Project Report For CS661: **BIG DATA VISUAL ANALYTICS**
2024–2025 Summer Semester

Nutriviz

Group Number - 6

Banoth Anand - 220281 (banotha22@iitk.ac.in)
Ramavath Dinesh Naik - 220866 (ramavath22@iitk.ac.in)
Sikha Vamsi - 221058 (svamsi22@iitk.ac.in)
Akarsh Verma - 220094 (averma22@iitk.ac.in)
Deepavath Raghu Ram Naik - 220333 (raghurn22@iitk.ac.in)
Pujari Krishna Chandu - 220832 (pkrishna22@iitk.ac.in)
R Vinod Kumar - 220843 (rvinodk22@iitk.ac.in)
Harsha Kumar - 220358 (dharshak22@iitk.ac.in)
Ravula Harshith Sai - 220878 (ravula22@iitk.ac.in)

IIT Kanpur

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1 Introduction:

Nutrition is essential for overall health and well-being. It affects everything from energy levels to preventing diseases. However, understanding nutritional information can be difficult because of the large amount of data available in food databases. Our goal is to create **NutriViz**, an interactive visual analytics system that allows users to explore nutritional data through easy-to-understand visuals. We want to reveal patterns in macronutrients, micronutrients, and bioactive compounds in over 8,800 food items. This will help users make informed dietary choices.

2 Data Preparation and Exploration:

2.1 Data Sourcing:

We used the **Nutrition Dataset from Kaggle** for this project, which includes detailed nutritional profiles for over 8,800 different food items. Each entry has 77 measured nutritional characteristics standardized per 100 grams. This standardization allows for consistent comparisons across foods. The dataset covers complete macronutrient breakdowns, including protein fractions, saturated and unsaturated fats, and complex carbohydrates. It also includes extensive information on micronutrients, covering all essential vitamins from A to K and over 20 minerals. Additionally, it records bioactive compounds such as antioxidants and phytochemicals. This rich dataset forms the basis for our nutritional analysis, providing the detail needed for discovering visual patterns and making dietary recommendations.

For our project, we primarily focused on the **nutrition_fullcleaned.xlsx** file for all the visualizations and the Analysis.

2.2 Data Preprocessing

Our data preprocessing pipeline used strong techniques to make sure our analysis was solid. We first combined nutritional data into a clear format suitable for multidimensional visualization. The main dataset (`nutrition.xlsx`) had about 18% missing values in the `saturated fat` column.

When we looked into the food items linked to these missing values, we discovered that, in almost all cases, they had little to no saturated fat. We decided to replace the missing values with `0` to accurately reflect this nutritional absence.

After this adjustment, we cleaned the dataset thoroughly and saved it as `nutrition_fullcleaned.xlsx` for further analysis. All nutrient measurements were converted and standardized to a consistent per-100g unit to allow fair comparisons across different food types.

Lastly, we classified all the food items into **22 distinct categories** to support group-based analysis and category-level visualizations.

2.3 Data Visualization

We created a wide range of interactive visualizations to help users explore nutritional patterns from different angles. To show the Overview we used **horizontal bar graphs**, **pie charts**. To compare macronutrients, we used **box plots**, **violin plots**, and **radar charts** showing average macronutrient profiles across food categories.

For micronutrients, we showed **bar charts**, **parallel coordinate plots**, and **t-SNE clustering visualizations** with **K-means clustering** to group nutritionally similar foods.

To visualize protein quality, we created **treemaps** that break down amino acid profiles into essential and non-essential components. For deeper insights, we also built a **3D scatter plot** of macronutrients vs. energy content and used **t-SNE** for macronutrient similarity mapping.

We included **stacked bar charts** to break down fat subtypes, **Sankey diagrams** to show fat flow from foods to health outcomes, and **correlation matrices** to examine relationships between fat types and cholesterol.

Additionally, we used **grouped bar charts**, **PCA biplots** for dimensionality reduction, and **Gaussian Mixture Model (GMM)** clustering over the t-SNE embeddings to recommend foods with similar nutritional profiles.

All visualizations are interactive, allowing users to filter, zoom, and switch between macroscopic and detailed nutritional views.

3 Tasks:

3.1 Nutritional Overview Dashboard

Proposed Solution

- **Interactive Search Interface:** Implemented a real-time search bar enabling users to instantly lookup any of the 8,800+ food products, with auto-complete suggestions and dynamic filtering capabilities that display matching results as users type, providing immediate access to detailed nutritional profiles.
- **Top Nutrients Bar Graph:** Developed a horizontal bar chart visualization highlighting the top 7 most abundant nutrients in any selected food item, with proportional bar lengths representing concentration levels and color-coding indicating nutrient categories (macronutrients, vitamins, minerals) for quick nutritional assessment.
- **Composition Pie Charts:** Created three coordinated pie charts showing: (1) Macronutrient distribution (carbohydrates, proteins, fats with subtype breakdown), (2) Vitamin profile (relative proportions of vitamins A-K), and (3) Mineral composition (top 7 minerals by concentration), providing an at-a-glance understanding of nutritional balance.
- **Automated Nutrient Labeling:** Engineered threshold-based classification that automatically generates descriptive labels (e.g., ”high-fiber,” ”low-sodium,” ”iron-rich”) based on FDA/WHO nutritional guidelines, displayed as interactive badges that reveal detailed metrics on hover.

Insights

- **Instant Food Lookup:** Real-time search with auto-suggestions allows quick access to detailed nutritional info for 8,800+ food items.
- **Visual Nutrient Breakdown:** Bar and pie charts simplify nutrient analysis through category-wise color-coding and composition visuals.
- **Smart Health Labels:** Auto-generated badges (e.g., "high-fiber") offer quick health insights using global nutritional standards.

Results

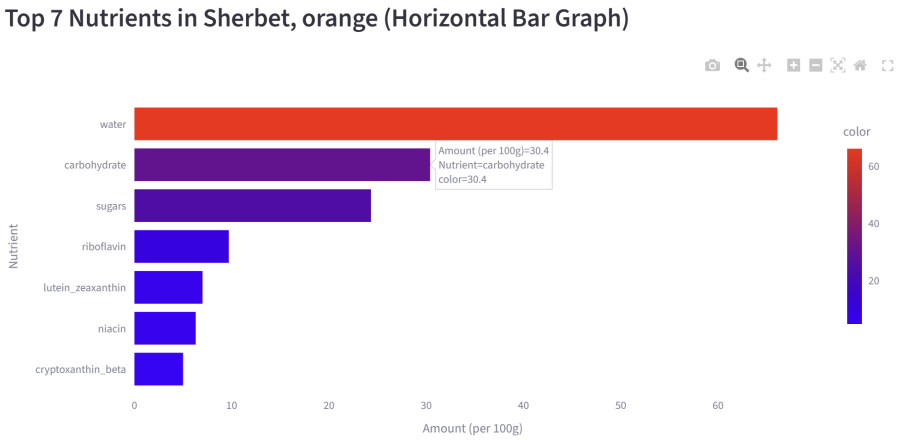


Figure 1: Top 7 Nutrients in Sherbet, orange (Horizontal Bar Graph)

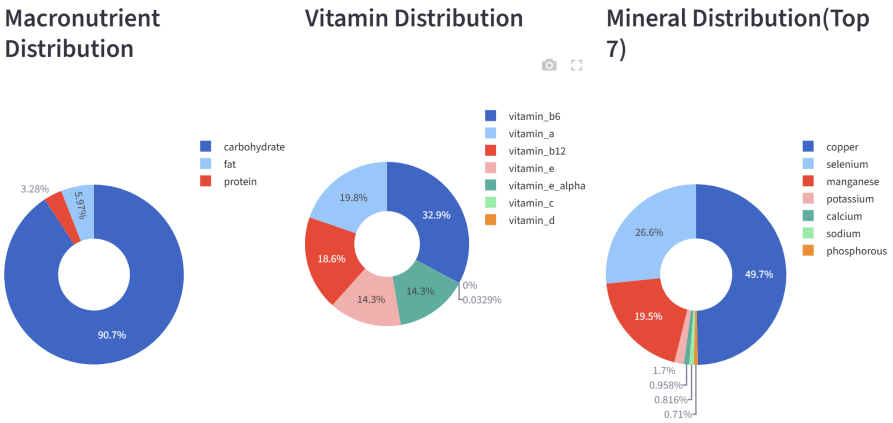


Figure 2: Pie Charts of Macronutrient Distribution, Vitamin Distribution and Mineral Distribution(Top 7) for Sherbet, orange

3.2 Macronutrient Distribution Analysis

Proposed Solution

- **Category Distribution Plots:** Designed comparative box plots and violin plots showing the statistical distribution of proteins, fats, and carbohydrates across 12 food categories (dairy, meats, fruits, etc.), with jittered points revealing individual food items and annotations highlighting category-specific outliers.
- **Composition Radar Charts:** Implemented multi-axis radar diagrams visualizing the complete macronutrient signature of each food category, with vertices representing specific nutrients (saturated fats, fiber, sugars) and polygon area indicating nutritional density for direct category comparisons.

- **Amino Acid Treemaps:** Created hierarchical treemaps that decompose proteins into essential/non-essential amino acid components, with nested rectangles sized by concentration and colored by amino acid type, revealing complete protein quality profiles.
- **Energy-Nutrient 3D Scatter:** Developed interactive 3D scatter plots positioning foods along protein-fat-carbohydrate axes, with point size representing caloric density and color indicating food category, enabling identification of nutrient-dense vs. calorie-dense foods.
- **t-SNE Macronutrient Mapping:** Applied t-distributed Stochastic Neighbor Embedding to project high-dimensional macronutrient data into 2D similarity clusters, with point clustering revealing nutritionally analogous foods and convex hulls grouping similar food categories.

Insights

- **Category-Based Nutrient Insights:** Box, violin, and radar plots highlight nutrient distribution and signatures across food categories for easy comparison.
- **Protein Quality Visualization:** Amino acid treemaps show essential/non-essential protein composition to assess protein quality.
- **Nutrient Pattern Discovery:** 3D scatter and t-SNE mapping uncover clusters of calorie-dense and nutritionally similar foods.

Results

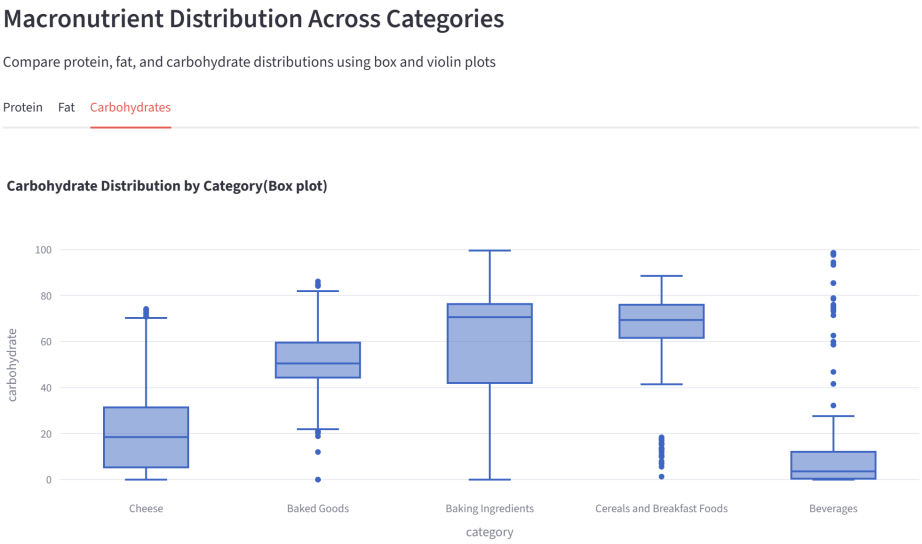


Figure 3: Carbohydrate Distribution by Category (Box Plot)

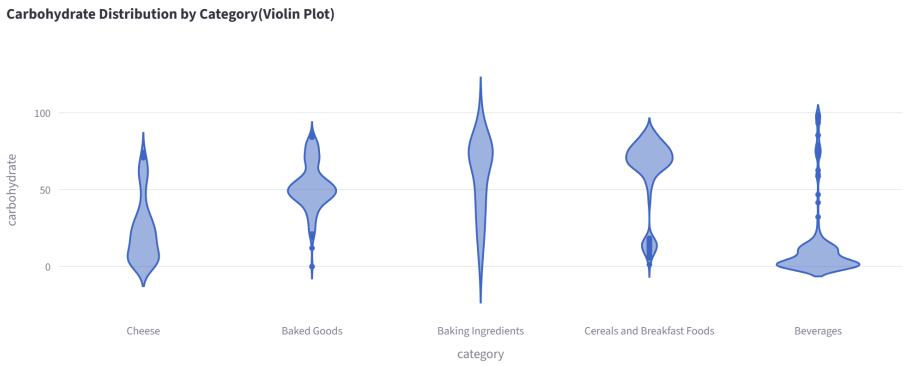


Figure 4: Carbohydrate Distribution by Category (Violin Plot)

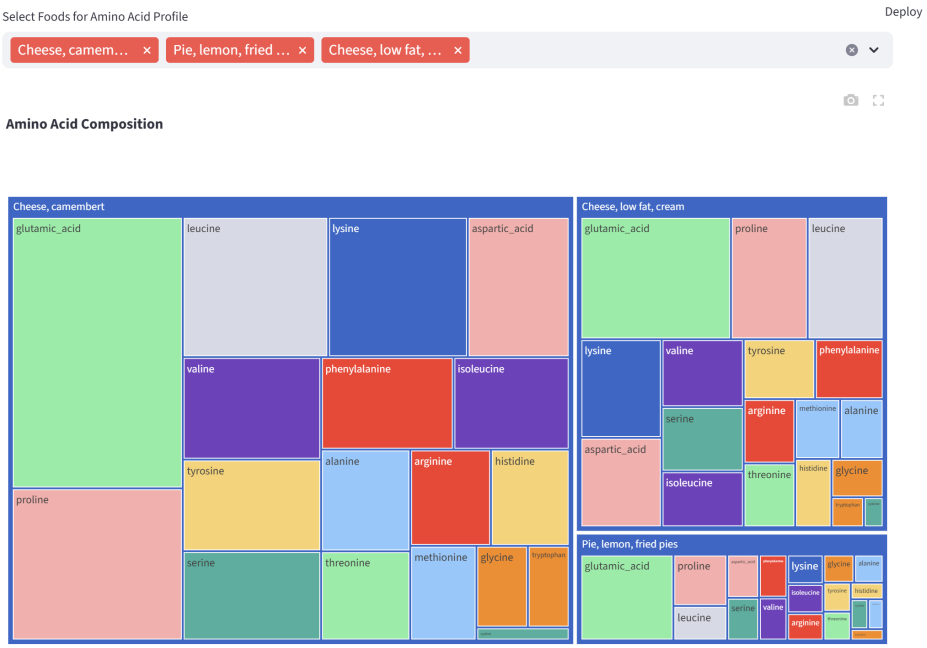


Figure 5: Amino acid composition for selected foods (Treemap)

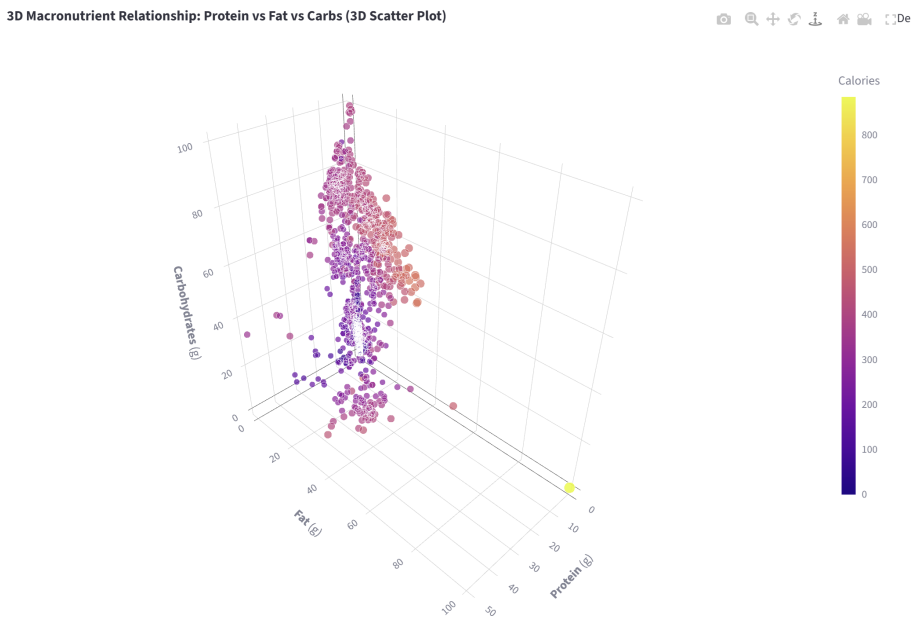


Figure 6: 3D Macronutrient Relationship: Protein vs Fat vs Carbs (3D Scatter Plot)

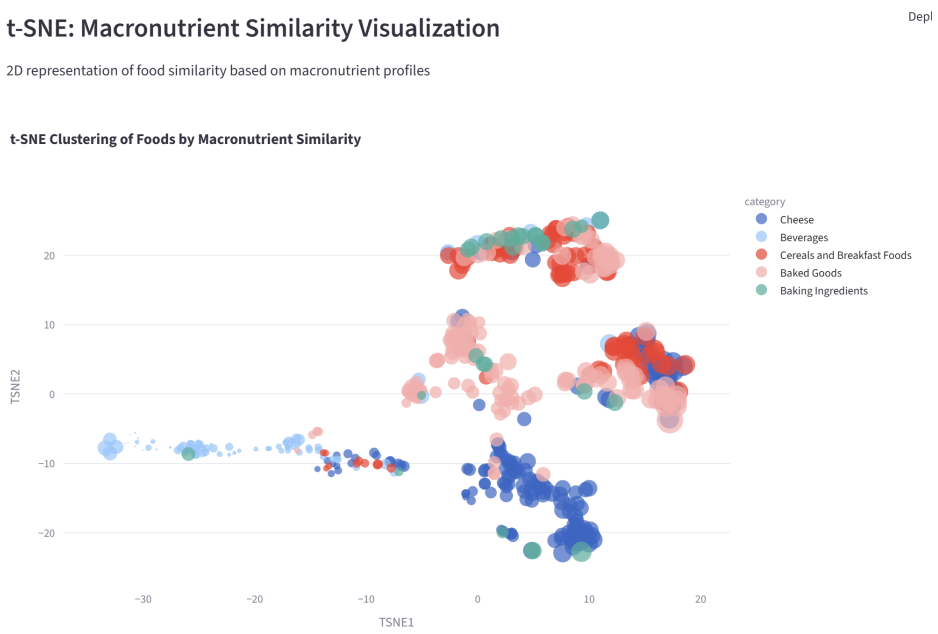


Figure 7: t-SNE clustering (2D Representation) of Foods by Macronutrient Similarity

3.3 Vitamin and Mineral Density

Proposed Solution

- **Nutrient-Dense Treemaps:** Engineered category-based treemaps where tile size represents total micronutrient density and color intensity shows specific vitamin/mineral concentrations, visually identifying ”superfoods” within each category through size-position encoding.
- **Parallel Coordinates Profiling:** Implemented parallel coordinate plots connecting 20+ micronutrient axes, enabling multivariate comparison of nutritional signatures across multiple food categories simultaneously, with brushing/linking to highlight exceptional profiles.
- **Micronutrient t-SNE Clustering:** Utilized t-SNE dimensionality reduction to cluster foods based on 35+ micronutrient dimensions, generating 2D similarity maps where spatial proximity indicates nutritional analogy, revealing unexpected relationships between disparate foods.

Insights

- **Micronutrient-Rich Food Discovery:** Treemaps visually highlight “superfoods” using micronutrient density and concentration cues.
- **Multivariate Nutrient Comparison:** Parallel coordinate plots enable side-by-side analysis of 20+ micronutrients across categories.
- **Micronutrient-Based Clustering:** t-SNE maps reveal hidden similarities between nutritionally analogous but diverse foods.

Results

Figure 8: Average Vitamin a Content by Food Category (Bar Graph)

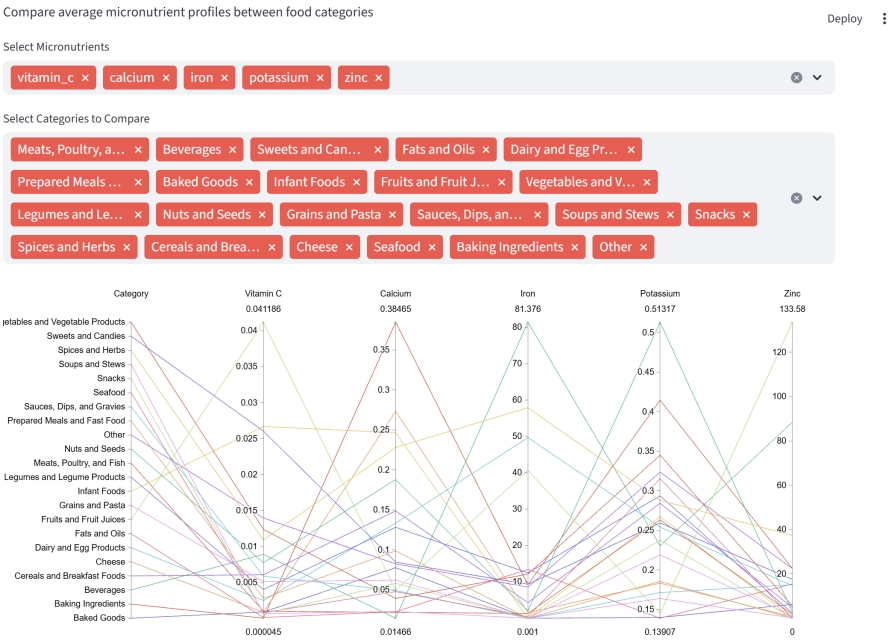


Figure 9: Parallel Coordinates for Micronutrient Profiles

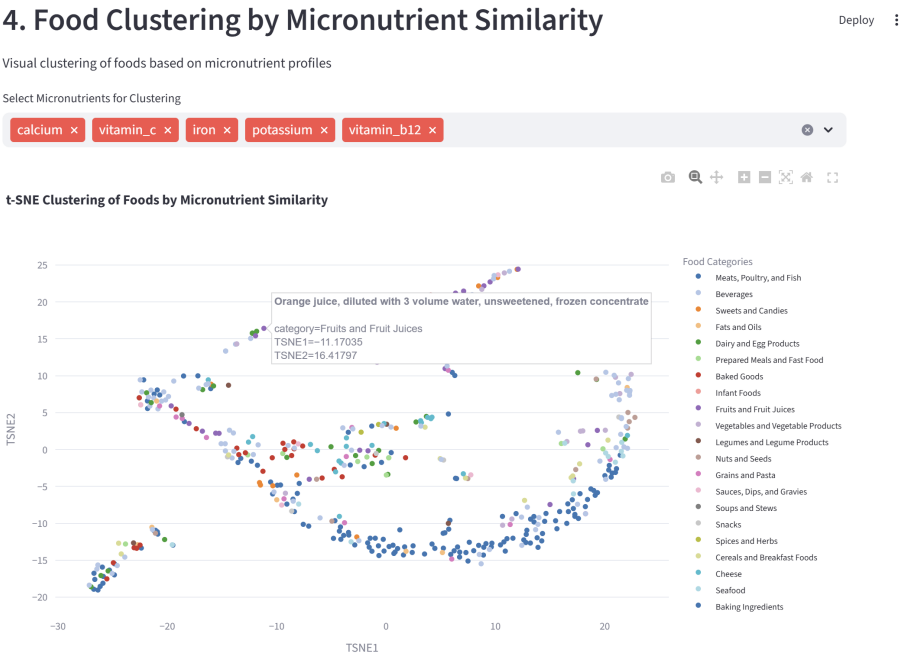
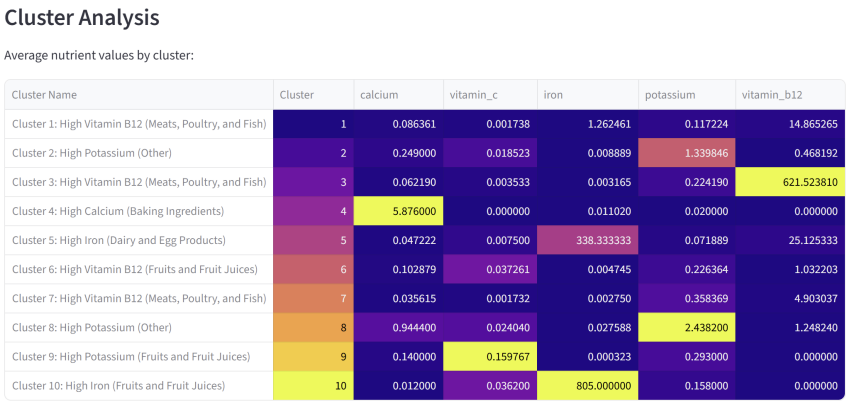


Figure 10: t-SNE clustering of Foods by Micronutrient Similarity



Cluster Name	Cluster	calcium	vitamin_c	iron	potassium	vitamin_b12
Cluster 1: High Vitamin B12 (Meats, Poultry, and Fish)	1	0.086361	0.001738	1.262461	0.117224	14.865265
Cluster 2: High Potassium (Other)	2	0.249000	0.018523	0.008889	1.339846	0.468192
Cluster 3: High Vitamin B12 (Meats, Poultry, and Fish)	3	0.062190	0.003533	0.003165	0.224190	621.523810
Cluster 4: High Calcium (Baking Ingredients)	4	5.876000	0.000000	0.011020	0.020000	0.000000
Cluster 5: High Iron (Dairy and Egg Products)	5	0.047222	0.007500	338.333333	0.071889	25.125333
Cluster 6: High Vitamin B12 (Fruits and Fruit Juices)	6	0.102879	0.037261	0.004745	0.226364	1.032203
Cluster 7: High Vitamin B12 (Meats, Poultry, and Fish)	7	0.035615	0.001732	0.002750	0.358369	4.903037
Cluster 8: High Potassium (Other)	8	0.944400	0.024040	0.027588	2.438200	1.248240
Cluster 9: High Potassium (Fruits and Fruit Juices)	9	0.140000	0.159767	0.000323	0.293000	0.000000
Cluster 10: High Iron (Fruits and Fruit Juices)	10	0.012000	0.036200	805.000000	0.158000	0.000000

Figure 11: Average Micronutrient values by each cluster

3.4 Fat Composition Analysis

Proposed Solution

- **Fat Subtype Breakdown:** Created stacked bar charts quantifying proportions of saturated, monounsaturated, and polyunsaturated fats across food categories, with interactive tooltips showing exact values and health impact indicators based on cardiology guidelines.
- **Fat-Cholesterol Correlation:** Developed scatter matrix plots correlating fat subtypes with cholesterol levels, featuring regression lines, confidence intervals, and density contours to validate relationships while avoiding ecological fallacy.
- **Sankey Flow Diagrams:** Implemented Sankey visualizations mapping fat composition flows from food sources through metabolic pathways to health impact categories, with edge widths proportional to quantity and color indicating fat type.

Insights

- **Fat Type Analysis:** Stacked bar charts show fat subtype proportions and health impacts across categories.

- **Fat-Cholesterol Link Validation:** Scatter plots with regressions confirm correlations between fat types and cholesterol.
- **Metabolic Flow Visualization:** Sankey diagrams trace fat sources to health outcomes, emphasizing quantity and type.

Results

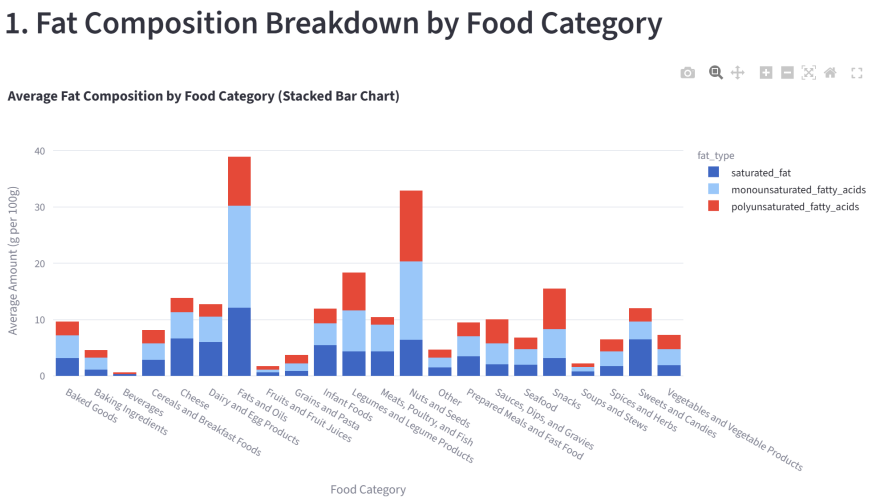


Figure 12: Average Fat Composition by Food Category (Stacked Bar Graph)

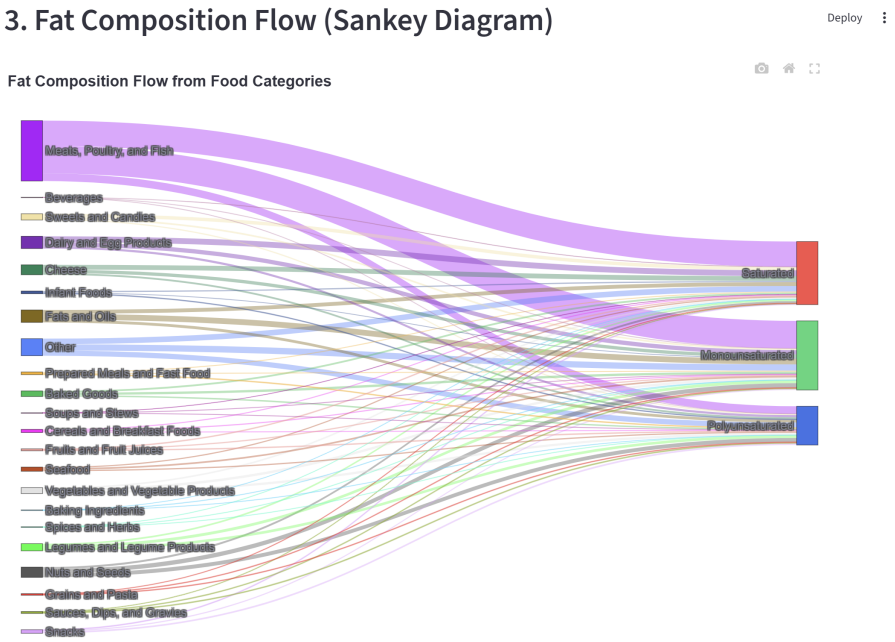


Figure 13: Fat Composition Flow from Food Categories (Sankey Diagram)

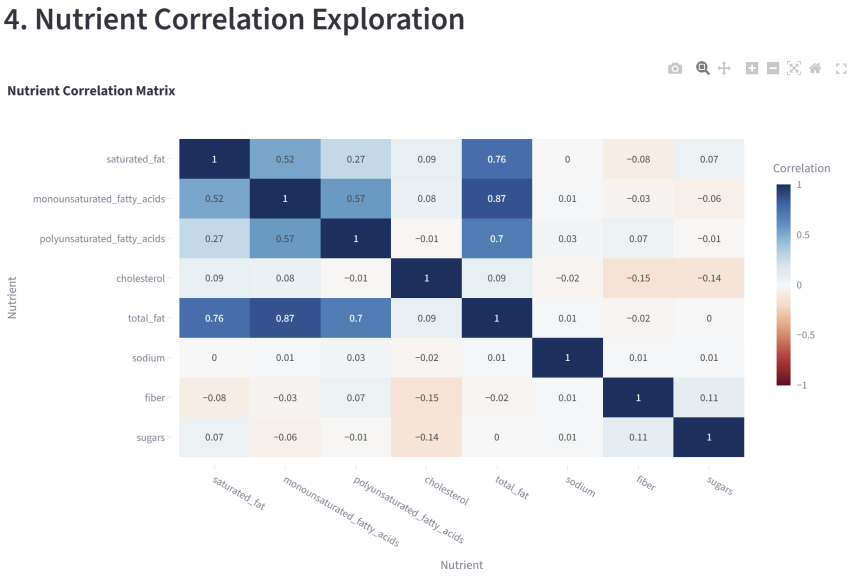


Figure 14: Nutrient Correlation Matrix between fats and other nutrients

3.5 Food Category Benchmarking

Proposed Solution

- **Grouped Nutrient Bar Charts:** Designed grouped bar charts comparing average nutritional values (protein, sugars, fiber, etc.) across categories, with statistical significance indicators and standard deviation error bars for reliable benchmarking.
- **PCA Biplot Reduction:** Applied Principal Component Analysis to reduce 77 nutritional dimensions to interpretable components, visualizing category clustering in PCA space with vectors showing nutrient contributions to each axis.
- **GMM Nutritional Clustering:** Implemented Gaussian Mixture Models to identify latent dietary patterns, with t-SNE projections revealing probabilistic cluster assignments and gradient transitions between nutritional archetypes.

Insights

- **Category-Based Nutrient Benchmarking:** Different food categories exhibit characteristic nutrient profiles, allowing clear benchmarking using grouped bar charts.
- **Principal Component-Based Category Clustering:** PCA biplots reveal a meaningful clustering of categories based on the dominant nutrient dimensions.
- **Latent Dietary Patterns from GMM Clustering:** GMM clustering uncovers hidden dietary patterns and transitional nutrient behaviors between food types.

Results

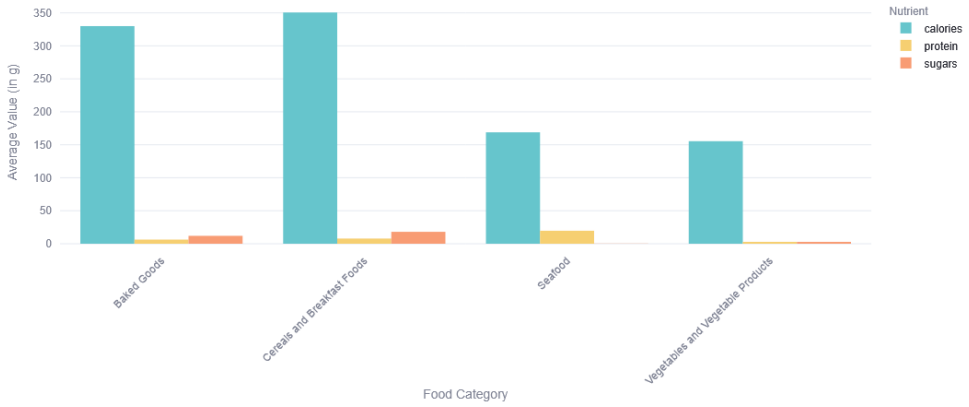


Figure 15: Average nutrient values across food categories (Grouped Bar Graph)

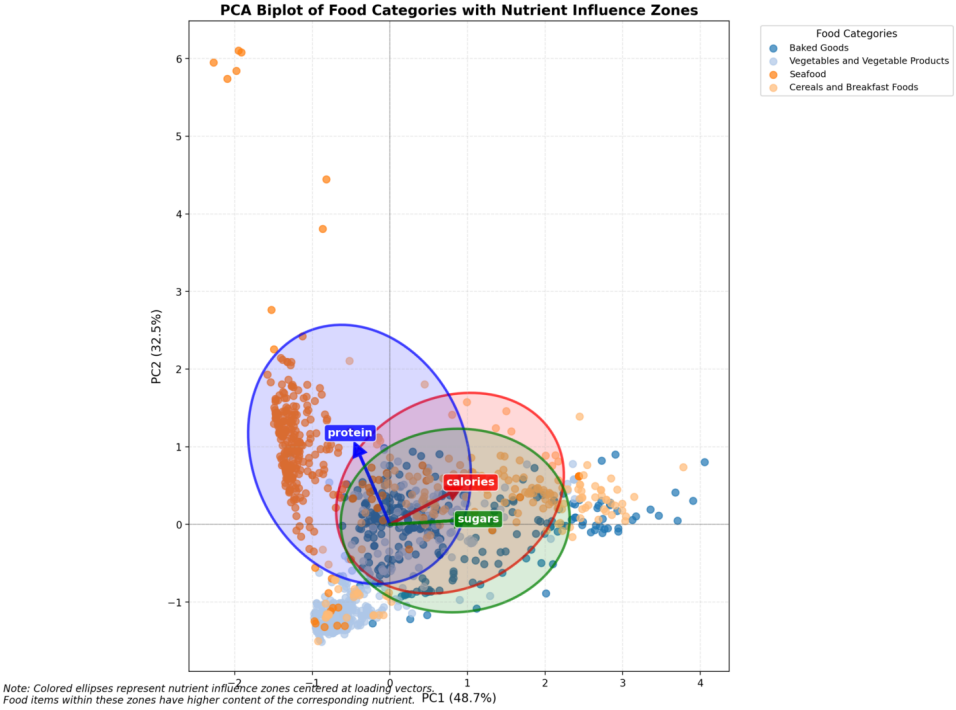


Figure 16: PCA Biplot of food categories with nutrient influence zones

Nutrient Loadings

	PC1	PC2	Magnitude	Angle (degrees)
calories	0.775	0.402	0.873	27.418
protein	-0.392	0.901	0.982	113.504
sugars	0.842	0.05	0.844	3.371

Explained Variance

	Component	Explained Variance Ratio	Cumulative Variance
0	PC1	0.487	0.487
1	PC2	0.325	0.812

Figure 17: Nutrient loadings and explained variance

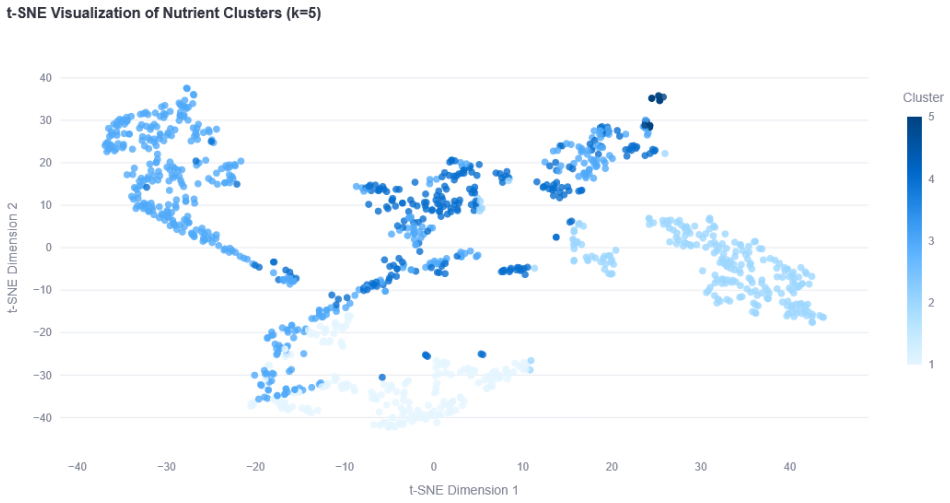
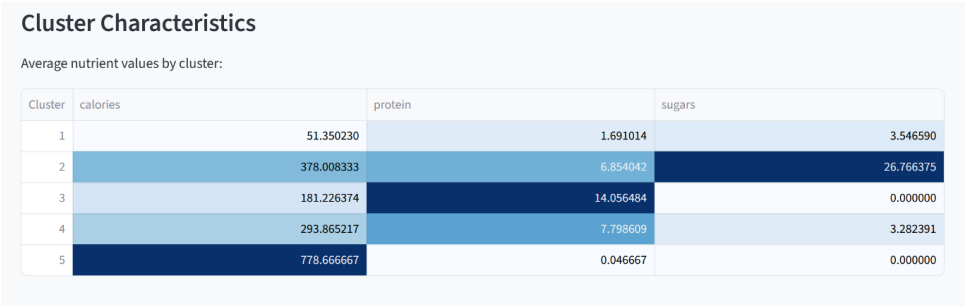


Figure 18: Gaussian Mixture Model clustering visualized with t-SNE dimensionality reduction



Cluster Characteristics

Average nutrient values by cluster:

Cluster	calories	protein	sugars
1	51.350230	1.691014	3.546590
2	378.008333	6.854042	26.766375
3	181.226374	14.056484	0.000000
4	293.865217	7.798609	3.282391
5	778.666667	0.046667	0.000000

Figure 19: Average nutrient values by cluster

3.6 Nutrition Based Food Search

Proposed Solution

- **Deficiency-Focused Filtering:** Created dynamic sliders and medical condition presets that filter foods based on nutrient thresholds and percentile rankings within their category.
- **Ranked Food Displays:** Engineered sortable data tables, ranking top food recommendations, showing how candidate foods match specified nutrient requirements.
- **GMM Similarity Suggestions:** Utilized GMM-derived nutritional clusters to suggest alternatives to user-selected foods, identifying items with analogous nutrient profiles that meet dietary constraints.

Insights

- **Condition-Based Smart Filtering:** Smart filtering lets users discover foods tailored to their specific nutrient deficiencies or health conditions.
- **Ranked Nutritional Recommendations:** Ranked recommendations simplify decision-making by presenting top food options based on nutritional fit.
- **Similarity-Driven Food Suggestions:** Similarity-based suggestions help users explore healthier or equivalent alternatives to commonly consumed foods.

Results

Choose Nutrient

calories

Choose Requirement Level

High

Products with High Calories

	name	serving_size	calories	percent_dv
0	Fish oil, menhaden	100	902	45.1
1	Fat, beef tallow	100	902	45.1
2	Fish oil, cod liver	100	902	45.1
3	Fish oil, herring	100	902	45.1
4	Fat, mutton tallow	100	902	45.1
5	Fish oil, sardine	100	902	45.1

Figure 20: Food items ranked on selected nutrient

GMM-Based Similar Food Suggestions

Pick a Food Item to Find Similar Alternatives

Cornstarch

	name	serving_size	gmm_cluster	similarity
0	Arrowroot flour	100	0	4.1167
1	Pears, solids and liquids, extra heavy syrup pack, canned	100	0	4.5321
2	Puddings, with no added salt, dry mix, tapioca	100	0	4.6093
3	Puddings, regular, dry mix, lemon	100	0	4.8974
4	Pears, solids and liquids, extra light syrup pack, canned	100	0	4.9781
5	Snacks, gluten- free made with cornstarch and potato flour, Pretzels	100	0	5.0856

Figure 21: GMM based similar food suggestions

Search by Health Condition

Choose a Condition

Anemia-Friendly

🔍 **Criteria:** Foods rich in Iron, Vitamin B6, Folate (B9), B12, and Vitamin C (enhances iron absorption)

Top Foods for: Anemia-Friendly

	name	serving_size	disease_score	iron	vitamin_b6	folate	vitamin_b12	vitamin_c
0	Beverages, prepared with whole milk, powder, natural, Malted drink mix	100	2.9353	1	0.6667	0.8081	0.4605	0.00007
1	Yogurt, nonfat, plain, Greek	100	2.872	0.7778	0.6364	0.7071	0.7508	0
2	Egg, fresh, raw, white	100	2.6989	0.8889	0.5051	0.404	0.9009	0
3	Yogurt, lowfat, strawberry, Greek	100	2.6826	0.7778	0.4949	0.9091	0.5005	0.0003
4	Fast Food, thin crust, pepperoni topping, 14" pizza, Pizza Chain	100	2.6506	0.0002	0.9596	0.9293	0.7608	0.0007
5	Cheese, low sodium, mozzarella	100	2.6381	0.00003	0.8081	0.9091	0.9209	0

Figure 22: Top foods for selected health condition

3.7 Nutrient Correlation Explorer

Proposed Solution

- **Correlation Matrix:** Implemented hierarchically-clustered correlation matrices identifying synergistic and antagonistic nutrient relationships across 8,800 foods, with intensity of color and direction that indicate the strength and type of relationship.

- **Interactive Nutrient Pairing:** Developed scatter plots with quadrant analysis for user-selected nutrient pairs (e.g., calcium-vitamin D), featuring highlighted ”ideal zones” (high fiber/low sugar).
- **Summary Statistics:** Aggregated key statistics (mean, median, min, max) for each nutrient across food categories. Visualized category-wise average using bar plots with adjustable nutrient selection.
- **Nutrition Similarity Explorer:** Allowed selection of any food item to find top 5 nutritionally similar foods using Euclidean distance. Enabled users to select specific nutrients for similarity computation with normalization applied.
- **Risky Nutrient Pairs:** Enables detection of foods with extreme nutrient values using customizable thresholds, with visual risk classification through interactive scatter plots.

Insights

- **Interactive Exploration of Nutrient Trends:** Interactive visualizations help identify relationships and trends among nutrients across thousands of food items.
- **Similarity Search for Healthier Alternatives:** Nutrient-based similarity search enables quick discovery of comparable or healthier food alternatives.
- **Statistical Insight Through Correlation Analysis:** Summary statistics and correlation analysis support data-driven understanding of nutrient distribution patterns.

Results

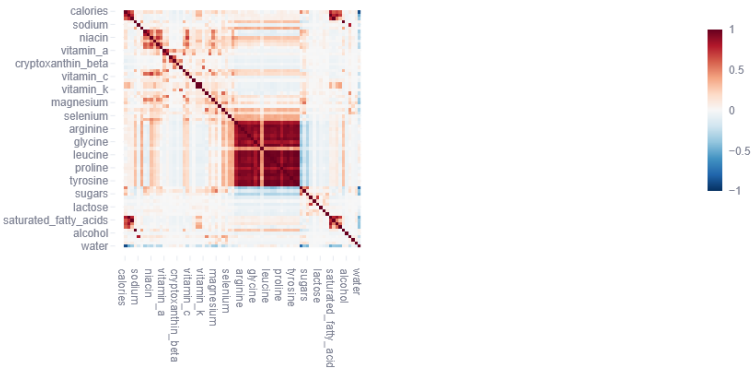


Figure 23: Correlation matrix of all nutrients across all food categories

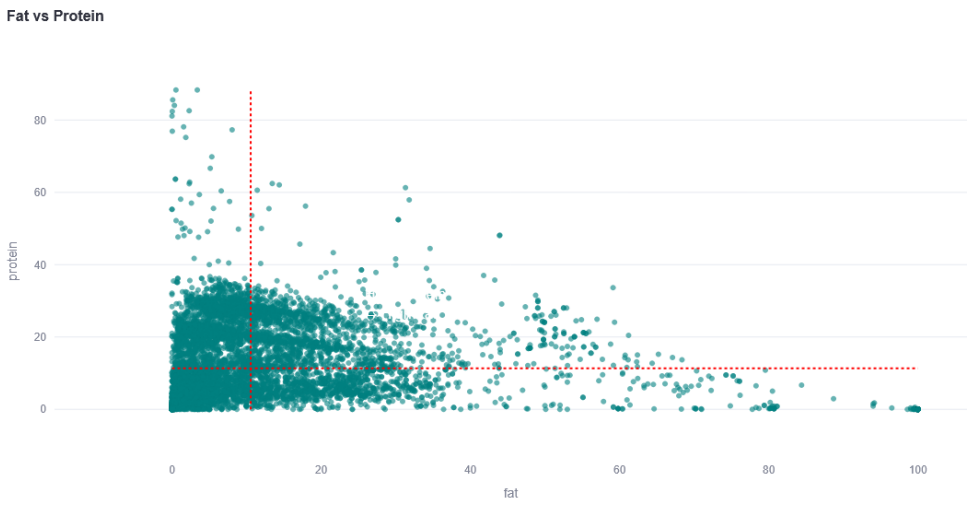


Figure 24: Scatter plot of Fat vs Protein, visualising nutrient variation across foods

Choose a Nutrient

calories

	category	mean	median	min	max
0	Baked Goods	320.850242	297.000000	53	558
1	Baking Ingredients	322.040000	362.000000	51	421
2	Beverages	100.658854	52.500000	0	880
3	Cereals and Breakfast Foods	386.368421	393.500000	58	489
4	Cheese	311.153846	334.000000	67	560
5	Dairy and Egg Products	246.618090	173.500000	15	718
6	Fats and Oils	453.617647	416.000000	34	902
7	Fruits and Fruit Juices	133.202765	60.000000	0	557
8	Grains and Pasta	255.009050	329.000000	27	511
9	Infant Foods	239.525000	127.000000	63	524

Figure 25: Summary statistics of calorie content per 100g serving across food categories

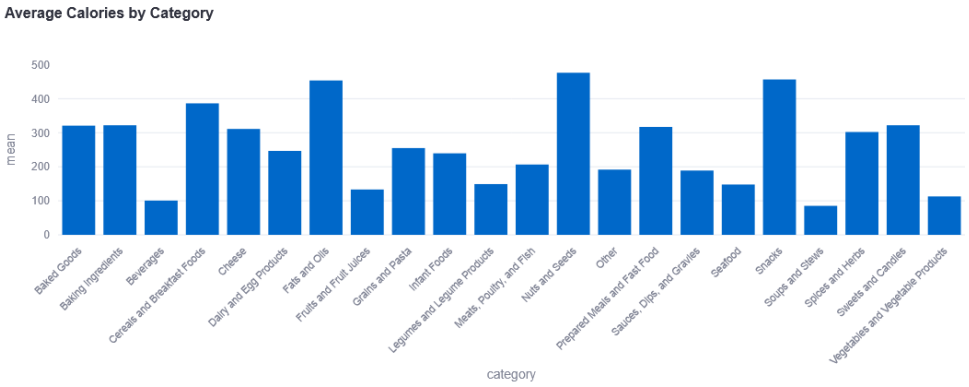


Figure 26: Average bar chart of calorie content per 100g serving across food categories

Select a Food Item

Nuts, pecans

Nutrients for Similarity Calculation

protein × total_fat × fiber × sugars × calcium × vitamin_d ×

Foods Similar to *Nuts, pecans*:

- *Nuts, with salt added, dry roasted, pecans* (Distance: 0.14)
- *Nuts, without salt added, dry roasted, pecans* (Distance: 0.14)
- *Nuts, with salt added, oil roasted, pecans* (Distance: 0.19)
- *Nuts, without salt added, oil roasted, pecans* (Distance: 0.19)
- *Nuts, raw, macadamia nuts* (Distance: 0.38)

Figure 27: Shows Foods similar to selected food item

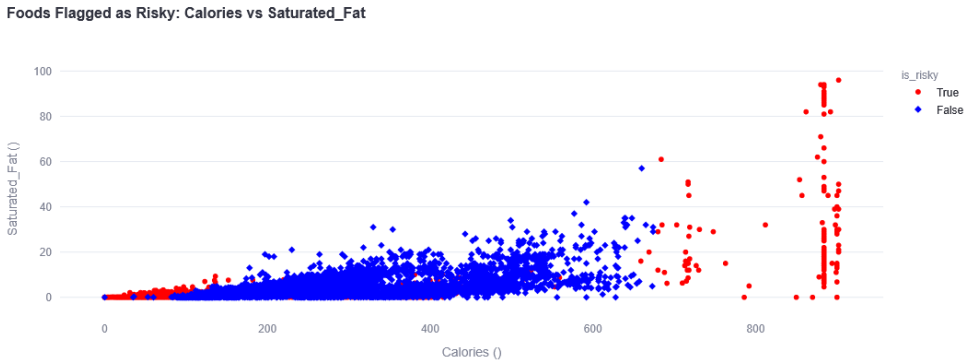


Figure 28: Visualizes the risky foods on the Scatter Plot

3.8 Calorie & Macro Calculator

Proposed Solution

- **Calorie & Macronutrient Estimation:** Collects user-specific inputs such as age, gender, weight, height, activity level, and dietary goals and calculates personalized daily energy requirements using the Mifflin-St Jeor equation and allocates target macronutrient ranges.
- **Ternary Plot Visualization:** Displays macronutrient balance on an interactive ternary plot for intuitive understanding of proportion trade-offs.
- **Food Recommendation & Nutritional Breakdown:** Suggests a list of foods from the dataset that closely align with the computed macro targets, supporting goal-specific diet planning. Provide a comprehensive tabular view of suggested food items along with their calorie and macro contributions per serving.

Insights

- **Personalized Macronutrient Alignment:** Personalized macronutrient balance helps users align their diets with specific fitness or health goals.
- **Macro Ratio Visualization with Ternary Plots:** Visualizing nutrient ratios through ternary plots simplifies complex macro planning.
- **Goal-Based Food Recommendations:** Goal-driven food recommendations enable users to make informed dietary choices without manual tracking.

Results

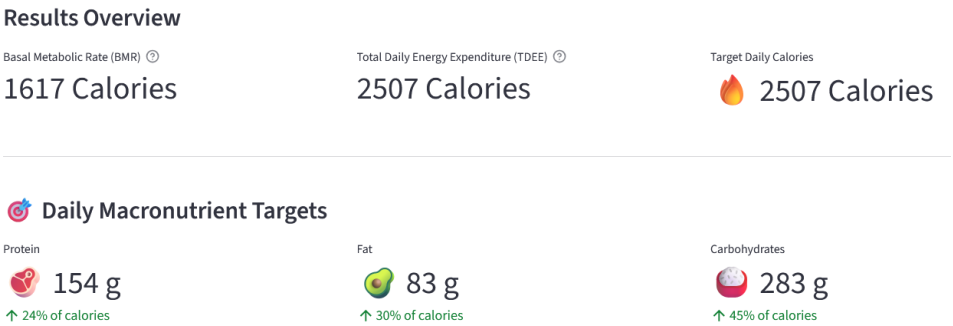


Figure 29: Overview of target calories and macronutrients

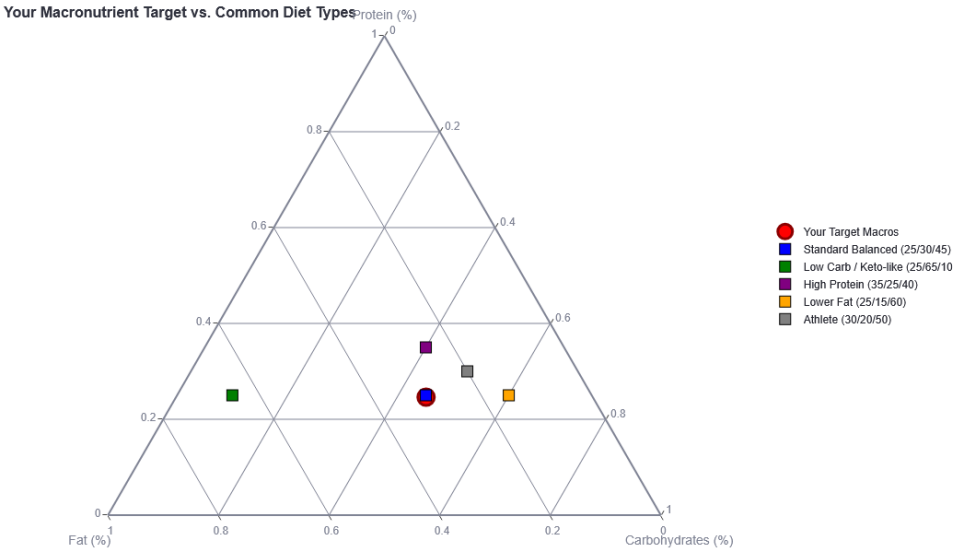


Figure 30: Ternary plot of macronutrients for target vs. common diet types

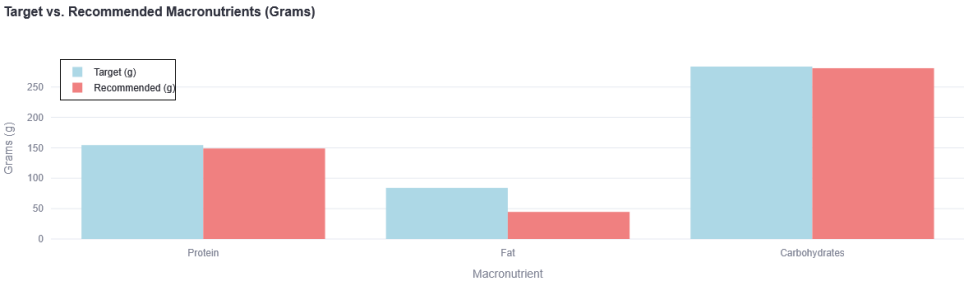


Figure 31: Target vs. recommended macronutrients (Bar Chart)

Detailed Breakdown of Recommended Food Items:

Food Item	Serving Info	Calories	Protein (g)	Fat (g)	Carbohydrates (g)
Cereals ready-to-eat, frosted oat cereal with marshmallows	approx. 2.0x serving (100)	800	14.2	6.7	169.4
Pasta, as purchased, spinach, fresh-refrigerated	approx. 2.0x serving (100)	578	22.5	4.2	111.4
Beef, broiled, cooked, all grades, trimmed to 1/8" fat, separable lean only, steak, tend	approx. 2.0x serving (100)	400	58.1	16.8	0
Beef, baked, cooked, loaf, 93% lean meat / 7% fat, ground	approx. 2.0x serving (100)	384	54.1	16.9	0

Figure 32: Detailed breakdown of recommended food items

Figure 33: Macronutrient contribution per recommended food item

4 Conclusion:

NutriViz makes complex nutritional data easy to understand and interact with. We started with a rich dataset of over 8,800 foods. We cleaned, standardized, and organized the data into 22 categories to ensure accuracy and consistency. This solid foundation let us create useful visualizations and analysis tools. These tools explore macronutrient balance, micronutrient density, fat composition, and vitamin content. The preprocessing step also revealed key facts, such as the number of foods with missing saturated fat data that actually had no fat at all. This justified our decision to replace those missing values with zero.

Each module in NutriViz gives users a different way to explore nutrition. Users can compare food groups, discover hidden patterns, or get healthy food recommendations based on dietary needs. Visual tools like radar charts, t-SNE plots, GMM clustering, and PCA biplots make it easier to see trends and relationships that would be hard to spot in raw numbers. By combining careful preprocessing with user-friendly design and statistical power, NutriViz helps researchers and health-conscious individuals make better, informed dietary choices.

5 Team Contributions:

The following table outlines the contributions made by each team member to specific modules in the NutriViz project:

Module	**Contributor(s)**
`Overview.py`	R Vinod Kumar (220843)
`Macronutrient_Distribution_Analysis.py`	Deepavath Raghu Ram Naik (220333)
`Vitamin_and_Mineral_Density.py`	Banoth Anand (220281)
`Fat_Composition_Analysis.py`	Harsha Kumar (220358)
`Food_Category_Benchmarking.py`	Pujari Krishna Chandu (220832), Ravula Harshith Sai (220878)
`Nutrient_Based_Food_Search.py`	Ramavath Dinesh Naik (220866)
`Nutrient_Correlation_Exploration.py`	Akarsh Verma (220094)
`Calorie_Macro_Calculator.py`	Sikha Vamsi (221058)

Table 1: Team Members and Their Module Contributions

6 Link to Source Code:

The complete implementation is available at: `https://github.com/AnandBanoth2004/CS661_Final_Project-Nutriviz` including vscode documenting analytical workflows and Streamlit deployment configuration.

7 References:

1. https://www.kaggle.com/datasets/gokulprasantht/nutrition-dataset