	−0.03 (0.026)	0.383 (0.451)
Strongest Meal Influencer: Family[a]	0.218 (0.28)	0.025 (0.32)	1.105 (1.017)	−0.089 (0.176)	2.177 (2.365)
Strongest Meal Influencer: Food environmental factors[b]	0.067 (0.277)	−0.165 (0.316)	0.782 (1.015)	−0.085 (0.172)	1.582 (2.313)
Strongest Meal Influencer: Personal factors[c]	−0.176 (0.275)	−0.512 (0.314)	0.167 (1.014)	−0.111 (0.17)	−0.591 (2.282)
Strongest Meal Influencer: Price	−0.025 (0.273)	−0.302 (0.31)	0.201 (1.011)	−0.067 (0.169)	1.189 (2.254)
Price of NCD-Protect Foods	1.923*** (0.322)	3.704*** (0.431)	3.138*** (0.868)	0.594*** (0.215)	3.995 (3.869)
Price of NCD-Risk Foods	1.388*** (0.181)	3.892*** (0.278)	4.948*** (0.555)	0.510*** (0.114)	0.215 (2.301)
Age (years)	−0.003** (0.001)	−0.005*** (0.002)	−0.016*** (0.003)	0.0001 (0.001)	0.036** (0.016)
Gender Women (compared to Men)	−0.201*** (0.044)	−0.161*** (0.059)	−0.075 (0.108)	−0.03 (0.028)	1.296*** (0.474)
Distance from Fresh Market[d] (km)	−0.021*** (0.003)	−0.031*** (0.004)	−0.061*** (0.008)	−0.002 (0.002)	−0.039 (0.202)
Formal Education (years)	0.013*** (0.005)	0.017*** (0.006)	0.052*** (0.01)	0.0001 (0.003)	0.051 (0.049)
Household Size (persons)	0.014 (0.013)	0.019 (0.016)	0.026 (0.03)	0.003 (0.008)	0.691 (0.512)
Share of Children in Household	0.006 (0.099)	−0.02 (0.13)	−0.505** (0.221)	0.043 (0.068)	1.881* (1.079)
Observations (n)	686	686	686	686	419
Log Likelihood	−1438.30	−1269.37	−860.688	−1533.00	–
Akaike Inf. Crit.	2908.60	2570.74	1753.38	3098.00	–

*p < 0.1; **p < 0.05; ***p < 0.01.
[a] Dummy variable for 1.children, 2.spouse, & 3.elderly in the family.
[b] Dummy variable for seasonality, availability in market, food produced by own or neighbouring farms.
[c] Dummy variable for selecting food for energy, beauty, health, taste or discovery, ease of preparation.
[d] Squared values used for BMI model to adjust for skewed data.
[e] $R^2 = 0.1063$, Adjusted $R^2 = 0.0661$, Residual SE = 3.794 on 400 degrees of freedom, F Statistic = 2.644 on 18 and 400 DF, p-value <0.01.

foods.

4.5. Food beliefs regarding human and environmental health

Focus group discussions (FGDs) were conducted to understand local perspectives on foodscapes, particularly how they relate to personal and environmental health. Participants shared their beliefs and experiences as both food producers and consumers. Fig. 2 illustrates the most frequently mentioned components of foods that participants perceived as beneficial for their health with Supplement 5 presenting participants' demographic data.

When asked about health-promoting food, participants did not appear to reflect on the environmental consequences of their selections. For example, in Sers, when asked whether any of the foods listed as health-promoting would cause environmental stress, the participants stated that "none" had any negative environmental impact. However, upon further probing, participants mentioned *idawi* or chemical treatment of plants having a negative environmental impact.

In exploring the concept of using legumes as meat alternatives, the participants stated that they consumed legumes in dishes like *"couscous, soups and mohammsa"* that are usually eaten in winter. Legumes were perceived as healthier alternatives to meat and relatively less expensive. They were also considered sustainable as they did not require a lot of water to grow. Female participants in Sers also mentioned the combination of meat and legumes increased the nutritional value of a meal. However, not all participants saw legumes as alternatives to meat. Some emphasized how "*Nothing replaces meat"* and that *"We know that meat is unhealthy, especially its fat, but we continue to eat it" (Male participant, Kesra)*. Similarly, of the 293 responses in the household survey, only 1 % mentioned legumes as a potential replacement for meat with majority providing no answer or saying they did not know. Some participants also mentioned the word '*Arbi*', referring to local or regional type of animal-sourced food like chicken. This connoted cultural pride. There also appeared to be a strong sense of pride and positive health associations with organic food.

An interesting finding was how sugar-sweetened foods, like *aseeda* (a pudding) and *bsisa* (mix of roasted grains, legumes, and nuts sweetened with sugar) were perceived as health-promoting, while commercially packaged products were considered health-risking, because "there is more sugar in them" (Female participant, Makthar). Searching for recipes and discussion with locals indicated that many sweet dishes were traditionally made with honey, which has been replaced with sugar. This, however, did not surface in the FGDs. The use of timeline mapping tool triggered discussions about changes such as increased canned foods being unhealthy and unavailability of plants previously foraged for human consumption. The FGDs, in general, revealed important insights into food beliefs about health-promoting and health-risking foods that participants see in their foodscapes.

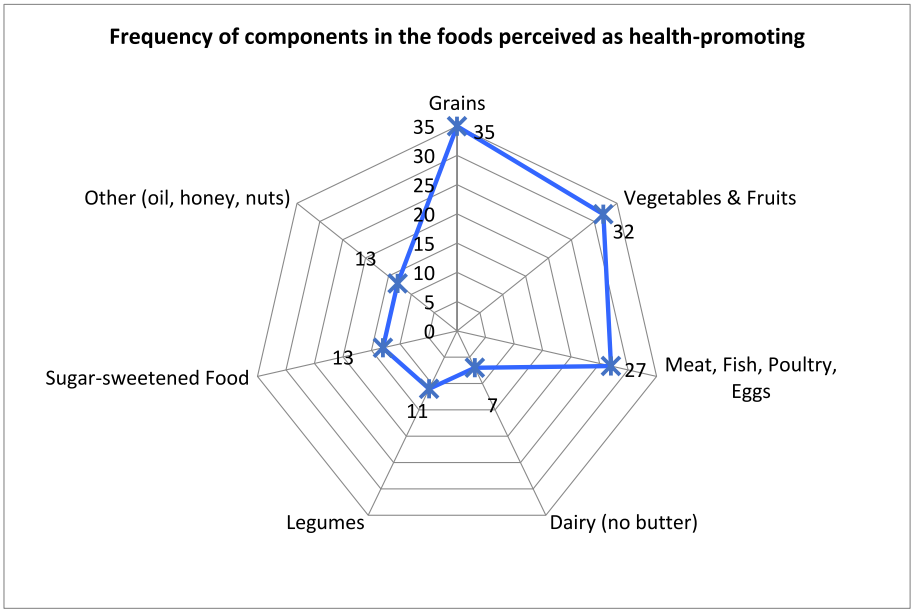

Fig. 2. Frequency of appearance of the listed type of food components in the list of the healthy foods as perceived by participants in focus groups (38 participants) across four rural communities (adapted with permission from (Sabir, 2023)).

4.6. Other socio-economic aspects of foodscapes explored

Market availability and the price of food were not the only factors influencing diets. Socioeconomic aspects of the foodscapes that emerged as influencers of nutrition outcomes included social roles and market arrangements related to food production. The interplay of socially assigned roles for women and men and household caring responsibilities influenced meal preparation decisions. Findings from FGDs showed that mainly women oversaw food preparation. FGD participants in all communities pointed to children influencing the choice of meals prepared by mothers, because they feel emotionally hurt when children do not like the food. Male participants indicated that women were influenced by their circle of relatives and friends and television programs. Female participants pointed to shortage of time, compared to their youth or childhood years when women had more time for processing grains to make whole-grain bread. Other dietary influencers included availability and accessibility of health-promoting foods, food price, religious and traditional food-related customs, ease of preparation and flexibility of an ingredient and knowledge or competency in preparing certain food items. Male participants pointed to women and children being the major food decision makers in their households while women presented their duty to cater to children's food preferences and elderly family members' health as strong social determinants of the meals they prepared.

Participants acknowledged religion's role in influencing dietary practices. In one group participants pointed that more food was wasted during Ramadan, a month for fasting, compared to other months. However, participants also stated that their religion's teachings were against food waste. Furthermore, although not clearly mentioned as stemming from religion, some food items that participants perceived as health-promoting, such as olive oil, honey and figs are indeed foods mentioned positively in Quran.

Critical observations about changes in labor and market arrangements shared in FGDs pointed to poor nutrition outcomes. For example, olive harvesters were paid in cash rather than oil, which lowered their consumption of olive oil. Meanwhile, dairy farmers were paid by milk collectors who brought forage as part of the payment for milk. This made milk unavailable for private sale in farmers' neighbourhoods. Thus, participants' dietary choices were shaped by socio-religio-cultural factors and changes in economic arrangements for food production that contributed to shaping participants' foodscapes and dietary outcomes.

5. Discussion

This study showcases a systematic approach in assessing foodscapes that included a systematic observation of the marketplace and restaurants, a dietary quality and demographics survey of the target population, food beliefs, perceptions of sustainable diets, and consumer-oriented dietary determinants. The use of multiple data sources in convergent parallel mixed-methods design, highlighted as a requirement for the study of foodscapes (Turner et al., 2018; Caspi et al., 2012), helped triangulate findings assessing different aspects of foodscapes. Tools employed in this study enabled collection of data on food environmental factors such as price and availability of NCD-Protect and NCD-Risk food groups, socio-religio-cultural.

5.1. Consumer behavior determinants

Overall, both mean BMI and the prevalence of obesity were lower among the studied population compared to other studies in Tunisia (El et al., 2012; Tlili et al., 2020). The difference may be explained by higher physical activity in farming, reliance on public transport, and less availability of high-calorie street foods in rural compared to urban areas (Steyn et al., 2014).

It is unclear whether the perceived negative effect of children's food preferences influence actual food consumption. This can be related to the limitation of the DQQ as it captures only one day's food intake and indicates number of food groups consumed rather than quantities of food.

Formal education also showed significant and positive relationships with the consumption of NCD-Protect foods and dietary diversity; yet also with NCD-Risk foods. Since education typically has a positive correlation with income (Card, 1999), it may be the higher purchasing power leading to a higher diversity of foods consumed, independent of their nutritional profile. This significant association with both NCD-Protect and NCD-Risk food groups may also explain the insignificant association between BMI and formal education. The evidence for education leading to normal-range BMI attainment has not been conclusive (Kim and Roesler, 2017) although one review has shown female's education to have a desirable effect on BMI (Brunello et al., 2013). However, the review was restricted to European countries with different cultural, economic and environmental factors compared to

those of Tunisia. Higher education also does not directly translate to nutrition education, which is why the latter was included in the survey as a factor with the potential to influence dietary quality. Its marginally significant positive association with dietary diversity and a nonsignificant negative association with health-risking food groups' consumption show dietary counseling's effect to be a promising intervention. The lower number of respondents who had received dietary education (14 %) may have obscured the significance of this factor. Considering how the advice from health care professionals was suggested in FGDs as potentially effective in shaping dietary habits, attention to preventative medicine can be an area for further action (Keyworth et al., 2020).

The effect of religion on food choice was acknowledged regarding fasting and special religious festivals. However, what was not acknowledged yet noted was the inseparable effect of religion and culture on being hospitable and showing generosity to guests, as in the example of food waste in Ramadan where people invite guests for breaking the fast meal. What was overlooked was the act of generosity and hospitality as a religious and social obligation for Muslims (Ayoub, 2005) that could have led to more food waste. Also, the mentioning of foods referred to in Quran in positive terms, such as healing connected to honey, emerged as health-protecting foods yet their connection to religion was not voiced. Religious messages often merge with cultural beliefs and their origins become less consciously discerned over time (Abdulla, 2018). Thus, the interplay between religious beliefs and cultural practices continue to shape food-related beliefs implicitly.

Another unexpected result was the share of children in the household being negatively associated with NCD-Risk food consumption. Children's food preferences were noted in FGDs as negatively influencing participants' meal plans. However, the share of children in the household did not show any significant negative association with participants' dietary diversity. On the contrary, households with a higher share of children had a significant negative association with NCD-Risk food groups' consumption. Meanwhile, it showed a non-significant negative effect on the number of NCD-Protect food group's consumption. It may be that the number of health-risking foods showed a decrease, because parents might have had a lower food budget limiting their health-risking food consumption, or because the health-risking food was kept for children, whose dietary information was not collected in this study. There could be other uncaptured factors by DQQ since this tool excludes food quantity measurements. For example, the fact that over half of the participants had consumed meat or chicken does not show the quantity of the meat that was consumed.

The perceived importance of meat in this study can be traced to its traditional consumption as a main source of nutrition for North Africans (Gagaoua and Boudechicha, 2018). A systematic review documents the deep cultural significance of meat and animal products in Africa highlighting how meat is not only a source of nutrition but also a valued cultural asset that features in social, religious, and symbolic practices (Williams et al., 2025). Therefore, changes in this regard are bound to encounter resistance. Also, quantities and type of meat used should be considered when comparing consumption to Planetary Health Diet's recommendations. Thus, cultural factors, including implicit religious beliefs, combined with formal and dietary education, and household composition should be considered in designing nutrition interventions in rural Tunisia.

5.1.1. Gender

Gender disparities in formal education, obesity, dietary diversity, and roles within the food system reflect broader structural inequalities affecting women's health and nutrition in rural Tunisia. In fact, Tunisian women have been reported to have the highest obesity rates in the region (Tlili et al., 2020). A factor contributing to lower BMI for men compared to that for women may be the higher rate of smoking among Tunisian men (Cherif et al., 2022) than that among women. Smoking can lower food intake leading to lower BMI (Chao et al., 2019), albeit increasing the need for some micronutrients due to the oxidative stress caused by smoking (Northrop-Clewes and Thurnham, 2007). However, men's smoking in a household can also expose women to negative effects of smoke inhalation as was seen in the case of a person smoking during a FGD in addition to women's exposure to smoke if they chose to bake bread in wood-heated furnace (Hamdi et al., 2023).

Women were disadvantaged regarding their dietary diversity, specifically regarding the consumption of NCD-Protect food groups, although NCD-Risk food groups' consumption was not significantly different between women and men. FGDs showed that the poor consumption of whole grains was attributed to women's time poverty pointing to the general trend of no reduction in domestic workload for women despite their increased engagement in formal employment that has been recognized in other contexts (Hyde et al.). The absence or higher price of processed whole grains and whole grain products compared to refined grains, observed in the markets, was not mentioned in the FGDs. Whether the respondents, who were farmers themselves, felt powerless to influence the food processing and availability of products in the market, requires further inquiry. The EPOCH tool did not capture gendered participation in the foodscape. The participation of women in the markets, restaurants, and supermarkets as sellers and buyers can be easily integrated into EPOCH. This was considered important to note as the gender of sellers have a differential effect on the type of food sold as shown elsewhere (Ambikapathi et al., 2021). Participation of women in the marketplace was noted as per researchers' observations, recalled after the data collection period and supplemented by the pictures taken during the market survey. This did not allow for precise assessment of differences among the markets due to recall bias. Nonetheless, the presence of women as workers in family-owned businesses or cashiers in supermarkets may indicate low-paying jobs or informal labor, which has been demonstrated by another study in rural Tunisia in the context of women in farming households (Gaillard et al., 2022).

5.2. Food price as a driver of consumer behavior

Food price had a significant association with the type of food consumed in this study. The positive association of concern over food prices and NCD-Risk food groups intake reflected the previously acknowledged link between poverty and health-risking foods (Chen, 2016; Vilar-Compte et al., 2021). The higher price of NCD-Protect and NCD-Risk food groups having a positive relationship with their consumption was unexpected. It may be due to omitted variable bias (Cinelli and Hazlett, 2020) such as participants' access to vegetables by growing them or acquiring them at a different price from other farmers informally or higher dietary diversity being linked to higher average prices of foods in the market with more imported foods available or variations in participants' income, which was not collected. These and possibly other factors could distort the model's accuracy overall. To enable an overview of how much a health-promoting sample diet for an average healthy man and a woman would cost, the food prices collected in January were used to design a generic culturally and nutritionally appropriate diet that fit within the Planetary Health Diet (Willett et al., 2019) boundaries. The high quantity of foods of animal origin was selected due to potentially micronutrient inadequacy of the Planetary Health Diet (Beal et al., 2023), high prevalence of iron-deficiency-anemia (Doggui et al., 2020) and cultural preference for foods of animal origin and beliefs about meat being necessary for health as indicated in FGDs as in household surveys. Considering that the guaranteed minimum agricultural wage (Salaire Minimum Agricole Garanti (SMAG)) (Caisse et al.) in 2023 was 441.6 TND per month, the cost of the sample diet for a single adult would be a large proportion of over 50 % to over 60 % of SMAG for an adult female and male, respectively. The observed low consumption of legumes and the knowledge that these can be used as substitutes for meat from a nutritional perspective is an area for intervention that can help in both lowering food expenditure and improved environmental sustainability

in addition to the health benefits this food group confers in fighting obesity and chronic disease prevention (Rebello et al., 2014). Promoting legumes can be expected to be facilitated as it is not a novel food and are perceived positively for their environmental sustainability profile and culinary acceptance, as highlighted in FGDs.

5.3. Food environmental factors influencing consumer behavior

The food availability assessment showed that the fresh market was the main source of vegetables, fruits, and legumes. These markets were near butcher shops and convenience stores, many of which sold grains, legumes, spices, nuts, and oil. The tool did not capture foods from kitchen gardens or produce acquired informally. A component for assessing the informal ways of food acquisition would provide a more wholesome picture of the foodscape, particularly in the context of farming households. Asking respondents where they obtained the food they reported having consumed in the dietary survey can capture this in the household survey. This method can also be used to obtain the cost of food. However, bartering or consuming food from one's own garden would distort food price data. Regarding the restaurant food availability, dairy, and legumes were lacking or offered minimally. There was only one type of salad commonly available despite the abundance of various types of vegetables observed in the market. This may be due to poor demand or perceptual value for these types of food compared to meat and chicken-based menu items, as was confirmed in FGDs and the household survey responses. Assessing one restaurant per locality suffers from selection bias based on an assumption that the selected restaurant was highly frequented. Including different types of restaurants can help provide a better understanding of the restaurant food environment. Selecting a popular family restaurant identified in FGDs can help reduce selection bias and help explore reasons for participants' choice of a restaurant. Furthermore, a standardized tool assessing sustainable food choices in restaurants and street food carts in LMIC context would be desirable to allow for foodscape comparisons.

The use of timeline mapping tool (Kolar et al., 2015) in FGDs triggered reflection among participants on the increased duties of women affecting health-promoting food preparation negatively and the changing foodscapes in both natural settings with perished food foraging possibilities and in commercial food settings with more processed foods' availability. This tool can be used in participatory-action research to induce not only reflection on the past, but also to build a collective future vision. This potential of the tool can be harnessed in vertical FGDs including not only farmers, but also food processors and policy makers.

Accessibility was assessed by the existence and frequency of public transportation, paved highways connecting villages to the rural areas' centers, and the distance between respondents' residences and the closest fresh market. Weekly markets in central locations, supported by transportation and highways, influenced food acquisition. Despite operating for only 4 h until noon, participants did not find market hours inconvenient for accessing fresh produce. However, fermented milk was noted in FGDs and confirmed by the market survey as less accessible. Local stores offered refrigerated sugar-sweetened yogurt and drinks, potentially contributing to high sugar consumption. The restaurant survey found no price difference between soda and water, offering no economic incentive for choosing water. Government-levied price cap kept sugar price low, which may have contributed to increased use of sugar by industry and households. Shifting subsidies for sugar to subsidise legumes or whole grains can help not only population health, but also support local production and processing industry. However, this can also risk public unrest if the change causes caloric insecurity.

Distance from the fresh market was negatively associated with dietary diversity and consumption of health-risking food, which are related to negative and positive nutrition outcomes. Confirming this, FGD participants also pointed to the difficulty in accessing healthy foods as a barrier to regular consumption. The significant association between formal education and consumption of both health-protecting and -risking food groups in this study has been shown in the context of UK as well This may reflect higher income associated with formal education (Yang and Qiu, 2016) easing access to health-risking foods and diverse health-promoting food groups. This stands in contrast to some studies that show higher formal education is related to more healthful eating (Azizi et al., 2021). Considering that women were identified as primary food preparers, had lower education level than men, the education level may have been inadequate in influencing food choices. Determining minimum years of formal education to allow for adequately positive nutrition outcomes can guide effective conjoint health and education policies.

Another element of the food environment, food advertisements in stores, restaurants, and fresh market areas, displayed mostly health-risking food and beverages. Numerous empty spaces were noted, which could be used to promote positive health and nutrition messages that may positively affect health behavior (Yousef et al., 2023). Data on digital food advertisements targeting young adults and children potentially influencing the next generations' food behaviors (Demers-Potvin et al., 2022) was, unfortunately, not collected, which should be incorporated in future studies.

5.3.1. Food value chain

Most of the foods with identified country-of-origin being Tunisia point to the in-house policies having a higher impact on food markets than food import policies. The market survey was limited in evaluating the food value chain. A comprehensive assessment would include elements ranging from agricultural inputs for food production to governance and policy including issues related to labor conditions and market structures (Trienekens, 2011). A foodscapes assessment can contribute directing these structures.The inclusion of restaurants and street food in the foodscape's assessment using the adapted version of EPOCH was advantageous as it allowed for providing an overview of the type of foods commonly served in these outlets. The almost invisible inclusion of legumes, dairy, except cheese, and whole grain products as well as inadequate amounts of vegetables and no fruits in restaurant and street food carts, the ready-to-eat food environment appeared unsupportive of health and environmental sustainability. In light of the FGDs, the type of foods in the restaurants appear to reflect the food beliefs of participants regarding meat, which shows how foodscapes can also be shaped by consumers (Park and Widyanta, 2022). The social equity aspect of sustainable diets as per the observed value chains could not be ascertained with EPOCH. Therefore, data on the origin of foods that were priced was collected simultaneous to the markets and supermarkets' survey. Nonetheless, the existence of locally produced, processed, and distributed food products, as observed in the products surveyed, has been pointed out to be relevant to socio-economic and territorial sustainability (Luzzani, 2022).

5.4. Limitations

While some of the specific limitations of the study have already been pointed out, a few general shortcomings are discussed here. The systemic political and technological factors influencing the foodscape could not be captured well with the methods and tools used in this study. A foodscape study that aims at guiding food trade policies or technologies that affect the food value chain, would require different type of data to assist decision-making. However, this study provided an adequate picture of locality-level factors associated with nutritional health, which not only contributes to data for effective policy decision-making, but more specifically, provides data that can guide locality-based interventions. One of the limitations noted was inadequate observational data on conversations prevalent in foodscapes. This would provide an enhanced picture of the culture and contribute to discourse analysis regarding food and consumption and associations with different foodscapes.

The EPOCH tool partially captured a static cross-sectional view of

foodscapes. Foodscapes, however, constantly change as they are subject to volatile prices and food commodities that become available in different seasons. Restaurant and supermarket assessments were limited to a single restaurant per locality, which may not be representative, although efforts were made to select family restaurants that were centrally located catering to middle-income customers. Selecting different types of restaurants can provide a better picture. Another point noted regarding the food-value-chains assessment was the lack of data on food packaging, which is of relevance for sustainable diets both from a food safety and environmental health perspective. This information should be incorporated in EPOCH for food sustainability assessments. Assessing the environmental- and health-sustainability aspects of the diet requires quantification of the food, which was not possible with the DQQ tool. Multiple 24-h recalls can provide a better assessment in this regard.

In assessing the associations among foodscapes and personal variables and health outcomes, the models presented are limited to the identified variables only. For example, the variables in the model for BMI can only explain 10 % of the BMI variation in the data. This means that there are other factors associated with BMI that have not been captured, such as smoking, long-term dietary intake, socio-economic status, and physical activity, which could improve the model (Eljamay et al., 2022). Similar concerns pertain to other models. Future studies can help in detecting consistencies in patterns.

Furthermore, BMI as a health indicator has inherent limitations, as it does not measure body composition and the classifications may not be equally applicable to different races regarding chronic disease risk (Sweatt et al., 2024b). Considering that health is not limited to physical, but entails mental, social and spiritual aspects, the use of BMI can be critiqued as biodmedical reductionism. Nonetheless, BMI can be used as a screening tool for population rather than clinical nutrition interventions due to its practicality in large-scale studies, where self-report data for measures other than height and weight is unlikely to be available. It was also complemented by other health outcome indicators like dietary intake of both health-protecting and health-risking food groups.

A challenge faced during the study was in assessing gender equity and participation in the foodscape. Systematic observations regarding women's participation in the tools used were missing. Pictures and researcher observations helped in understanding the gender dynamics in the marketplace to some extent. This should be integrated in the market survey tool. While this study illuminated key locality-level factors shaping nutritional health and food beliefs, addressing the identified gaps in capturing the drivers of nutritional health will be essential for a comprehensive understanding of foodscapes.

6. Conclusion

This study of foodscapes provided a rich description of how to practically assess foodscapes at a locality level in a low-medium-income country setting. The use of convergent parallel mixed methods allowed for the comparison of qualitative and quantitative data regarding the socio-economic aspects of foodscapes influencing nutritional outcomes. Market observational tools specific to food availability, price, and quality contributed to a better understanding of foodscapes at the locality-level. Meanwhile restaurant observation tool and food advertising observations complemented the foodscapes understanding in relation to sustainable food outcomes focused on human health. Considering the consumption of foods that decrease and those that increase the risk of non-communicable diseases offered a better view of the effect of personal and environmental factors embedded in the foodscapes. Age, gender, education, distance to fresh market, share of children in the household composition, and various influencers of meal decisions appeared to be associated with the nutrition outcomes measured. Women appeared to fare worse than their male counterparts regarding their BMIs, dietary quality indicators, and education. They also appeared to contribute to a lesser degree than men to the shaping of marketplaces. Future research should include digital foodscapes in assessments of foodscapes, as their influence is expected to increase and use a practical tool to assess food advertising and its influence. Overall, the methods and tools employed in this study provided a sufficiently detailed understanding of foodscapes, albeit with certain limitations that could be addressed through the inclusion of specific additional data.

CRediT authorship contribution statement

Ghezal Sabir: Writing – review & editing, Writing – original draft, Visualization, Methodology, Data curation, Conceptualization. **Lina M. Tennhardt:** Writing – review & editing, Visualization, Validation, Software, Formal analysis. **Veronique Alary:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation, Data curation. **Aymen Frija:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

Authors' attestation

All authors agree with the contents of the manuscript and its submission to Food Security journal. A part of the findings has been published in a report titled "Mapping Foodscapes for Dietary Change to Promote Sustainable Diets in Rural Farming Communities in Tunisia" (Sabir, 2023; Beirut, Lebanon) on ICARDA's website. No part of the research has been published in its current form elsewhere. The manuscript is not being considered for publication elsewhere while it is being considered for publication in this journal. Any research in the paper that was not carried out by the authors has been referenced in the manuscript.

Compliance with ethical standards

The authors have no competing interests to declare that are relevant to the content of this article. All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional research committee at ICARDA. The data collection tools and procedures were designed in accordance with the research ethics guidelines of the International Center for Agricultural Research in the Dry Areas (ICARDA) in Tunisia, thus protecting personal data in all its forms. Written consent was obtained from all focus group and household survey participants. Oral consent was obtained in the presence of two researchers from all shop and restaurant owners if pictures of food advertising inside or outside their premises were to be taken. Focus group participants were assigned numbers so none of the participants' names were used in transcribing audio recordings.

Data availability

Data for this study is part of a larger dataset, i.e. meta-data, which will be made publicly available by International Centre for Agricultural Research in Dry Areas (ICARDA).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2025.103520.

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