

Article

Mapping Eastern European Dietary Patterns (2010–2022) Using FAOSTAT: Implications for Public Health and Sustainable Food Systems

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Abstract

Background: Dietary patterns in Eastern Europe are unevenly characterized despite their relevance for public health, food policy, and the sustainability of regional food systems. **Objective:** This study aimed to identify and compare the main dietary patterns across Eastern European countries (2010–2022) using FAOSTAT food balance data, and to examine their implications for public health and sustainable food systems. **Methods:** We conducted a comparative ecological analysis of FAOSTAT Food Balance Sheets for ten Eastern European countries (2010–2022). Multi-annual means were standardized as Z-scores. We applied principal component analysis (PCA) to major food groups and to selected subgroups (cereals, meat, vegetable oils), followed by agglomerative hierarchical clustering (Ward, Euclidean). EFSA macronutrient ranges and fiber cut-offs were used solely as descriptive benchmarks. **Results:** The PCA of major food groups identified two dominant axes separating plant-based patterns (cereals, vegetables) from animal/lipid-centered diets; subgroup analyses reproduced these oppositions (e.g., sunflower vs. rapeseed oils). Hierarchical clustering revealed a stable Central–Eastern core with higher lipid profiles (Czechia, Hungary, Slovakia, partially Poland) and a second pattern with higher carbohydrates and energy (Romania, Ukraine; proximity of Moldova, Belarus, Russian Federation). Countries differed markedly in fiber and energy: Romania showed the highest energy intake, while Slovakia had the lowest fiber, and Ukraine combined very high carbohydrates with low lipids. These structures were robust to sensitivity checks and consistent across biplots, heatmaps, and dendrograms. **Conclusions:** Eastern Europe comprises coherent dietary subgroups rather than a homogeneous profile. Beyond their public health relevance, these typologies provide an operational map for tailoring dietary guidelines, strengthening food security, and supporting the transition toward sustainable food systems. Future work should link food availability data with individual consumption, environmental indicators, and resilience metrics to inform long-term strategies for sustainable and equitable nutrition.

Keywords: food balance sheets; FAOSTAT FBS; apparent availability; multivariate analysis; principal component analysis; hierarchical clustering; macronutrient structure; energy intake



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1. Introduction

Dietary patterns describe the overall structure of diets, reflecting recurrent combinations of foods and beverages consumed by a population or its subgroups. Unlike the isolated analysis of individual nutrients, the pattern-based approach provides an integrated view of the relationship between diet and health [1,2]. Such patterns can be identified through a priori methods, such as predefined dietary scores (e.g., the Healthy Eating Index, the Mediterranean diet), or through a posteriori methods based on exploratory statistical analyses (principal component analysis—PCA, cluster analysis) [1,3].

At the global level, the nutritional transition of recent decades has led to significant changes in diets, marked by an increase in the consumption of ultra-processed products and a decline in the intake of micronutrient-rich foods [4–8]. These transformations, accelerated by globalization and socio-economic shifts, have driven a homogenization of dietary habits, with direct effects on the diversity of traditional diets [9–13].

In Europe, the literature highlights clear differences among the Western, Northern, and Eastern regions, shaped by historical, cultural, and economic factors [11,14].

Eastern European countries display a distinct profile: diets rich in refined cereals and animal fats, yet relatively poor in fruits, vegetables, and fiber, along with the elevated consumption of processed animal-based products [15–17]. This pattern is relevant not only for public health, but also for guiding food policies and dietary recommendations adapted to the regional context [18].

Even valuable studies, such as the analysis of the traditional Eastern European model in relation to mortality [19] or individual-level nutritional research [16], do not combine the simultaneous assessment of food groups and subgroups through methodological triangulation. Moreover, global-scale evaluations highlight disparities but also reveal the lack of comparable data for regions such as Eastern Europe [14,20], which hampers the development of evidence-based nutritional recommendations at the subregional level.

Therefore, the objective of this study was to systematically map and compare the main dietary patterns of Eastern European countries (2010–2022) using FAOSTAT Food Balance Sheets and multivariate statistical methods (PCA and hierarchical clustering). The analysis aimed to identify coherent subregional typologies and discuss their implications for public health and sustainable food systems.

Through this approach, this article makes an original contribution to the understanding of dietary convergences and divergences within the region and provides a robust empirical basis for supporting the transition toward healthier and more sustainable diets, at a time when food security and the adaptation of dietary guidelines are becoming major priorities at the European level.

In addition to their public health implications, these findings highlight the interconnection between dietary typologies, agricultural structures, and the sustainability of regional food systems, providing a foundation for policies that improve nutrition, strengthen food security, and support environmental resilience.

2. Materials and Methods

2.1. Study Design

This comparative ecological study included ten Eastern European countries, as defined by the FAO: Belarus, Bulgaria, Czechia, Hungary, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia, and Ukraine [21,22]. Country selection followed the official FAO regional classification for Eastern Europe (UN M49; FAO Statistical Division), ensuring methodological consistency and comparability across national Food Balance Sheet (FBS) data [23]. The overall research design and analytical workflow are illustrated in Figure S1 (Supplementary Materials).

This time frame was selected to ensure full methodological comparability, as the FAO introduced a revised Food Balance Sheet (FBS) framework after 2010, under the dataset *Food Balances (2010–)*. According to FAOSTAT FBS metadata (updated 19 July 2024), this series follows a new methodology and is not directly comparable with earlier data compiled under the previous framework [23]. The unit of analysis was the national level, expressed as average per capita availability. For the Russian Federation, as for all other countries included, FAOSTAT FBS report only national-level aggregates, with per capita denominators based on the total resident population. No subnational (territorial) divisions were analyzed, as Food Balance Sheets provide aggregate country-level estimates only.

2.2. Data Sources

Data were obtained from the FAOSTAT FBS database. We used the FBS Food element (apparent food supply for human consumption), which excludes exports, feed, seed, processing, and other non-food uses, and is expressed on a per capita-per-day basis [23]. Values are expressed on a per capita basis consistent with national population aggregates applied in FAOSTAT FBS methodology.

The analysis included the major food groups defined by the FAO (animal products, cereals excl. beer, starchy roots, sugar and sweeteners, vegetable oils, vegetables, fruits excl. wine, alcoholic beverages, and animal fats) and the corresponding subgroups for cereals, meat, and vegetable oils. Apparent energy supply and food supply were expressed in kcal/capita/day, whereas carbohydrates, proteins, lipids, and fiber were expressed in g/capita/day, as reported by FAOSTAT FBS [23]. Macronutrient energy shares were subsequently derived and used exclusively as descriptive benchmarks against EFSA reference ranges [24,25]; no EFSA thresholds were used in the multivariate modeling [24,25].

2.3. Data Processing

For each country and dietary variable, a multi-annual mean (2010–2022) was calculated in order to reduce inter-annual variation and capture the typical level of apparent availability. These multi-annual averages were computed directly from the raw annual FAOSTAT FBS series (2010–2022), ensuring the transparency of derivation from year-by-year values. Values were standardized within the Eastern Europe sample using Z-scores (mean = 0, SD = 1 across countries for each variable). The datasets were complete, with no missing values. Annual trends (2010–2022) and cross-country dispersion statistics are reported in Table S12 (Supplementary Materials).

2.4. Statistical Analyses

Principal component analysis (PCA): PCA was applied to the correlation matrix of Z-scores, which is equivalent to using covariance given the standardization of variables. Component selection was based on the Kaiser criterion (eigenvalue > 1) and scree plot inspection [26–28]. The results were reported as explained and cumulative variance. Graphical representations included PC1–PC2 biplots displaying country scores and variable loadings.

To provide quantitative support beyond visual patterns, we computed Pearson's correlations between PCA axes (PC1–PC2) and macronutrient indicators (carbohydrate, fat and protein % of energy, and dietary fiber, g/day); the results are reported in Table S10.

The analysis was performed both on the major food groups (9 variables) and separately on subgroups of cereals (8), meat (4), and vegetable oils (7).

Descriptive analyses (Z-score heatmaps): To highlight relative differences among countries, heatmaps of Z-scores were generated for food groups and subgroups [29]. In the graphs related to macronutrients, fiber, and energy, reference lines were included according

to EFSA recommendations, which were used solely as descriptive benchmarks without influencing the multivariate models.

Time trend visualization: Annual country series of apparent energy supply (kcal/capita/day) for 2010–2022 were plotted as a multi-series line chart (Figure S2), using FAOSTAT FBS values reported in Table S12; no smoothing was applied.

Hierarchical clustering: Dietary patterns were further explored using agglomerative hierarchical clustering with Ward's method and Euclidean distance applied to the Z-scores. The number of clusters was determined by dendrogram inspection and evaluated through cophenetic correlation.

Cluster stability was assessed by bootstrap resampling ($n = 1000$) in PAST 5, using the Ward.D2 linkage, Euclidean distance, and bootstrap support (%) is reported on dendrogram branches (Figure S3).

Software: The processing and aggregation of the FAOSTAT FBS series were conducted in Microsoft Excel (Microsoft 365, macOS; Microsoft Corporation, Redmond, WA, USA), using Power Query for data importing and consolidation. Multivariate analyses (PCA and biplots) were performed in GraphPad Prism (v.10.5.0, macOS; GraphPad Software, San Diego, CA, USA). Hierarchical clustering analysis was conducted in PAST 5 (Hammer Ø. & Harper D.A.T., Natural History Museum, University of Oslo, Norway).

3. Results

3.1. Overall Consumption by Major Food Groups

During 2010–2022, energy intake was predominantly derived from cereals (964 kcal/capita/day) and animal products (866 kcal/capita/day), followed at a distance by vegetable oils and sugar/sweeteners (370–361 kcal/capita/day).

It should be clarified that these estimates refer to the apparent food supply reported by FAOSTAT FBS, and do not reflect measured individual dietary intake. Therefore, they provide a macro-level representation of food availability and structural composition within national food systems, rather than the actual consumption of populations. The annual dynamics of apparent energy supply across countries are illustrated in Figure S2 (Supplementary Materials), which visualizes the time trend corresponding to Table S12. Comparative macronutrient (% energy) and fiber (g/capita/day) profiles derived from the same FAOSTAT data are presented separately in Table S9.

The remaining food groups contributed modestly, each below 205 kcal/capita/day (Table 1).

Table 1. Average daily energy intake from major food groups in Eastern European countries (2010–2022), expressed in kcal/capita/day.

Country	Cereals, Excluding Beer	Animal Products	Starchy Roots	Sugar, Sweeteners	Vegetable Oils	Vegetables	Fruits, Excluding Wine	Alcoholic Beverages	Animal Fats
Belarus	826 ± 36	873 ± 81	301 ± 15	329 ± 23	414 ± 39	114 ± 12	92 ± 11	198 ± 9	172 ± 22
Bulgaria	1025 ± 84	701 ± 47	47 ± 11	286 ± 20	359 ± 104	57 ± 11	86 ± 14	151 ± 20	132 ± 18
Czechia	770 ± 76	938 ± 64	125 ± 6	376 ± 21	539 ± 53	60 ± 4	90 ± 11	279 ± 40	255 ± 41
Hungary	842 ± 33	960 ± 63	80 ± 11	374 ± 38	500 ± 63	72 ± 6	92 ± 13	191 ± 6	320 ± 26
Poland	1081 ± 32	1023 ± 105	182 ± 10	440 ± 19	319 ± 23	83 ± 5	81 ± 10	170 ± 6	253 ± 27
Republic of Moldova	864 ± 51	758 ± 62	120 ± 13	373 ± 23	205 ± 18	93 ± 11	172 ± 28	105 ± 18	173 ± 15
Romania	1190 ± 53	968 ± 27	167 ± 13	286 ± 16	372 ± 42	123 ± 20	135 ± 21	173 ± 17	154 ± 5
Russian Federation	1148 ± 49	863 ± 20	176 ± 30	422 ± 21	357 ± 26	78 ± 6	88 ± 6	150 ± 15	133 ± 13
Slovakia	823 ± 68	882 ± 21	89 ± 19	319 ± 37	376 ± 39	54 ± 7	76 ± 7	146 ± 10	371 ± 88
Ukraine	1071 ± 80	694 ± 53	233 ± 12	410 ± 43	261 ± 24	126 ± 7	79 ± 9	121 ± 29	88 ± 22
Mean	964	866	152	361	370	86	99	168	205
STDEVP	146	109	72	52	95	26	29	46	86
CV, %	15.2	12.5	47.7	14.4	25.5	29.9	29.3	27.2	42.1

Legend: Values represent multi-annual means (2010–2022) of apparent energy supply from FAOSTAT FBS for each country. Columns correspond to food groups, and rows to countries. The last three rows summarize, across the ten Eastern European countries, the overall mean, the standard deviation of population values (STDEVP), and the coefficient of variation (CV, %). Variability across countries was highest for starchy roots (CV = 47.7%) and animal fats (CV = 42.1%); intermediate for vegetable oils, alcoholic beverages, fruits, and vegetables; and lowest for cereals and animal products.

The heatmap of Z-scores highlights major contrasts among countries: Romania and Poland exhibited high contributions from cereals and animal products, whereas Czechia was distinguished by a more pronounced lipid/alcohol profile, confirming systematic divergences among states (Figure 1). Z-scores were computed relative to the regional multi-annual mean (2010–2022) for each food group. All variables were expressed in kcal/capita/day, which ensured energy-adjusted comparability across countries. FAOSTAT FBS data for this period were complete, thus no imputation was required.

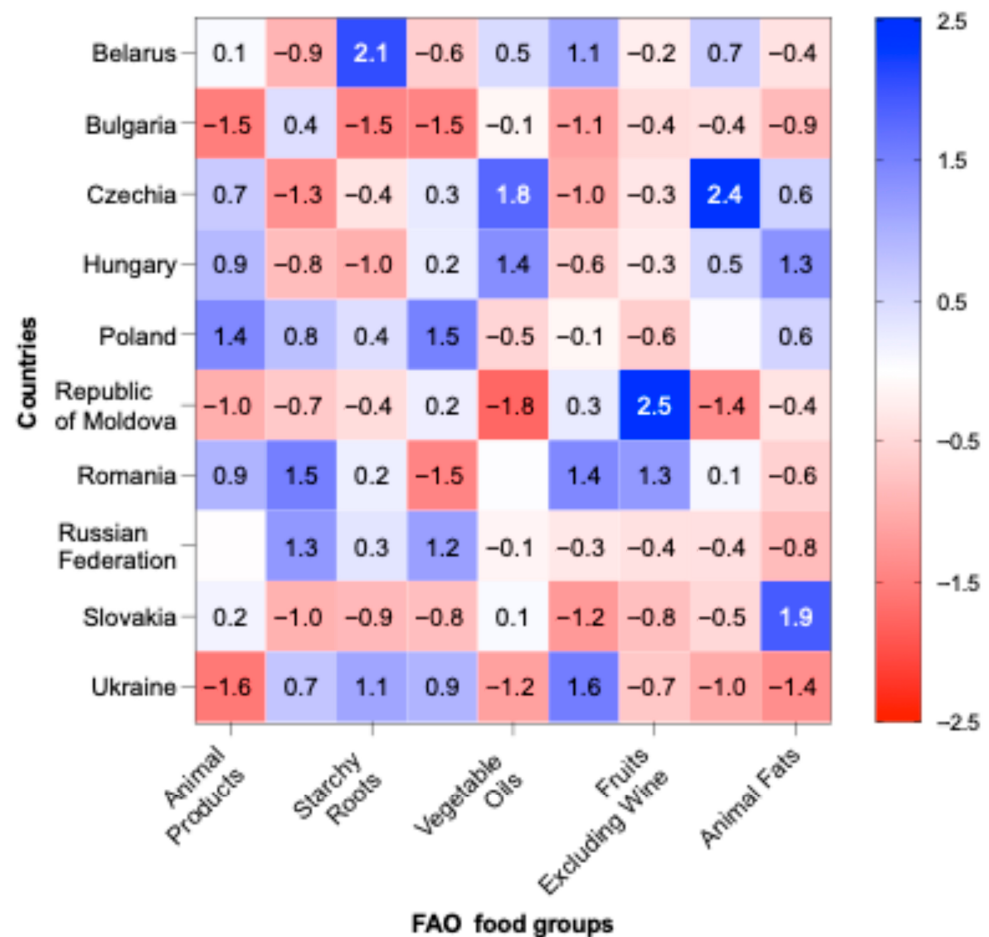


Figure 1. Heatmap of standardized Z-scores for nine FAO food groups in Eastern European countries (2010–2022). Legend: Z-scores are based on multi-annual means (2010–2022) across ten Eastern European countries. Positive (red) values indicate above-regional-mean apparent availability; negative (blue) values indicate below-mean availability. The color scale is fixed at -2.5 to $+2.5$ (midpoint 0) to ensure comparability across figures. Cell values are Z-scores (1 decimal).

3.2. Consumption of Main Food Subgroups

Cereals: The analysis of standardized scores reveals clear cross-country differences. Belarus and Poland exhibited high intakes of barley and oats, whereas Czechia, Hungary, and Slovakia consistently ranked below average. Romania and Bulgaria stood out for maize consumption, while Belarus showed higher relative standardized scores for rice (Figure 2a; Table S1). This reflects their relative positioning within the regional Z-score distribution rather than high absolute intake; the apparent energy contribution of rice in Belarus remains low compared with wheat and starchy roots.

Meat: The consumption structure shows marked variation. Pork predominated in Poland, Czechia, and Slovakia, whereas Belarus and the Republic of Moldova reported low levels. Romania and the Russian Federation recorded higher values for beef, while

Bulgaria and Slovakia fell below the regional mean. Poultry consumption was substantial in Romania and Bulgaria but lower in Belarus and Czechia (Figure 2b; Table S2).

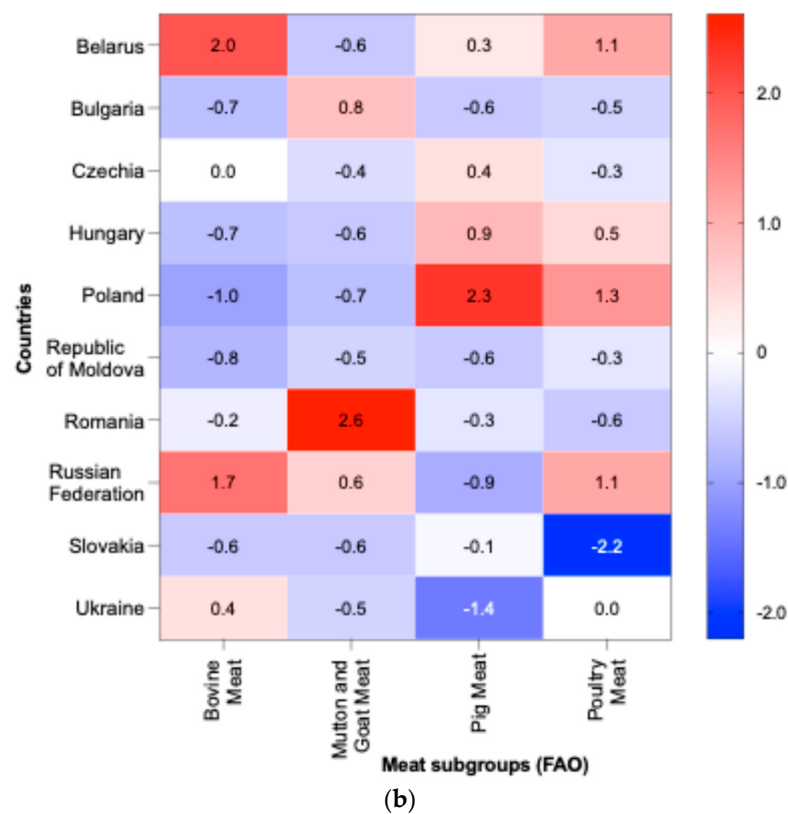
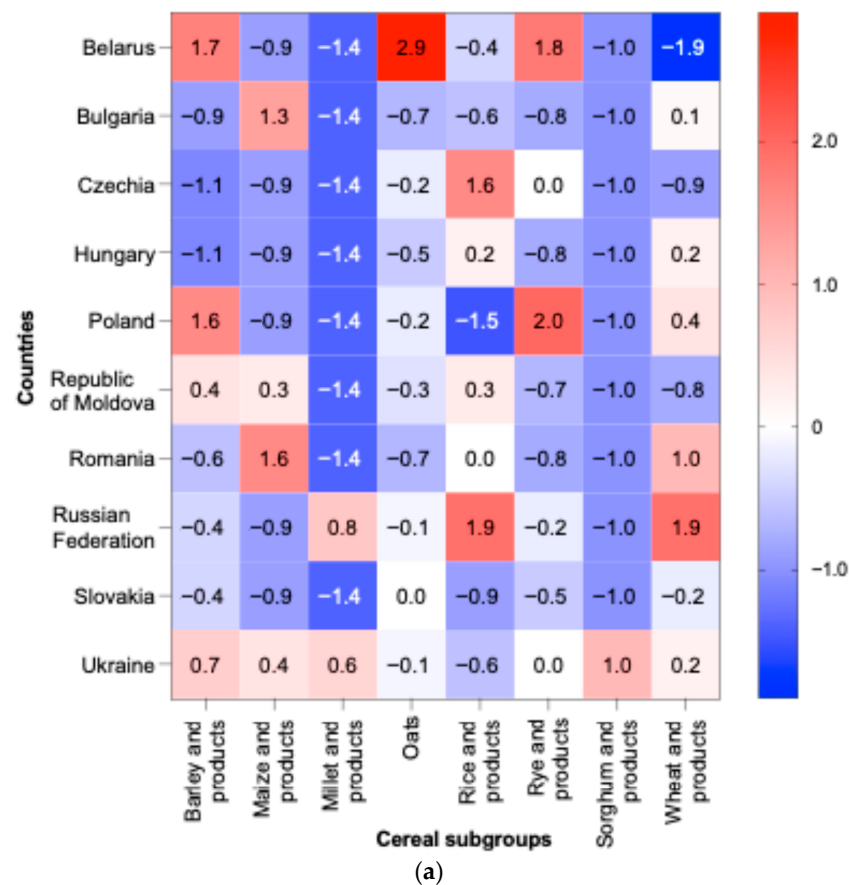
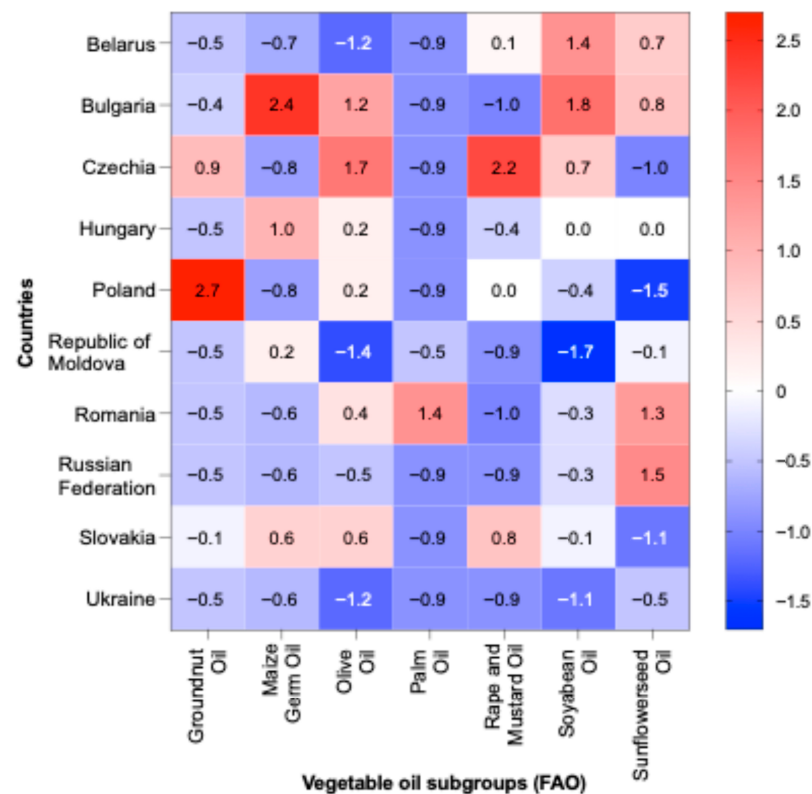


Figure 2. Cont.



(c)

Figure 2. Standardized Z-scores for FAO food subgroups in Eastern European countries (2010–2022). Legend: Z-scores are based on multi-annual means (2010–2022) across ten Eastern European countries. Panels show standardized apparent availability for (a) cereals, (b) meat, (c) vegetable oils. Red and blue indicate above- and below-regional-mean values, respectively. The color scale is fixed at -2.5 to $+2.5$ (midpoint 0) for comparability. Numerical data are provided in Supplementary Materials (Tables S1–S3).

Oils: Consumption displayed clear geographical differentiation. Sunflower oil dominated in Ukraine, the Republic of Moldova, and Bulgaria, while Czechia and Slovakia reported lower values. Rapeseed and mustard oil were characteristic of Central–Eastern countries, with the highest levels in Czechia and Poland and the lowest in Romania and Bulgaria. Olive oil intake was generally low, but slightly more prominent in Czechia and Hungary (Figure 2c; Table S3).

Complete numerical details are provided in the Supplementary Materials (Tables S1–S3).

3.3. PCA—Principal Component Analysis

The principal component analysis applied to the nine major food groups identified two main axes that together explained 59.6% of the total variability (Table 2). PC1 (39.6%) described the opposition between plant-based patterns—particularly cereals and vegetables—and those centered on animal products and lipids. PC2 (20.0%) captured the variation introduced by starchy roots and alcoholic beverages.

To formally verify this visual opposition, we compared countries with positive ($n = 6$) versus negative ($n = 4$) PC1 scores using a two-tailed Welch’s unequal variance *t*-test. The PC1-positive group displayed a significantly higher share of energy from carbohydrates ($+6.8$ percentage points, $p = 0.019$) and a significantly lower share from fat (-7.2 percentage points, $p = 0.029$) than the PC1-negative group, whereas protein and total energy did not differ (Table S11).

Table 2. Principal component analysis (PCA) loadings and variance explained for major food groups (2010–2022).

Component	Eigenvalue	Explained Variance (%)	Cumulative Variance (%)
PC1	3.564	39.60	39.60
PC2	1.802	20.02	59.61
Food Group	PC1		
	PC2		
Animal Products	−0.580	0.504	
Cereals	0.613	0.212	
Starchy Roots	0.429	0.798	
Sugar and Sweeteners	0.100	0.434	
Oils	−0.862	0.280	
Vegetables	0.717	0.512	
Fruits	0.402	−0.318	
Alcoholic Beverages	−0.753	0.460	
Animal Fats	−0.819	−0.153	

Legend: This table shows loadings of nine major food groups on the first four principal components (PC1–PC4), derived from standardized Z-scores of multi-annual mean energy supply (2010–2022). Values indicate the correlation between each food group and the respective component. The percentage of variance explained by each component is provided at the bottom of the table.

The PC1–PC2 biplot highlights the following structure: Poland and Belarus aligned with the plant-based axis and Romania and the Russian Federation with the animal/lipid axis, while Czechia, Slovakia, and Hungary occupied intermediate positions (Figure 3).

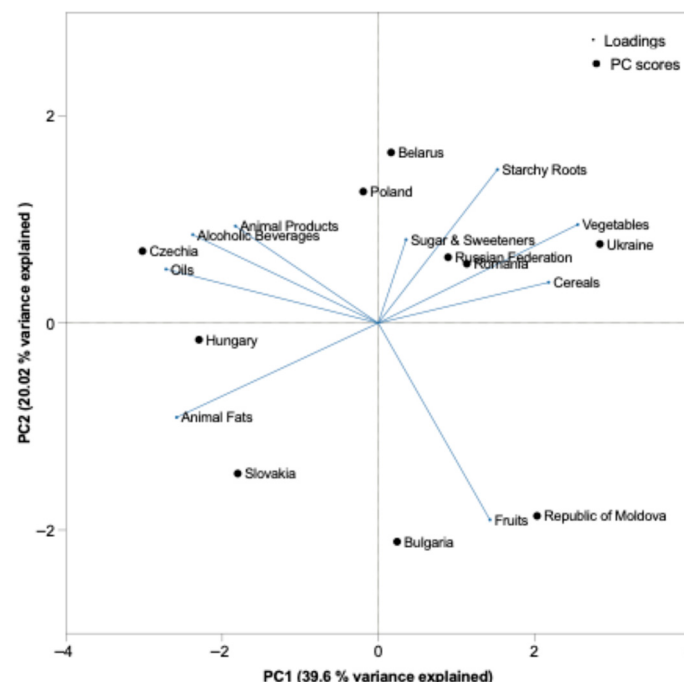


Figure 3. Principal component analysis (PCA) biplot (PC1 vs. PC2) for major food groups in Eastern European countries (2010–2022). Legend: The analysis is based on standardized Z-scores of multi-annual mean apparent availability for nine FAO food groups. Arrows indicate the direction and strength of variable loadings, while country points reflect relative positions along the plant-based and animal/lipid axes. Detailed loadings and additional components (PC3–PC4) are presented in Table S4.

3.4. PCA on Subgroups (Cereals, Meat, Oils)

The principal component analysis applied to food subgroups retained two components (Kaiser's criterion), explaining 63.4% of the variance for cereals, 74.8% for meat, and 64.2% for oils (Table 3).

Table 3. Principal component analysis (PCA) loadings and variance explained for food subgroups (2010–2022).

Subgroup	Component	Eigenvalue	Explained Variance (%)	Cumulative Variance (%)
Cereals	PC1	3.178	39.73	39.73
	PC2	1.897	23.71	63.44
Meat	PC1	1.566	39.16	39.16
	PC2	1.426	35.66	74.82
Oils	PC1	2.631	37.59	37.59
	PC2	1.864	26.63	64.22

Legend: The table presents loadings for the main food subgroups included in the PCA: cereals, meat, and vegetable oils. Each subgroup was analyzed separately using standardized Z-scores of multi-annual mean energy supply (2010–2022). Loadings indicate the strength and direction of the relationship between subgroups and principal components (PC1–PC3). The percentage of variance explained by each component is provided at the bottom of the table.

For cereals, PC1 separated patterns based on maize and wheat from those associated with barley, oats, and rye, while PC2 reflected variation driven by millet and sorghum. Romania and Bulgaria aligned with maize and wheat, Poland and Belarus with barley and rye, and Ukraine with millet. The Republic of Moldova, Czechia, and Slovakia displayed mixed patterns (Figure 4a).

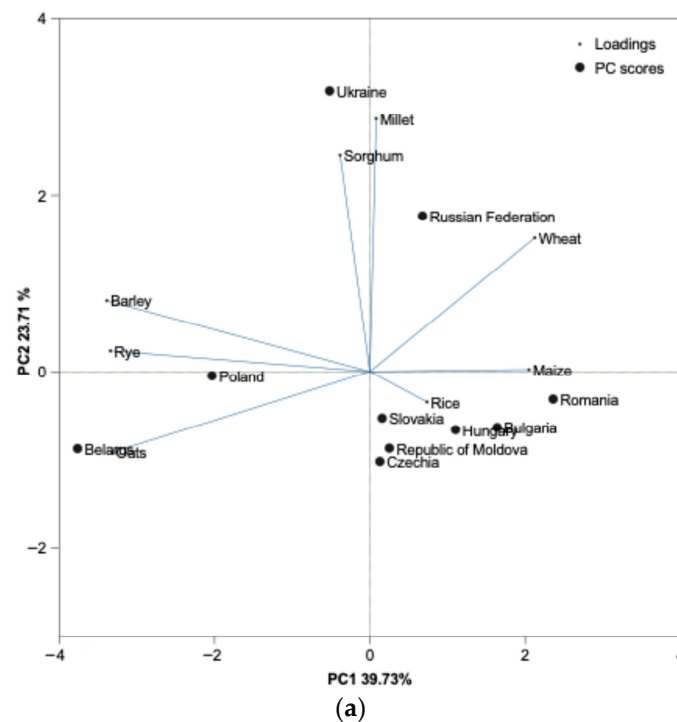


Figure 4. Cont.

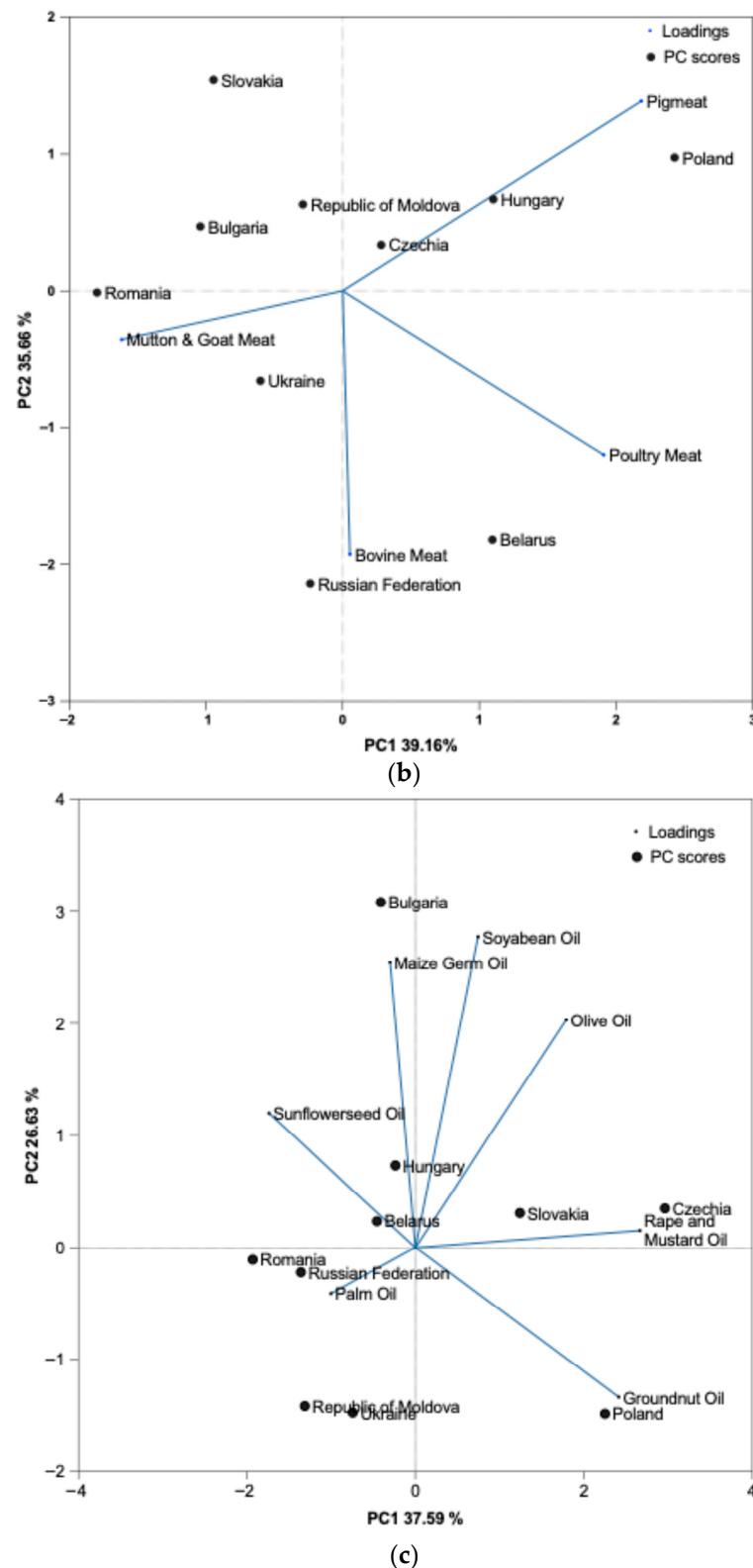


Figure 4. PCA biplots (PC1 vs. PC2) for main food subgroups in Eastern European countries (2010–2022). Legend: Principal component analysis (PCA) based on multi-annual mean Z-scores for (a) cereals, (b) meat, (c) vegetable oils. Arrows represent variable loadings, while country positions indicate relative dietary patterns. The plots illustrate main contrasts—e.g., maize/wheat vs. barley/rye, pork vs. beef, and sunflower vs. rapeseed oil.

For meat, PC1 contrasted pork with beef consumption, whereas PC2 introduced variation through sheep/goat and poultry. Poland and Hungary were oriented toward

pork, Romania and the Russian Federation toward beef, while Belarus and the Republic of Moldova showed moderate profiles. Slovakia occupied an intermediate position (Figure 4b). FAOSTAT FBS data are available only at the national level; therefore, the analysis cannot account for possible subnational differences across regions or cultural and climatic contexts within the Russian Federation.

For vegetable oils, PC1 differentiated sunflower oil (high in Ukraine, the Republic of Moldova, and Bulgaria) from rapeseed and mustard oil (Czechia and Poland). PC2 reflected the occasional contribution of imported oils (soy, olive). Eastern countries clustered around sunflower oil, whereas Central–Eastern countries clustered around rapeseed (Figure 4c).

Together, these results confirm the dominant oppositions identified at the level of major food groups and justify the subsequent application of hierarchical clustering. Additional components (PC3–PC4) are provided in the Supplementary Materials (Tables S5–S7).

3.5. Hierarchical Clustering (Ward, Euclidean)

The hierarchical analysis of Z-scores revealed coherent groupings of countries based on aggregated food consumption. The dendrogram (Figure 5) showed a stable Central–Eastern European core (Hungary–Slovakia–Czechia), the association of Poland with the Russian Federation and subsequently with Romania, as well as the southeastern pair Belarus–Bulgaria. Ukraine occupied an intermediate position, while the Republic of Moldova merged last with the cluster ensemble, indicating the greatest distance from other profiles.

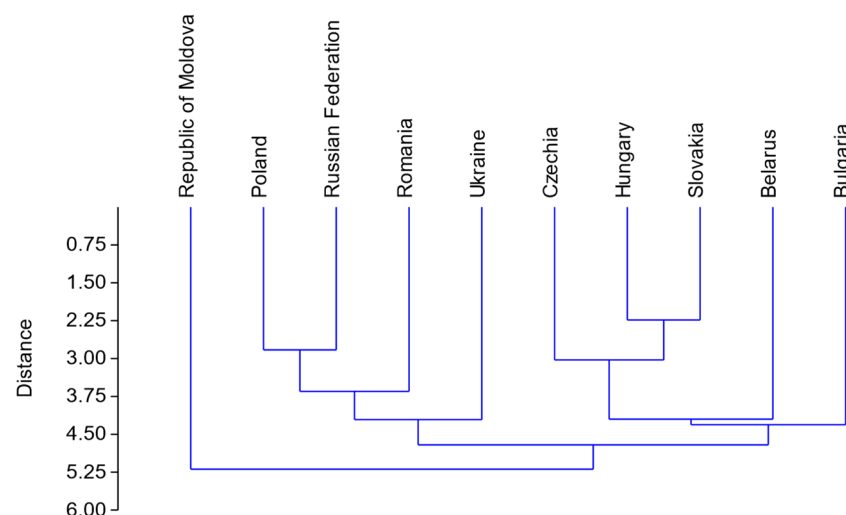


Figure 5. Hierarchical clustering (Ward’s method, Euclidean distance) for major food groups in Eastern European countries (2010–2022). Legend: The dendrogram displays country groupings based on standardized Z-scores of multi-annual mean apparent availability. The cophenetic correlation coefficient ($r = 0.698$) indicates a good fit between the dendrogram and original distances. A sensitivity test using an alternative linkage criterion (average linkage/UPGMA) confirmed the robustness of the structure. For bootstrap support values see Figure S3 (Supplementary Materials).

Bootstrap validation corroborated the qualitative structure (Figure S3): the closest pairings showed moderate support—Czechia–Hungary 58% and Poland–Russian Federation 68%—whereas broader aggregates such as (Czechia–Hungary) + (Slovakia–Bulgaria) 23%, Ukraine–Republic of Moldova 32%, and Belarus–Romania 34% exhibited weak support; higher-level splits received low support (10–18%).

For the subgroups, the dendrograms (Figure 6) revealed configurations consistent with the overall analysis: Poland–Belarus and Romania–Bulgaria for cereals; a southeastern cluster (Romania, Moldova, Ukraine, Bulgaria) and an eastern bloc Belarus–Russian Federation–Poland for meat; and the opposition between sunflower (Ukraine, Moldova, Bul-

garia) and rapeseed (Czechia, Poland) for vegetable oils. Cophenetic coefficients (0.75–0.88) confirmed the stability of these clusters. The comparison of dendrograms highlighted recurring patterns such as the stable Hungary–Slovakia pair, the frequent Romania–Bulgaria association, and the Belarus–Russian Federation bloc, while also showing subgroup-specific variations (e.g., the Republic of Moldova shifting between cereals and meat/oils). Overall, the general structure (Figure 5) was confirmed by the subgroup analysis, but these also revealed finer regional particularities.

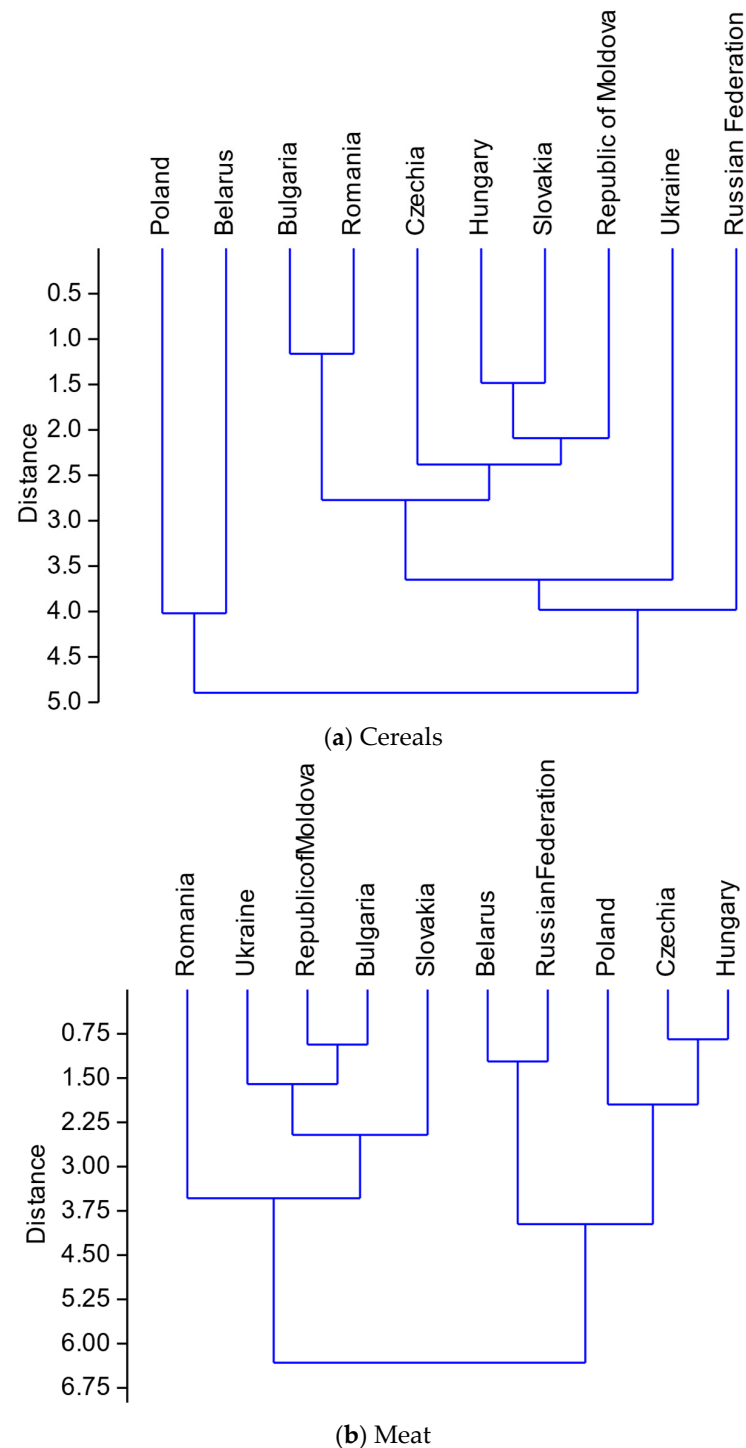


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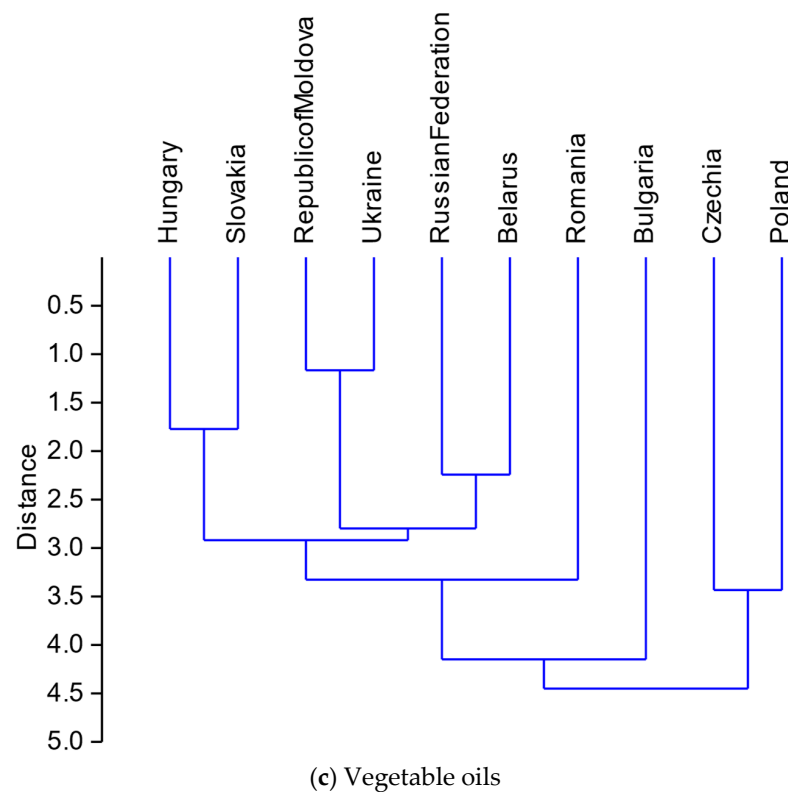


Figure 6. Hierarchical clustering (Ward’s method, Euclidean distance) for selected food subgroups in Eastern European countries (2010–2022). **Legend:** Dendrograms were constructed using Ward’s linkage and Euclidean distance for (a) cereals, (b) meat, (c) vegetable oils. Analyses are based on standardized Z-scores of multi-annual mean apparent availability. Cophenetic correlation coefficients ($r = 0.75\text{--}0.88$) indicate high structural stability across subgroups.

Figure 6 shows hierarchical dendrograms (Ward’s method, Euclidean distance) for food subgroups in Eastern European countries (2010–2022): (a) cereals, (b) meat, (c) vegetable oils. The analysis highlights distinct regional structures: Poland–Belarus and Romania–Bulgaria for cereals; a southeastern cluster (Romania, Moldova, Ukraine, Bulgaria) and an eastern bloc (Belarus–Russian Federation–Poland) for meat; and the reliance on sunflower oil (Ukraine, Moldova, Bulgaria) versus rapeseed orientation (Czechia, Poland) for vegetable oils. Cophenetic coefficients ($0.75\text{--}0.88$) confirmed the stability of these clusters. To facilitate comparison and illustrate subgroup-specific consistencies or shifts, a comparative synthesis of clusters is provided in the Supplementary Materials (Table S8).

Comparative synthesis: Comparing subgroup dendrograms with the overall clustering highlights both consistencies and differences. Hungary and Slovakia consistently formed a stable pair across all analyses, suggesting nutritional convergence. Romania and Bulgaria frequently clustered together, particularly for meat and oils, reflecting Southeastern European coherence. The Republic of Moldova showed variable behavior: clustering with Ukraine for meat and oils but aligning with the central group for cereals. The eastern bloc of the Russian Federation–Belarus remained stable in most analyses, whereas Poland and Czechia displayed more flexible positions depending on the food group. Overall, the general structure (Figure 6) was confirmed by subgroup analyses, while also revealing finer regional particularities.

3.6. Regional Subgroup Synthesis

The comparative analysis revealed clear differences between the subgroups of countries statistically identified through PCA and clustering. The first pattern comprised countries with a high lipid intake and relatively lower levels of carbohydrates (Czechia, Hungary, Slovakia, and partly Poland). These countries often reached 39–41% of total energy from fat, thus exceeding the EFSA upper bound (35%E) and approached or fell below the lower threshold for carbohydrates; fiber intake also tended to be lower, particularly in Slovakia and Czechia. A second pattern was characterized by high carbohydrate and total energy intake but lower lipid levels (Romania and Ukraine, along with the Republic of Moldova, Belarus, and the Russian Federation in some analyses). Romania and Ukraine stood out with very high values for carbohydrates and energy, while the Republic of Moldova displayed an intermediate profile, closer to Ukraine in terms of lipids and energy.

With respect to fiber, Belarus, Poland, and Romania recorded the highest values, in contrast to Slovakia, Czechia, and Hungary. Romania was distinguished by the highest caloric intake and among the highest values for carbohydrates and fiber; Ukraine had a moderate caloric intake but very high carbohydrates and low lipids; while Slovakia exhibited the opposite profile, with low carbohydrate and fiber intake but lipid levels above recommendations.

These differences delineate distinct dietary patterns within Eastern Europe (as defined by the FAO), with subgroups of countries characterized by a high energy density and lipid intake versus subgroups dominated by carbohydrates and plant-based foods. This typology provides a useful framework for interpreting nutritional differences and for informing regionally tailored food policies.

4. Discussion

4.1. Regional Dietary Patterns in the Context of the Literature and EFSA Guidelines

The analysis identified three major groups of countries with similar dietary patterns, outlining clear subregional differences within Eastern Europe. These configurations are not merely statistical arrangements but reflect persistent dietary traditions and economic structures, confirming the opposition described in the literature between plant-based diets and those centered on animal products and lipids [19,30,31]. At the same time, this study adds a level of detail that has been insufficiently documented for this region.

The Food-Based Dietary Guidelines (FBDGs) recommend that messages be adapted to national or subregional contexts [32]. However, comparative analysis shows that only a subset of countries have updated their official guidelines. Romania and Bulgaria rely on outdated guidelines from 2006; the Republic of Moldova only published its FBDGs in 2019; and in other cases (e.g., Belarus) guidelines are either absent or not publicly available [33]. This context underlines the relevance of the differences identified through PCA and clustering, which provide an empirical foundation for revising and developing dietary guidelines.

The comparison of macronutrient distributions with EFSA reference ranges reveals clear oppositions between subgroups: countries in the Central–Eastern core (Czechia, Hungary, Slovakia, and in some cases Poland) frequently exceed the upper threshold for lipids while approaching the lower bound for carbohydrates; in contrast, Romania and Ukraine display markedly higher levels of carbohydrates and total energy. These contrasts converge with the typologies identified through PCA and clustering, underscoring the need to calibrate public health messages at the subregional level, while recognizing that these benchmarks reflect food availability patterns rather than individual consumption [24,25,34].

Thus, the relatively stable clustering of certain countries (e.g., Hungary–Slovakia–Czechia), the proximity of Poland, the Russian Federation, and Romania, or the repeated

association of Belarus and Bulgaria do not represent mere variations in consumption but rather indicate clear directions for calibrating nutritional priorities and public health messages.

Our findings complement the existing literature, demonstrating that the nutritional transition in the region is not uniform but marked by internal divergences with direct relevance for food policy.

4.2. Explanatory Factors (Socio-Cultural and Economic)

The identified dietary patterns can be explained by the convergence of three sets of factors.

Agricultural structure and local availability: Certain countries in the region remain more dependent on cereal and local oil supply chains (e.g., maize, sunflower), while other groups of states are characterized by a higher share of animal products and the use of rapeseed oil. These differences persist in long-term analyses derived from Food Balance Sheets [15,35,36].

Cultural–historical heritage: Traditional diets in Eastern Europe exhibit a specific profile of food groups, with documented effects in population health studies (e.g., HAPIEE). This context explains the observed inertias and continuities, as well as the resistance to rapid shifts in regional dietary patterns [16,19,37].

Economic integration and trade: Differentiated access to imports (e.g., olive oil) and the distinct pace of transition from subsistence agriculture to liberalized markets have shaped the directions of dietary change [31,38,39].

Overall, these factors explain why certain groups of countries evolve convergently within their clusters but diverge from others, thereby reinforcing the explanatory basis for the identified clusters.

4.3. Robustness of Results: PCA–Cluster–Subgroup Triangulation

The coherence of the conclusions is supported by the triangulation of methods and levels of analysis. At the aggregate level, the major contrasts among Eastern European country groups remain stable, with the dendrogram highlighting consistent pairs such as Hungary–Slovakia, Poland–Russian Federation, and Belarus–Bulgaria. Romania clusters with the Poland–Russian Federation group, Ukraine occupies an intermediate position, while the Republic of Moldova joins last, reflecting the greatest distance from the other profiles.

The cophenetic coefficient (0.698) indicates an adequate fit between the original distances and the hierarchical structure.

Subgroup analyses (cereals, meat, oils) reproduce the core message but also reveal food group-specific alliances. For instance, recurrent regional associations emerge for oils, while Romania–Moldova–Ukraine proximities are observed for meat. The Republic of Moldova exhibits a “pivot” behavior—closer to the cereal-based core, yet more aligned with Eastern European countries in oils and meat.

The concordance across biplots, heatmaps, and dendrograms—further validated by a sensitivity check with average linkage (UPGMA)—shows that the results are not dependent on a single representation, but instead reflect the underlying structure of Eastern European dietary patterns.

4.4. Limitations

This analysis relies on Food Balance Sheets (FAOSTAT FBSs), which capture per capita apparent availability rather than actual individual consumption. These series may contain reporting errors and do not account for heterogeneity by age, sex, or socioeconomic status. As such, the results describe food system patterns rather than individual nutritional intakes.

A further limitation stems from the multi-year aggregation (2010–2022). While average values enhance the robustness of cross-country comparisons, they may obscure fluctuations triggered by economic, health, or geopolitical shocks and attenuate emerging trends. Given the small number of countries ($n = 10$) and the use of multi-annual means, the statistical power is limited and coarse partitions should be read cautiously. To gauge stability, we complemented the dendrogram with a bootstrap assessment (Figure S3), which indicated support concentrated at the pair level and weakness at broader joins. Cophenetic coefficients for the baseline and subgroup trees suggest an adequate, though not perfect, fit. The ecological design also implies that EFSA benchmarks serve only as indicative references; they are defined for individual intakes, whereas FAOSTAT FBS reflects national-level availability. Consequently, conclusions cannot be directly extrapolated to population nutritional status.

From a methodological standpoint, PCA captures only linear structures and is sensitive to standardization and outliers, while clustering outcomes depend on the choice of distance metric and agglomeration method. Although the main food group and subgroup patterns are robust, finer configurations may vary, and dendrogram cut-off levels inherently involve some arbitrariness.

Geographically, this analysis is restricted to ten Eastern European countries according to FAO classification. This small sample size limits statistical generalizability and precludes the formal testing of inter-cluster differences. Contextual covariates (income, urbanization, food prices, agricultural policies) were also not integrated, though they may help explain cross-country variation.

Finally, this study does not include micronutrients or clinical indicators. The objective was to map dietary patterns across major food groups and subgroups; thus, implications for public health remain hypothetical and require further investigation.

Despite these limitations, the concordance between PCA, dendrograms, and subgroup analyses, together with the stability of regional blocks, supports the robustness of the conclusions on structural dietary differences across the countries examined.

Accordingly, subsequent work should triangulate FAOSTAT FBS availability with individual intake data and with environmental and resilience indicators to test the robustness and policy relevance of the observed clusters.

4.5. Implications for Public Health and Sustainable Food Systems

The differentiated dietary typologies identified in this study highlight not only nutritional disparities but also systemic challenges for food security and sustainability in Eastern Europe. Countries clustered around lipid-dense diets require policies that address both health risks and the environmental burden of high animal fat consumption. Conversely, carbohydrate-oriented patterns underscore the need for the diversification of plant sources and improved fat quality, linking nutritional goals with the resilience of agricultural supply chains. These dual perspectives demonstrate that dietary guidelines must be designed in synergy with broader food system strategies to ensure long-term sustainability and equity.

The findings provide an operational map for differentiated food policies tailored to statistically identified subgroups of Eastern European countries (FAO classification).

For the subgroup characterized by a high energy density and a large proportion of lipids, priorities include reducing total fat intake—particularly animal fats—while promoting replacement with predominantly unsaturated sources and increasing the share of whole-grain and plant-based foods. For the subgroup where carbohydrate intake and the plant-based foundation of the diet are relatively higher, the key objectives are diversifying sources, increasing the share of whole-grain products, and improving fat quality to balance energy density and fatty acid profiles.

For the subgroup with a relative dependence on a few key food groups (e.g., specific vegetable oils and animal products), predominantly Belarus–Russian Federation, priorities should focus on diversification and strengthening food system resilience, with emphasis on the economic accessibility of diverse plant sources.

Strengthening dietary guidelines in Eastern Europe requires not only adapting nutrition messages to the identified typologies but also embedding them within a broader sustainability perspective. Policies should address the diversification of food sources, the improvement of fat quality, and the moderation of energy density, while simultaneously enhancing the resilience of agricultural supply chains and ensuring equitable access to healthy foods. In this way, the regional dietary profiles mapped in this study can serve as an evidence base for advancing sustainable food systems that balance health, cultural traditions, and long-term environmental security.

Future research should triangulate FAOSTAT FBS availability with individual intake data and environmental/resilience indicators, while incorporating contextual covariates and testing stability beyond 2010–2022 to validate the clusters and their policy relevance.

5. Conclusions

This study reveals that the Eastern European dietary landscape is not homogeneous but composed of two coherent and regionally stable typologies. The first cluster, including Czechia, Hungary, Slovakia, and partly Poland, follows a *fat-oriented* nutritional structure in which energy is predominantly derived from animal products and vegetable oils, particularly rapeseed and mustard oils. These countries consistently exceed the EFSA upper threshold for total lipid intake (35% of total energy), while dietary fiber remains comparatively low, particularly in Slovakia and Czechia. The second cluster, comprising Romania and Ukraine, with the Republic of Moldova, Belarus, and the Russian Federation showing close proximity, is *carbohydrate-oriented*, marked by a higher energy density, elevated contributions from cereals and starchy roots, and lower lipid shares. Within this configuration, Moldova and Ukraine display the highest mutual similarity in their vegetable oil profiles, dominated by sunflower oil, reflecting a distinct east–southeast subregional coherence.

From a nutritional and public health perspective, these findings emphasize the need for differentiated, region-sensitive strategies rather than one-size-fits-all recommendations. In fat-oriented contexts, reducing total and animal fat intake while improving fat quality through a higher proportion of unsaturated sources—such as rapeseed, olive, or soybean oils—should be prioritized. Increasing dietary fiber through whole grains, legumes, fruits, and vegetables is essential to reduce overall energy density and enhance metabolic balance. In carbohydrate-oriented regions, strategies should focus on diversifying plant sources, improving lipid quality, and ensuring that fiber-rich foods occupy a central position in national dietary guidelines. For mixed or transitional profiles such as those observed in the Republic of Moldova and Belarus, integrated approaches combining diet diversification with the improved affordability and accessibility of healthy foods are critical to strengthen dietary resilience.

Overall, this typology provides an operational framework for developing subregion-specific dietary guidelines and aligning national nutrition programs with the sustainability objectives of European food systems. By connecting macro-level food availability data with nutritional and environmental indicators, this study establishes a solid empirical foundation for evidence-based policymaking in Eastern Europe. The conclusions are relevant both for the scientific community—by refining the regional monitoring of dietary patterns—and for public health professionals and policymakers seeking to design targeted interventions that improve dietary quality, food security, and long-term sustainability across the region.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su17209223/s1>, Table S1: Average energy supply from cereal subgroups (2010–2022), expressed in kcal/capita/day; Table S2: Average energy supply from meat subgroups (2010–2022), expressed in kcal/capita/day; Table S3: Average energy supply from vegetable oil subgroups (2010–2022), expressed in kcal/capita/day; Table S4: Principal component analysis (PCA) for major food groups (2010–2022); Table S5: Principal component analysis (PCA) for the cereals subgroup in Eastern European countries (2010–2022); Table S6: Principal component analysis (PCA) for the meat subgroup in Eastern European countries (2010–2022); Table S7: Principal component analysis (PCA) for the vegetable oils subgroup in Eastern European countries (2010–2022); Table S8: Comparative synthesis of food subgroup clusters across Eastern European countries; Table S9: Multi-annual mean supply of macronutrients, and energy in Eastern European countries (2010–2022). Table S10: Pearson’s correlation coefficients (r) between principal component scores (PC1–PC2) and dietary indicators in Eastern European countries (multi-annual means, 2010–2022); Table S11: Welch’s t-test comparing countries with positive versus negative PC1 scores; Table S12: Food supply, kcal/capita/day (FAOSTAT Food Balance Sheets); Figure S1: Research design and analytical workflow. Figure S2. Annual time trend in apparent energy supply (kcal/capita/day), 2010–2022; Figure S3. Bootstrap-validated hierarchical clustering of countries based on Z-score diet structure (10 countries $\times$ 9 food groups).

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