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Evaluation of the nutritional quality of snack bars available in the Turkish market using Nutri-Score: A cross-sectional study

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ABSTRACT

Despite the worldwide popularity of snack bars, the lack of nutritional data for the Turkish market highlights the need for localized assessments. This study aimed to evaluate the Nutri-Score profiles of 237 snack bars available in Türkiye and compare these profiles across different product categories (protein, fruit & nut, whole grain/oat, and functional/active/energy). In this analysis, Nutri-Score categories (A to E) were calculated from nutrition label data, and statistical analysis was performed using Kruskal-Wallis tests. 82.7 % of Turkish snack bars were classified as Nutri-Score C–D–E. Protein bars fell into Nutri-Score categories C (45.9 %) and D (27.6 %), whereas fruit & nut bars were mostly categorized as D (62.9 %). Significant nutritional differences were observed among the categories. Protein bars had the highest saturated fat content and the lowest sugar content. Fruit & nut bars had the highest sugar content. Whole grain/oat bars had the highest salt content among all the products. In conclusion, the significant nutritional variability among snack bars in Türkiye, driven by sugar and saturated fat content, suggests a need for targeted product reformulation and improved front-of-pack nutritional labeling.

1. Introduction

Recently, snack bars have become an increasingly prominent component of global dietary patterns, accompanied by significant market expansion (Haş et al., 2023; Klerks et al., 2022). Initially developed for athletes, these products are now widely consumed by individuals seeking convenient meal replacements and portable snacks (Haş et al., 2023; Loveday et al., 2009). This growing popularity is largely driven by evolving consumer preferences for convenience and health-oriented marketing claims, which often position snack bars as healthier alternatives to traditional confections (Williams and Mummery, 2013). Accelerated lifestyles, increasing health awareness, and innovations in product formulation, particularly those involving protein fortification or functional ingredients, have further reinforced this trend (Curtain and Grafenauer, 2019; Uliano et al., 2024).

Despite the common perception of healthfulness, the "health halo," the nutritional composition of snack bars exhibits significant variation. Many products contain significant amounts of added sugar, fat, and sodium to improve their palatability, texture, and shelf life (McKeon and Hallman, 2024; Mediano Stoltze et al., 2021). Analyses indicate that sugar levels are often in the range of 20–30 g per 100 g, often accompanied by significant amounts of saturated fat and sodium. However, it is also true that some bars provide valuable nutrients such as fiber, especially versions containing whole grains, nuts, or dried fruits, highlighting the diverse nutritional landscape within this product category (Curtain and Grafenauer, 2019; Klerks et al., 2022; Szydłowska et al., 2022). As consumer interest in health and product functionality increases, high-protein and functional snack bars have become increasingly popular (Tormási et al., 2025; Uliano et al., 2024). These functional variants often contain additional bioactive components, such

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as vitamins, minerals, and fiber, and are marketed with claims of specific health benefits (Sun-Waterhouse et al., 2010; Uliano et al., 2024). However, although these claims are in line with broader nutritional trends, they do not always reflect a reduction in nutrients of concern, such as sugars or saturated fats (Tormási et al., 2025).

Front-of-pack (FOP) nutrition labeling systems have been introduced internationally as tools to aid consumers in making more informed decisions. Among these, the Nutri-Score, developed in France, has gained widespread recognition. It uses a five-category, color-coded system underpinned by an algorithm that assesses nutritional content per 100 g (Dréano-Trécant et al., 2020; Chantal and Hercberg, 2017). The calculation balances points awarded for less desirable components (energy, sugar, saturated fat, and sodium) with points for beneficial components (protein, fiber, fruits, vegetables, and nuts) (Chantal and Hercberg, 2017). Adopted on a voluntary basis by several European countries, the Nutri-Score has been shown to be effective in enabling consumers to quickly assess nutritional quality (Egnell et al., 2020; Steering Committee, 2024; Stiletto et al., 2024). In addition, research indicates that the Nutri-Score not only has a positive impact on consumer purchasing habits but can also motivate manufacturers to improve product formulations (Hau and Lange, 2023; Roberto et al., 2021).

However, the Nutri-Score system is not used in Türkiye, and existing FOP labeling is voluntary and non-standardized. Consequently, there is a significant gap in the systematic evaluation of the nutritional quality of snack bars in the Turkish market using an internationally recognized framework. The present study addresses this gap by focusing specifically on snack bars, a product category selected for several reasons. First, this category offers one of the clearest examples of the "health halo" phenomenon (Fernan et al., 2018; McKeon and Hallman, 2024), making it an ideal context for examining discrepancies between consumer perceptions and the actual nutritional quality of products. In addition, because these products are heavily marketed to health-conscious consumers, the need for accurate and transparent nutrition information is particularly critical in this segment. This study is the first to systematically assess Turkish snack bars using the internationally recognized Nutri-Score system, addressing a critical gap in local nutritional evaluation research. Recent international studies have highlighted similar nutritional variability in snack bars and emphasized the necessity of improved nutritional labeling systems (Hasan Yusuf and Pérez-Jiménez, 2021; Klerks et al., 2022), further motivating the present investigation in the Turkish market context. It was hypothesized that there is considerable heterogeneity among snack bars in Türkiye, which would be reflected in their Nutri-Score distributions. Furthermore, lower Nutri-Score scores were expected to be strongly correlated with higher levels of key nutrients of concern, especially sugar and saturated fat. Accordingly, this cross-sectional study had two main aims. The first aim was to evaluate and classify the nutritional quality of snack bars available in Türkiye using the Nutri-Score algorithm. The second was to identify the main nutritional factors such as energy density, sugar, saturated fat, sodium, fiber, and protein, that determine these classifications. The results provide evidence-based insights for Turkish consumers, support future FOP labeling initiatives, and inform industry-level reformulation strategies.

2. Materials and methods

2.1. Sample selection and data collection

A cross-sectional study design was employed to evaluate the nutritional profiles of the snack bar products available in major supermarket chains across Türkiye. The study sample consisted of 237 products categorized into four main groups: protein bars (n = 98), fruit & nut bars (n = 97), whole grain/oat bars (n = 30), and functional/active/energy bars (n = 12).

Products were systematically assigned to one of four groups using a content-driven classification that prioritized primary ingredients, with on-pack descriptors and nutritional data used as supporting evidence. The detailed inclusion criteria for protein, fruit & nut, whole grain/oat, and functional/active/energy bars are provided in Table 1. Core composition was prioritized over marketing claims; for instance, bars with a clear fruit-nut matrix marketed with "energy" descriptors were classified as fruit & nut bars. For products combining protein positioning with a fruit-nut matrix, the assignment was guided by Table 1. If a discrete protein source appeared within the first three ingredients, the product was classified as a protein bar; otherwise, it was assigned to fruit & nut bars. Fruit slices—dried-fruit bars with thin wafer layers—were included within fruit & nut bars when dried fruits and/or nuts were listed among the first three ingredients, noting their potential to elevate sugars due to concentrated fruit matrices. Chocolate-containing bars, such as coated or flavored variants, were kept within these categories rather than forming a separate group to maintain the focus on nutrient composition.

Nutritional information—energy, total fat, saturated fat, carbohydrates, sugars, fiber, protein, and salt—was collected from product labels obtained through online supermarket databases and in-person store visits conducted in Türkiye's well-established national and premium supermarket chains, which represent a major share of the packaged food retail market. Fig. 1 provides an overview of the data processing steps, including collection, cleaning, categorization, nutrient extraction, and analysis. All data were collected between September and November 2024 to ensure market representation.

It is important to note that the relatively small number of functional/active/energy bars (n = 12) in our sample reflects their limited market availability in Türkiye. During data collection, we aimed to capture the full spectrum of this group by surveying both online and physical retail channels. Additionally, products that could be marketed as energy bars but had a dominant fruit-and-nut matrix were classified as fruit & nut bars in line with the content-driven approach summarized above and detailed in Table 1.

2.2. Nutri-Score calculation

The Nutri-Score, developed by Chantal and Hercberg (2017), was calculated based on the nutrient values declared on the label per 100 g of each snack bar. The calculation involved assigning negative points (Point A; ranging from 0 to 10) for energy (kJ), sugar, saturated fat, and sodium, and positive points (Point C; ranging from 0 to 5) for fiber, protein, and the percentage of fruits, vegetables, pulses, and nuts (FVPN), in accordance with the official Nutri-Score algorithm (Supplementary Material, Figure S1). As sodium values were not available on the product labels, the sodium content was calculated by multiplying the declared salt content by 0.4, which assumes that all sodium originated from sodium chloride (NaCl). The overall Nutri-Score was calculated by subtracting the sum of positive points (Point C) from the sum of negative points (Point A) using the following formula: Final Score = Point A − Point C. The resulting scores ranged from –15 to + 40, from the healthiest to the least healthy. Based on this score, products were classified into five Nutri-Score categories: A (≤–1), B (0–2), C (3–10), D (11–18), and E (≥19). Several examples of the Nutri-Score calculation are shown in the Supplementary Material (Table S1).

In cases where data for certain nutrients (e.g., FVPN percentage or dietary fiber) were missing or incomplete, imputation procedures were applied based on the methods described by Hafner and Pravst (2021). Missing fiber values were set to zero, specifically for product subcategories with a mean fiber content of less than 0.9 g/100 g. Dietary fiber was estimated using the available nutritional information on energy and macronutrients for other products. The FVPN percentage was estimated from the ingredient list, or if insufficient information was provided, based on the regulatory minimum values applicable to specific product categories. For dried fruits and concentrated vegetables or pulses, the estimated FVPN percentage was adjusted by a factor of two to account for the ingredient concentration. Ingredient lists were used only

Table 1
Category inclusion criteria and tie-break precedence for the content-driven product classification.

Category	Definition / Primary rule (ingredient-based)	Supporting evidence (on-pack descriptors/ positioning)	Resolution of borderline cases
Protein Bar	Products were classified as protein bars when a concentrated protein source (e.g., milk/ whey/soy/pea/ collagen) appeared within the first three ingredients, or when the product was explicitly positioned as a "protein bar" and listed a discrete protein source among the leading ingredients.	"Protein"/"With Protein"; "High Protein" statements.	When both a fruit–nut matrix and protein positioning were present, products were classified as protein bars if a discrete protein source was listed among the leading ingredients; otherwise they were classified as fruit & nut bars. If the matrix was grain-based, products were classified as whole grain/oat bars.
Fruit & Nut Bar	Products with dates, nuts, and/or dried fruit listed within the first three ingredients, with no dominant grain base or protein isolate.	"Fruit Bar", "Kids Fruit Bar", similar descriptors.	Products marketed with "energy/active/ vitamin" descriptors but lacking ergogenic stimulants and having a fruit–nut matrix were classified as fruit & nut bars; products listing ergogenic stimulants (e.g., caffeine/ guarana) were classified as functional/ active/energy bars.
Whole Grain/Oat Bar	Products with oats/ whole grains/barley malt listed within the first three ingredients (i.e., a grain-based matrix).	"Granola", "Whole Grain", "Weetabix", etc.	Products referencing "protein" in the name were classified as whole grain/oat bars when the grain base was predominant.
Functional/ Active/ Energy Bar	Products emphasizing ergogenic/energy-enhancing constituents (e.g., caffeine/guarana) and/or marked vitamin–mineral fortification or explicit "active/ energy" positioning, and not primarily fruit–nut based.	"Energy", "Active"; caffeine/guarana; prominent vitamin–mineral claims.	Fruit bars with a clear fruit–nut matrix were not reassigned to this category unless ergogenic stimulants were present.

The precedence was set as the ingredient list (primary), on-pack descriptors (secondary), and nutritional information (supporting). "Chocolate-coated/ chocolate" products were not placed in a separate category; because the analytical focus was on nutrient composition, they were evaluated within the four existing categories.

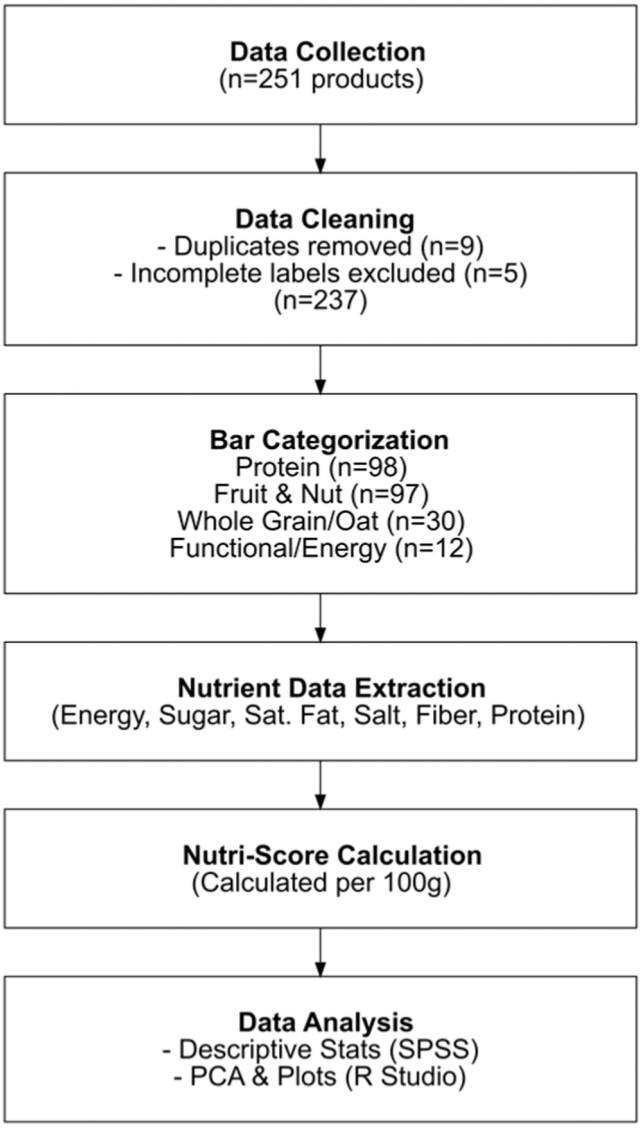


Fig. 1. Flowchart of data processing and analysis steps.

to compute the Nutri-Score FVPN component, relying on manufacturer-declared percentages when available and, when missing, the published imputation procedure, and no broader systematic ingredient-level coding was undertaken.

2.3. Ethical approval and research credibility

Ethics committee approval was not required for this study because all the data analyzed were collected from publicly available product labels. To increase the reliability of the data, two independent researchers performed data collection simultaneously but separately. The results were cross-checked and merged into a final dataset. The study was reported in accordance with STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

2.4. Statistical analysis and data visualization

Statistical analyses were performed using IBM SPSS Statistics (version 27.0; IBM Corp., Armonk, NY, USA) and RStudio software (version 4.4.3; RStudio, PBC, Boston, MA, USA). The distribution of Nutri-Score categories (A to E) and the nutrient composition of each bar type were determined. The normal distribution was tested using the

Shapiro-Wilk test. As the data were not normally distributed, the Kruskal-Wallis test was employed for group comparisons. Principal Component Analysis (PCA) was performed for exploratory visualization of nutrient co-variation. The biplot is provided in Supplementary Material (Figure S2). All statistical analyses were performed at a 95 % confidence level ($p < 0.05$).

3. Results

Table 2 summarizes the nutritional composition and the Nutri-Score values across the bar categories. Protein bars had the highest protein content (median: 25.1 g/100 g) compared to other bar groups ($p < 0.05$). Fruit & nut bars exhibited significantly higher sugar content (median: 39.0 g/100 g), whereas whole grain/oat bars contained higher salt content (median: 0.50 g/100 g) than other groups ($p < 0.05$). Energy content showed less variation across groups, although functional/active/energy bars exhibited the highest median value (416 kcal/100 g). Nutri-Score median values were comparable across groups, ranging from 8.0 to 9.0 points, mostly placing bars in categories C and D.

Fig. 2 illustrates the Nutri-Score distribution. Protein bars were mainly categorized as Nutri-Score C (45.9 %) and D (27.6 %), whereas fruit & nut bars were predominantly in category D (62.9 %). Functional/active/energy bars displayed the least variation, primarily in category C (75 %). Whole grain/oat bars had balanced distributions between categories C and D (53.3 % and 33.3 %, respectively). Green categories (A-B) were uncommon overall (17.3 %) and occurred most frequently among protein bars (25.5 %; 14 A and 11 B of 98), followed by whole grain/oat (13.3 %) and fruit & nut bars (12.4 %). No A-B products were observed among the functional/active/energy bars.

Fig. 3 illustrates the boxplot distributions of the nutritional parameters across the four snack bar categories. Protein bars displayed significantly higher protein content (median: 25.1 g/100 g) than fruit & nut (6.9 g/100 g), whole grain/oat (8.4 g/100 g), and functional/active/energy bars (11.5 g/100 g) ($p < 0.05$). Sugar content was highest in fruit & nut bars (median: 39.0 g/100 g), significantly differing from protein bars (22.9 g/100 g), whole grain/oat bars (25.0 g/100 g), and functional/active/energy bars (23.1 g/100 g) ($p < 0.05$). Whole grain/oat bars had significantly higher salt levels (median: 0.50 g/100 g) than fruit & nut bars (0.08 g/100 g) and protein bars (0.25 g/100 g) ($p < 0.05$). The saturated fat content differed significantly, being highest in protein bars (median: 4.0 g/100 g) compared to fruit & nut bars (1.7 g/100 g) and functional/active/energy bars (3.7 g/100 g) ($p < 0.05$). The fiber and energy content did not significantly differ across categories, reflecting similar nutritional profiles for these parameters ($p > 0.05$).

An exploratory PCA was conducted to visualize the co-variation among nutrients; the biplot is provided in the Supplementary Material (Figure S2). The first two principal components explained 55.2 % of the variance (PC1: 35.8 %; PC2: 19.4 %). Consistent with the univariate comparisons, the categories showed broad nutrient gradients with substantial overlap in the PCA space. Protein-oriented formulations were aligned with higher protein and saturated fat content, with substantial overlap across categories. Fruit & nut formulations aligned with higher sugar content on PC1, consistent with their ingredient matrices. Products classified as functional/active/energy showed higher energy density, grain-based products aligned with fiber, and salt contributed to limited discrimination at the category level. Products with a more favorable Nutri-Score (A-B) tended to have lower sugar and saturated fat contents and higher fiber content; the multivariate visualization is shown in Supplementary Material (Figure S2). On PC1, energy and saturated fat loaded in the same direction, while sugar loaded oppositely, indicating a trade-off across the products. The fiber was aligned with the grain-based profile, and salt showed a limited contribution.

4. Discussion

We first summarized the category-specific nutrient characteristics and subsequently related these patterns to the overall Nutri-Score distribution observed in the market. This study provides a comprehensive assessment of the nutritional quality of snack bars available in the Turkish market using the Nutri-Score nutrient profiling system. The results revealed considerable heterogeneity across product categories, with most items falling into less favorable Nutri-Score classes, mainly C and D. This finding raises significant public health concerns, as many snack bars marketed with health claims do not meet widely accepted nutritional quality standards. These findings are consistent with previous studies from European markets that reported similar patterns of sugar, saturated fat, and sodium levels in comparable snack products (Hasan Yusuf and Pérez-Jiménez, 2021; Klerks et al., 2022; Maalouf et al., 2017; Pallavi et al., 2015; Saraiva et al., 2024). Protein bars accounted for a significant proportion of the market and were characterized by their high protein content (median 25.1 g/100 g). Such products are commonly marketed as nutritious, fitness-focused snacks that are claimed to aid muscle maintenance, recovery, and synthesis (AlJaloudi et al., 2024). However, despite these beneficial properties, many protein bars contain high levels of saturated fat (median 4.0 g/100 g). Consequently, Fernan et al. (2018) observed that high protein content can create a “health halo,” leading consumers to overlook potentially high levels of other nutrients, such as saturated fat. This cognitive bias may lead consumers to underestimate the health risks associated with saturated fat intake, including cardiovascular complications. Therefore, while protein plays an important nutritional role, manufacturers should focus their reformulation efforts on reducing saturated fat to improve the overall nutritional profile of these bars. This issue is further complicated by health-centric marketing claims such as “high protein,” “fiber-rich,” “natural ingredients,” or “no added sugar” on snack bar packaging, which can mislead consumers. This phenomenon, widely documented as the health halo effect, often leads individuals to underestimate calorie density and nutrient content, negatively impacting their dietary choices (Fernan et al., 2018; McKeon and Hallman, 2024). Therefore, clear, standardized front-of-pack (FOP) labeling systems that reflect overall nutritional quality are critical for

Table 2
Descriptive statistics and Nutri-Score distribution across snack bar categories (n = 237).

	Protein Bars	Fruit & Nut Bars	Whole Grain/Oat Bars	Functional/ Active/Energy Bars
Number of product (n)	98	97	30	12
Number of brand (n)	22	17	9	6
Energy (kcal/100 g)	387 (358–406)	353 (334–406)	389 (364–424)	416 (370–445)
Saturated fat (g/100 g)	4.0 (2.3–6.3)^{a,b}	1.7 (0.8–3.5)^{a,c}	3.3 (1.6–5.1)	3.7 (2.6–5.9)^{b,c}
Sugar (g/100 g)	22.9 (5.6–30.6)^{a}	39.0 (33.5–46.5)^{a,b,c}	25.0 (15.0–31.0)^{b}	23.1 (13.8–26.3)^{c}
Salt (g/100 g)	0.25 (0.09–0.40)^{a,b}	0.08 (0.02–0.20)^{a,c}	0.50 (0.17–0.63)^{b,c}	0.21 (0.05–0.55)
Protein (g/100 g)	25.1 (20.0–30.0)^{a,b,c}	6.9 (4.9–8.9)^{a,d}	8.4 (6.7–12.1)^{b}	11.5 (7.8–16.0)^{c,d}
Fiber (g/100 g)	8.0 (5.3–11.1)	10.0 (7.7–13.0)	7.0 (5.5–9.6)	11.2 (7.3–12.9)
Nutri-Score	8.0 (1.0–11.0)	8.0 (4.0–11.0)	9.0 (7.0–11.0)	8.5 (7.0–10.8)

Values are expressed as median (25th–75th percentile). Different lowercase letters in the same row indicate statistically significant differences between groups ($p < 0.05$), as determined by Kruskal–Wallis test with multiple pairwise comparisons.

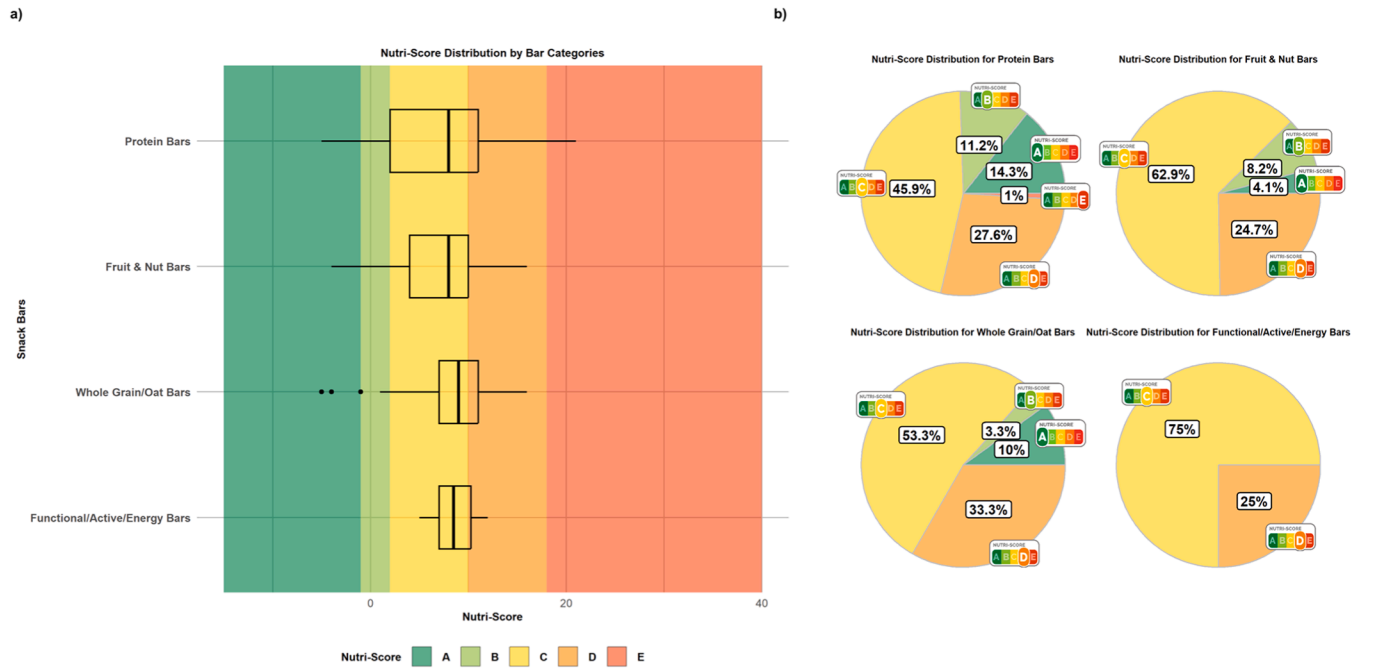


Fig. 2. a) Nutri-Score distribution across four snack bar categories (protein bars, fruit & nut bars, whole grain/oat bars, and functional/active/energy bars). Background shading indicates the Nutri-Score cut-off points from the healthiest (A, green) to the least healthy (E, red). **b)** Pie charts illustrating the percentage of products assigned to each Nutri-Score category (A–E) within each snack bar category.

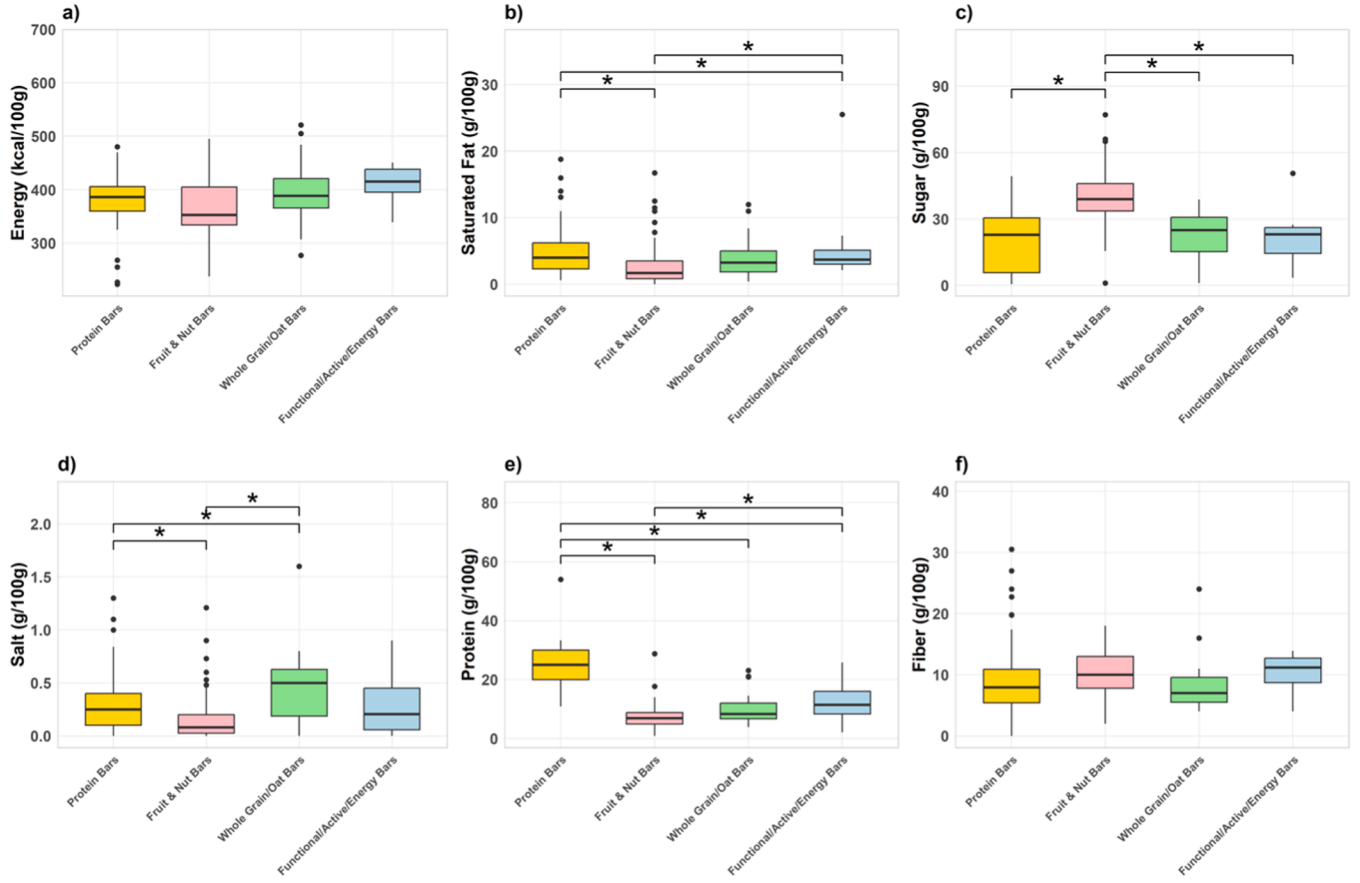


Fig. 3. Boxplot distributions of nutritional parameters across snack bar categories: (a) energy, (b) saturated fat, (c) sugar, (d) salt, (e) protein, and (f) fiber. Asterisks (*) denote statistically significant pairwise differences between groups ($p < 0.05$).

counteracting misleading health messages. Evidence from real-world evaluations and meta-analyses indicates that interpretive FOP labels can modestly improve the nutritional quality of purchases and support healthier choices, although the effects are context-dependent (Roberto et al., 2021; Ikonen et al., 2020). Complementary point-of-purchase cues, such as traffic-light labeling combined with choice architecture, have also yielded sustained improvements in healthier selections in cafeteria settings (Thorndike et al., 2014). In the Turkish context, an interpretive FOP system like the Nutri-Score could make these category-specific differences salient at a glance, while the nutrition facts panel can identify the primary driver (sugars, saturated fat, or sodium) for each product. In practice, this combination supports within-category substitution toward better-in-class options (e.g., lower-sugar fruit & nut bars, lower-saturated-fat protein bars) and, where available, a shift toward A-B products.

Because the Nutri-Score summarizes the overall nutritional quality, it does not specify which nutrient contributes most to an unfavorable grade. To aid interpretation, our category-level profiles indicate the predominant drivers—saturated fat in protein bars, sugars in fruit & nut bars, and sodium in whole grain/oat bars—so consumers can use the front-of-pack grade for an at-a-glance comparison and then consult the nutrition facts panel to target the specific nutrient of concern. Thus, even when many products cluster in C-D, this combined use helps differentiate the underlying 'problem' across the categories. An experimental online supermarket randomized trial found that the Nutri-Score improved the overall nutritional quality of intended purchases and lowered energy and saturated fat content compared to control labels. The effects were modest, and no significant change was observed for sugar content. Consequently, sodium was not tested further (Egnell et al., 2022). As an interpretive summary grade, the Nutri-Score does not include certain product attributes like micronutrient profiles, the presence of non-nutritive sweeteners, or the degree of processing. For example, products using polyols as sweeteners may obtain a more favorable Nutri-Score, even though some consumers may wish to consider such ingredients separately. Accordingly, the front-of-pack grade should be read together with the nutrition facts panel; where relevant, complementary frameworks that consider processing (e.g., NOVA) can add contextual information while capturing a construct different from nutrient profiling.

Fruit & nut bars represented another prominent category, exhibiting the highest median sugar concentration (39.0 g/100 g). Frequently promoted as natural and more wholesome alternatives to conventional confectionery, these bars derive their sweetness primarily from concentrated sources, such as dried fruits, fruit juice concentrates, and various sirups. These ingredients contribute substantially to the free sugar load (Pallavi et al., 2015). Excessive consumption of sugars from such snack items is epidemiologically linked to an increased risk of obesity, type 2 diabetes, and other metabolic disturbances (Huang et al., 2023). Therefore, it is essential to enhance consumer access to transparent nutritional information on these products, alongside targeted industry initiatives for sugar reduction, to address the associated public health implications.

Whole grain/oat bars, typically perceived as healthier options owing to their fiber content, were notable for their high salt content (median: 0.50 g/100 g). This increase in sodium content is likely due to the inclusion of sodium-containing ingredients to enhance flavor, prolong shelf life, or maintain product structure (Kloss et al., 2015). This finding is particularly relevant given the high national average salt consumption in Türkiye, estimated at 15 g/day (Erdem et al., 2017), which is almost three times the upper limit recommended by the World Health Organization (World Health Organization, 2012). As highlighted in one study, habitual consumption of high-sodium snacks is significantly associated with higher systolic and diastolic blood pressure levels in adolescents, exacerbating existing public health challenges related to hypertension (Ponzo et al., 2015). Accordingly, sodium reduction in these snack products deserves immediate attention, complemented by consumer education programs to raise awareness of the hidden sodium in commonly consumed foods (Nurmilah et al., 2022).

Although the nutrient drivers differed by category, the central tendency of the Nutri-Score was comparable across groups as presented in Table 2 (median 8–9 points). This result indicates that a "typical" bar—regardless of category—converged to a C-D rating. This pattern implies that category labels alone are a poor proxy for overall nutritional quality; consumers should pair the interpretive front-of-pack (FOP) grade with the nutrition facts to identify the specific limiting nutrient. Evidence syntheses show that while FOP schemes aid at-a-glance comparisons, the magnitude of purchase shifts is context-dependent and typically modest, reinforcing the value of within-category nutrient scrutiny (Roberto et al., 2021; Ikonen et al., 2020). For the market, a similar average Nutri-Score across categories suggests that competition has emphasized positioning more than composition, indicating room for within-category reformulation to shift products across the C-D boundary. For retailers and policymakers, interpretive FOP labeling combined with simple shelf cues (e.g., "better choice" tags within a category) could facilitate substitution toward better-in-class options and, where available, A-B products.

PCA provided a descriptive, supporting visualization of nutrient gradients already evident in the univariate analyses (e.g., higher sugar alignment among fruit–nut matrices), while categories showed considerable overlap. Therefore, we interpreted PCA descriptively and relied on univariate comparisons and Nutri-Score distributions for inference (Supplementary Material, Figure S2). To address this issue, reformulation strategies must focus on reducing sugar and saturated fat without compromising consumer acceptability (da Silva et al., 2014; Vermote et al., 2020). Such efforts can benefit from ingredient innovation, including the use of fruit purees, fiber-rich binders, and unsaturated fat sources as alternatives to less desirable components.

In addition to labeling improvements, the strategic reformulation of snack bars is critical. International experience highlights the positive impact of industry reformulation activities spurred by the implementation of the Nutri-Score. As discussed by Vandevijvere and Berger (2021), the visibility of Nutri-Score labeling can incentivize manufacturers to proactively reformulate products to avoid less favorable classifications. Encouraging similar proactive engagement in Türkiye could motivate snack bar manufacturers to prioritize healthier ingredients and reduce the levels of less desirable nutrients—sugar, saturated fat, and sodium in particular—thereby contributing positively to public health goals. Policy frameworks should facilitate reformulation through clear nutrient thresholds and industrial incentives. Regulators should establish clearer standards and guidelines for the maximum levels of sugar, saturated fat, and sodium in snack foods. In addition, providing incentives and support structures for manufacturers to make nutritional improvements could encourage wider industry adoption. Governments and public health organizations should increase their efforts in public awareness campaigns focused on nutritional literacy. Educating the public on how to interpret nutrition labels accurately and understand the real meaning behind health claims could significantly reduce the health halo effect and encourage healthier eating patterns.

Given the significant public health burden of obesity, diabetes, and cardiovascular disease in Türkiye (World Health Organization, 2020), the need for comprehensive policies to improve dietary quality is apparent. A study by Johannes (2023) indicated that the development of a corn- and spirulina-based snack bar resulted in significantly higher fiber and antioxidant content while maintaining acceptable sensory properties. Although primarily aimed at people with diabetes, the results suggest that even modest nutritional improvements in snack formulations can support chronic disease management by improving the overall diet quality. Guiding the food industry towards healthier ingredient substitutions, such as replacing saturated fats with unsaturated alternatives, reducing the use of concentrated sweeteners, and incorporating herbs and spices to replace excess salt, can significantly improve the nutritional profile of snack bars without compromising consumer

appeal.

Finally, the creation of collaborative platforms involving policymakers, industry representatives, public health experts, and consumer advocacy organizations is paramount for achieving effective and sustainable nutritional improvements (Hawkes et al., 2013). These collaborations can foster productive dialog, set achievable reformulation targets, monitor industry compliance, and assess consumer responses to modified products (Combet et al., 2017; Drewnowski, 2017). Fostering an ecosystem in which healthier snack alternatives are readily available and desirable requires comprehensive and sustained action at multiple stakeholder levels, with consumer education and transparent labeling highlighted as essential components (Chantal and Hercberg, 2017; Hawkes et al., 2013).

Future research should focus on examining the actual consumption patterns, dietary behaviors, and underlying motivations of consumers to provide deeper insights for developing effective public health strategies (Combet et al., 2017). Capturing these dimensions can better inform targeted interventions, refine public health communication, and strengthen the effectiveness of nutrition policies (Drewnowski, 2017). Investigating the economic viability of producing nutritionally superior snacks could encourage wider industry adoption and implementation of healthier formulations (Combet et al., 2017). In addition, the ongoing monitoring and evaluation of implemented interventions and resulting consumer responses are essential (Egnell et al., 2019). Regular assessment of the impact of the introduction of the Nutri-Score, reformulation trends, and consumer education initiatives can provide critical feedback for continuous adjustment and refinement (Chantal and Hercberg, 2017; Egnell et al., 2019). This iterative approach ensures that policy interventions remain relevant and adapt effectively to changing public health priorities and market conditions in the future.

In summary, because 82.7 % of products were classified as C–E and category-specific drivers differed (saturated fat in protein bars, sugars in fruit & nut bars, and sodium in whole grain/oat bars), our results point to concrete, category-tailored opportunities for reformulation and clearer labeling to improve overall nutritional quality. Drawing on international precedents and cultivating stakeholder partnerships are fundamental to achieving long-term nutritional progress and effectively addressing prevalent diet-related public health issues. A comprehensive strategy that synergizes regulatory action, industry accountability, and empowered consumer choice will be instrumental in mitigating the public health risks associated with nutritionally inadequate snack products, particularly in high-consumption, high-obesity populations such as Türkiye.

4.1. Limitations of study

Several limitations should be considered when interpreting the results of this study. A primary limitation of this study is the exclusive reliance on nutritional information provided by manufacturers on product labels. The accuracy of label data depends on the compliance and transparency of manufacturers; potential inaccuracies, especially for nutrients heavily weighted in the Nutri-Score algorithm (e.g., sugar, saturated fat, and sodium), could affect the calculated scores. For example, sodium levels were derived by calculating the reported salt content (using the conversion 1 g salt $\approx$ 400 mg sodium), a method that could introduce slight variations in the results. Moreover, this calculation assumes that all sodium is derived from sodium chloride (NaCl), whereas in practice, additional sodium may originate from other sources, such as sodium bicarbonate or sodium-based preservatives, which could lead to a slight under- or overestimation of the total sodium content. Subsequent research could improve accuracy through analytical verification of nutrient composition in a laboratory setting, especially for nutrients that are central to FOP labeling algorithms. We used ingredient lists solely to operationalize the Nutri-Score algorithm (i.e., to estimate the FVPN component and apply the published imputations) and did not conduct systematic ingredient-level coding (e.g., sweetener or fat types, degree of processing); this lies beyond the study's aims and should be addressed in future work explicitly designed for formulation profiling.

Another limitation is the small sample size (n = 12) for the 'functional/active/energy bars' category. Although this number reflects the current niche positioning of these products in Türkiye, it inherently limits the statistical robustness and the extent to which the findings can be generalized. Given the potential growth of this market segment, future research should focus on a larger and more representative sample of these specific bar types.

Additionally, as an inherent limitation of its cross-sectional design, this study cannot establish causal relationships or account for time-related changes in the market. The cross-sectional methodology of this study provides only a snapshot assessment at one point, precluding the observation of temporal shifts in product ingredients or market trends. Given the common practice of reformulating processed foods, the use of longitudinal designs or periodic cross-sectional surveys would provide a more dynamic understanding of dietary changes and the impact of policies over time. In addition, the scope of this research did not extend to external variables known to influence consumer purchasing decisions, such as recommended portion sizes, retail price points, organoleptic qualities (taste and texture), or socio-cultural factors. A comprehensive understanding of how these elements interact with nutritional characteristics is essential for developing effective public health strategies. Integrating these dimensions through a multidisciplinary research framework is recommended for future studies.

Finally, the analysis did not integrate sales data, which would allow for a sales-weighted assessment of the data. Such an approach could significantly enhance the public health applicability of the findings by identifying frequently purchased products with less favorable nutritional profiles, thereby helping prioritize reformulation initiatives for maximum population-level benefit.

Notwithstanding these limitations, the current study provides a valuable baseline assessment of the snack bar landscape in Türkiye and relevant information for researchers, industry stakeholders, and policy developers focused on improving the nutritional standards of packaged snacks.

5. Conclusion

This study revealed considerable nutritional heterogeneity among the snack bars available in the Turkish market, with variations largely due to differences in sugar, saturated fat, and salt content. In particular, while protein-focused bars provided high amounts of protein, a significant number also contained high levels of saturated fats. Fruit and nut bars were often high in sugar, whereas whole grain and oat bars were often high in salt. Higher levels of sugar and saturated fat coincided with less favorable Nutri-Score ratings (C-D), underscoring the need for targeted reformulations.

From a consumer perspective, these findings offer clear insights into snack bars that may appear healthy but have suboptimal nutritional profiles, reinforcing the importance of transparent FOP labeling, such as the Nutri-Score. Adopting a standardized FOP nutrition labeling system, such as Nutri-Score, could help consumers choose healthier snack options and encourage the industry to improve product composition. Strategic reformulation should prioritize the reduction of added sugars, saturated fats, and sodium, alongside efforts to increase fiber and protein content.

For producers, the Nutri-Score classification provides a practical framework for reformulation strategies that align with public health goals and improve product competitiveness. The effectiveness of such measures can be enhanced by transparent labeling practices complemented by public education campaigns, ethical marketing standards, and supportive government policies to counteract potentially misleading health-related branding.

Future research should investigate actual consumption patterns

associated with snack bars, explore consumer preferences, and assess the practicality of developing healthier product formulations. Achieving meaningful improvements in the nutritional quality of snack bars, thus making a positive contribution to wider public health objectives, will require synergistic collaboration among food manufacturers, health professionals, and regulators. This study provides actionable benchmarks that can support policymakers, guide industry reformulation targets, and inform consumer education efforts in Türkiye.

Ethical approval and research credibility

Ethics committee approval was not required for this study because all data analyzed were collected from publicly available product labels.

Author agreement statement

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

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CRediT authorship contribution statement

Duman Emre: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **İlayda Akkaya:** Writing – review & editing, Writing – original draft, Methodology, Data curation. **Emine Nur Yıldırım:** Writing – review & editing, Resources, Investigation. **Sıla Çömlekçioğlu:** Writing – review & editing, Resources, Investigation. **Alev Keser:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Conceptualization.

Declaration of Competing Interest

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

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jfca.2025.108419.

Data availability

Data will be made available on request.

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