MN_median_Clustering

May 3, 2024

[1]:

```
!pip install scikit-learn-extra
```

```
Requirement already satisfied: scikit-learn-extra in
c:\users\tky12\anaconda3\lib\site-packages (0.3.0)
Requirement already satisfied: numpy>=1.13.3 in
c:\users\tky12\anaconda3\lib\site-packages (from scikit-learn-extra) (1.26.4)
Requirement already satisfied: scipy>=0.19.1 in
c:\users\tky12\anaconda3\lib\site-packages (from scikit-learn-extra) (1.11.4)
Requirement already satisfied: scikit-learn>=0.23.0 in
c:\users\tky12\anaconda3\lib\site-packages (from scikit-learn-extra) (1.2.2)
Requirement already satisfied: joblib>=1.1.1 in
c:\users\tky12\anaconda3\lib\site-packages (from scikit-learn>=0.23.0->scikit-
learn-extra) (1.2.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in
c:\users\tky12\anaconda3\lib\site-packages (from scikit-learn>=0.23.0->scikit-
learn-extra) (2.2.0)
```

[2]:

```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import numpy as np
from mpl_toolkits.mplot3d import Axes3D
from scipy.stats import multivariate_normal
from scipy.stats import norm
import plotly.express as px
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import silhouette_score
import pickle
```

[3]:

```
# Surpress warnings
def warn(*args, **kwargs):
    pass
import warnings
warnings.warn = warn
```

[4]:

```
pd.DataFrame.iteritems = pd.DataFrame.items
```

```
[5]: # Retrieve dataset and read first 5 rows
     macroNutrient_median =pd.read_csv(r"../Dataset/Dataset_for_EDA/
       ↪macroNutrient_median.csv", encoding= 'unicode_escape')
     macroNutrient_median
```

```
[5]:
        No.                                        Description       Category  \
0     15155                          ABALONE,MIXED SPECIES,RAW        ABALONE
1     15156                           ABALONE,MXD SP,CKD,FRIED        ABALONE
2      9427                                        ABIYUCH,RAW        ABIYUCH
3      9002                                  ACEROLA JUICE,RAW  ACEROLA JUICE
4      9001                   ACEROLA,(WEST INDIAN CHERRY),RAW        ACEROLA
…     …                                                …            …
8785   1119        YOGURT,VANILLA,LOFAT,11 GRAMS PROT PER 8 OZ         YOGURT
8786   1220  YOGURT,VANILLA,LOFAT,11 GRAMS PROT PER 8 OZ,FO…         YOGURT
8787   1295                             YOGURT,VANILLA,NON-FAT         YOGURT
8788  16004                 YOKAN,PREP FROM ADZUKI BNS & SUGAR          YOKAN
8789   3217                                           ZWIEBACK       ZWIEBACK

      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0               105             6.01       17.10            0.76
1               189            11.05       19.63            6.78
2                69            17.60        1.50            0.10
3                23             4.80        0.40            0.30
4                32             7.69        0.40            0.30
…             …              …         …             …
8785             85            13.80        4.93            1.25
8786             85            13.80        4.93            1.25
8787             78            17.04        2.94            0.00
8788            260            60.72        3.29            0.12
8789            426            74.20       10.10            9.70

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                             0.1070                           0.104
1                             2.7410                           1.676
2                             1.9385                           0.696
3                             0.0820                           0.090
4                             0.0820                           0.090
…                              …                             …
8785                          0.3430                           0.036
8786                          0.3430                           0.036
8787                          0.0000                           0.000
8788                          0.0110                           0.026
8789                          4.2440                           2.073

      Saturated Fatty Acids(g)
0                        0.149
1                        1.646
```

```
2                          0.014
3                          0.068
4                          0.068
…                          …
8785                       0.806
8786                       0.806
8787                       0.000
8788                       0.043
8789                       2.525

[8790 rows x 10 columns]
```

[6]:

```
macroNutrient_median.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 8790 entries, 0 to 8789
Data columns (total 10 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   No.                             8790 non-null   int64
 1   Description                     8790 non-null   object
 2   Category                        8790 non-null   object
 3   Energy (Kcal)                   8790 non-null   int64
 4   Carbohydrate(g)                 8790 non-null   float64
 5   Protein(g)                      8790 non-null   float64
 6   Total Lipid(g)                  8790 non-null   float64
 7   Monounsaturated Fatty Acids(g)  8790 non-null   float64
 8   Polyunsaturated Fatty Acids(g)  8790 non-null   float64
 9   Saturated Fatty Acids(g)        8790 non-null   float64
dtypes: float64(6), int64(2), object(2)
memory usage: 686.8+ KB
```

[7]:

```
macroNutrient_median.describe()
```

[7]:

```
                No.  Energy (Kcal)  Carbohydrate(g)   Protein(g)  \
count   8790.000000    8790.000000      8790.000000  8790.000000
mean   15663.495222     226.317634        22.127710    11.342849
std     9251.413586     169.877539        27.270822    10.530474
min     1001.000000       0.000000         0.000000     0.000000
25%     9086.250000      91.000000         0.050000     2.380000
50%    14427.500000     191.000000         9.340000     8.000000
75%    20142.750000     337.000000        34.910000    19.880000
max    93600.000000     902.000000       100.000000    88.320000

       Total Lipid(g)  Monounsaturated Fatty Acids(g)  \
count     8790.000000                     8790.000000
mean        10.553725                        3.918673
std         15.814842                        6.763709
```

```
min          0.000000                        0.000000
25%          0.950000                        0.304000
50%          5.140000                        1.938500
75%         13.720000                        4.759000
max        100.000000                       83.689000

       Polyunsaturated Fatty Acids(g)  Saturated Fatty Acids(g)
count                     8790.000000               8790.000000
mean                         2.168267                  3.497547
std                          5.032118                  6.399843
min                          0.000000                  0.000000
25%                          0.249000                  0.259000
50%                          0.696000                  1.592000
75%                          1.880000                  4.173750
max                         74.623000                 95.600000
```

[8]:

```
macroNutrient_median.head()
```

[8]:

```
     No.                       Description       Category  Energy (Kcal)  \
0  15155         ABALONE,MIXED SPECIES,RAW        ABALONE            105
1  15156          ABALONE,MXD SP,CKD,FRIED        ABALONE            189
2   9427                       ABIYUCH,RAW        ABIYUCH             69
3   9002                 ACEROLA JUICE,RAW  ACEROLA JUICE             23
4   9001  ACEROLA,(WEST INDIAN CHERRY),RAW        ACEROLA             32

   Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0             6.01       17.10            0.76
1            11.05       19.63            6.78
2            17.60        1.50            0.10
3             4.80        0.40            0.30
4             7.69        0.40            0.30

   Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                          0.1070                           0.104
1                          2.7410                           1.676
2                          1.9385                           0.696
3                          0.0820                           0.090
4                          0.0820                           0.090

   Saturated Fatty Acids(g)
0                     0.149
1                     1.646
2                     0.014
3                     0.068
4                     0.068
```

[9]:

```python
float_columns = [x for x in macroNutrient_median.columns if x not in ['No.',␣
 ↪'Description', 'Category']]
```

[10]:

```python
skew_columns = (macroNutrient_median[float_columns]
                .skew()
                .sort_values(ascending=False))

skew_columns = skew_columns.loc[skew_columns > 0.75]
print("{} of the 7 columns are skewed with the vast majority being heavily␣
 ↪skewed".format(len(skew_columns)))
skew_columns
```

```
7 of the 7 columns are skewed with the vast majority being heavily skewed
```

[10]:

```
Saturated Fatty Acids(g)          6.722778
Polyunsaturated Fatty Acids(g)    6.401464
Monounsaturated Fatty Acids(g)    4.764472
Total Lipid(g)                    3.309724
Protein(g)                        1.166368
Energy (Kcal)                     1.148610
Carbohydrate(g)                   1.127598
dtype: float64
```

[11]:

```python
# Perform log transform on skewed columns
for col in skew_columns.index.tolist():
    macroNutrient_median[col] = np.log1p(macroNutrient_median[col])
```

[12]:

```python
macroNutrient_median[float_columns]
```

[12]:

```
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0          4.663439         1.947338    2.895912        0.565314
1          5.247024         2.489065    3.026746        2.051556
2          4.248495         2.923162    0.916291        0.095310
3          3.178054         1.757858    0.336472        0.262364
4          3.496508         2.162173    0.336472        0.262364
…               …              …          …              …
8785       4.454347         2.694627    1.780024        0.810930
8786       4.454347         2.694627    1.780024        0.810930
8787       4.369448         2.892592    1.371181        0.000000
8788       5.564520         4.122608    1.456287        0.113329
8789       6.056784         4.320151    2.406945        2.370244

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                           0.101654                        0.098940
1                           1.319353                        0.984323
2                           1.077899                        0.528273
3                           0.078811                        0.086178
4                           0.078811                        0.086178
```

```
…                              …                             …
8785                        0.294906                        0.035367
8786                        0.294906                        0.035367
8787                        0.000000                        0.000000
8788                        0.010940                        0.025668
8789                        1.657085                        1.122654

      Saturated Fatty Acids(g)
0                     0.138892
1                     0.973049
2                     0.013903
3                     0.065788
4                     0.065788
…                        …
8785                  0.591114
8786                  0.591114
8787                  0.000000
8788                  0.042101
8789                  1.259880

[8790 rows x 7 columns]
```

[13]:
```
macroNutrient_median.describe()
```

[13]:
```
                No.  Energy (Kcal)  Carbohydrate(g)   Protein(g)  \
count   8790.000000    8790.000000      8790.000000  8790.000000
mean   15663.495222       5.065342         2.137177     2.047259
std     9251.413586       0.997539         1.615109     1.068937
min     1001.000000       0.000000         0.000000     0.000000
25%     9086.250000       4.521789         0.048790     1.217876
50%    14427.500000       5.257495         2.336020     2.197225
75%    20142.750000       5.823046         3.581016     3.038792
max    93600.000000       6.805723         4.615121     4.492225

       Total Lipid(g)  Monounsaturated Fatty Acids(g)  \
count     8790.000000                     8790.000000
mean         1.770891                        1.126758
std          1.183944                        0.895498
min          0.000000                        0.000000
25%          0.667829                        0.265436
50%          1.814823                        1.077899
75%          2.689207                        1.750764
max          4.615121                        4.438986

       Polyunsaturated Fatty Acids(g)  Saturated Fatty Acids(g)
count                     8790.000000               8790.000000
mean                         0.752763                  1.054167
```

```
std                          0.733516                  0.871130
min                          0.000000                  0.000000
25%                          0.222343                  0.230318
50%                          0.528273                  0.952430
75%                          1.057790                  1.643598
max                          4.325760                  4.570579
```

[14]:
```
scaler = MinMaxScaler()
macroNutrient_median[float_columns] = scaler.
 ↪fit_transform(macroNutrient_median[float_columns])

macroNutrient_median.describe()
```

[14]:
```
                No.  Energy (Kcal)  Carbohydrate(g)   Protein(g)  \
count   8790.000000    8790.000000      8790.000000  8790.000000
mean   15663.495222       0.744277         0.463082     0.455734
std     9251.413586       0.146574         0.349960     0.237953
min     1001.000000       0.000000         0.000000     0.000000
25%     9086.250000       0.664410         0.010572     0.271107
50%    14427.500000       0.772511         0.506167     0.489117
75%    20142.750000       0.855610         0.775931     0.676456
max    93600.000000       1.000000         1.000000     1.000000

       Total Lipid(g)  Monounsaturated Fatty Acids(g)  \
count     8790.000000                     8790.000000
mean         0.383715                        0.253832
std          0.256536                        0.201735
min          0.000000                        0.000000
25%          0.144705                        0.059797
50%          0.393234                        0.242826
75%          0.582695                        0.394406
max          1.000000                        1.000000

       Polyunsaturated Fatty Acids(g)  Saturated Fatty Acids(g)
count                     8790.000000               8790.000000
mean                         0.174019                  0.230642
std                          0.169569                  0.190595
min                          0.000000                  0.000000
25%                          0.051400                  0.050391
50%                          0.122122                  0.208383
75%                          0.244533                  0.359604
max                          1.000000                  1.000000
```

[15]:
```
X = macroNutrient_median[float_columns]
X
```

[15]:
```
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0          0.685223         0.421947    0.644650        0.122492   
1          0.770972         0.539328    0.673774        0.444529   
2          0.624253         0.633388    0.203973        0.020652   
3          0.466968         0.380891    0.074901        0.056849   
4          0.513760         0.468498    0.074901        0.056849   
…               …               …          …             …         
8785       0.654500         0.583869    0.396246        0.175712   
8786       0.654500         0.583869    0.396246        0.175712   
8787       0.642026         0.626764    0.305234        0.000000   
8788       0.817624         0.893283    0.324179        0.024556   
8789       0.889955         0.936086    0.535802        0.513582   

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                           0.022900                        0.022872   
1                           0.297219                        0.227549   
2                           0.242826                        0.122122   
3                           0.017754                        0.019922   
4                           0.017754                        0.019922   
…                              …                               …       
8785                        0.066435                        0.008176   
8786                        0.066435                        0.008176   
8787                        0.000000                        0.000000   
8788                        0.002465                        0.005934   
8789                        0.373303                        0.259528   

      Saturated Fatty Acids(g)  
0                     0.030388  
1                     0.212894  
2                     0.003042  
3                     0.014394  
4                     0.014394  
…                        …      
8785                  0.129330  
8786                  0.129330  
8787                  0.000000  
8788                  0.009211  
8789                  0.275650  

[8790 rows x 7 columns]
```

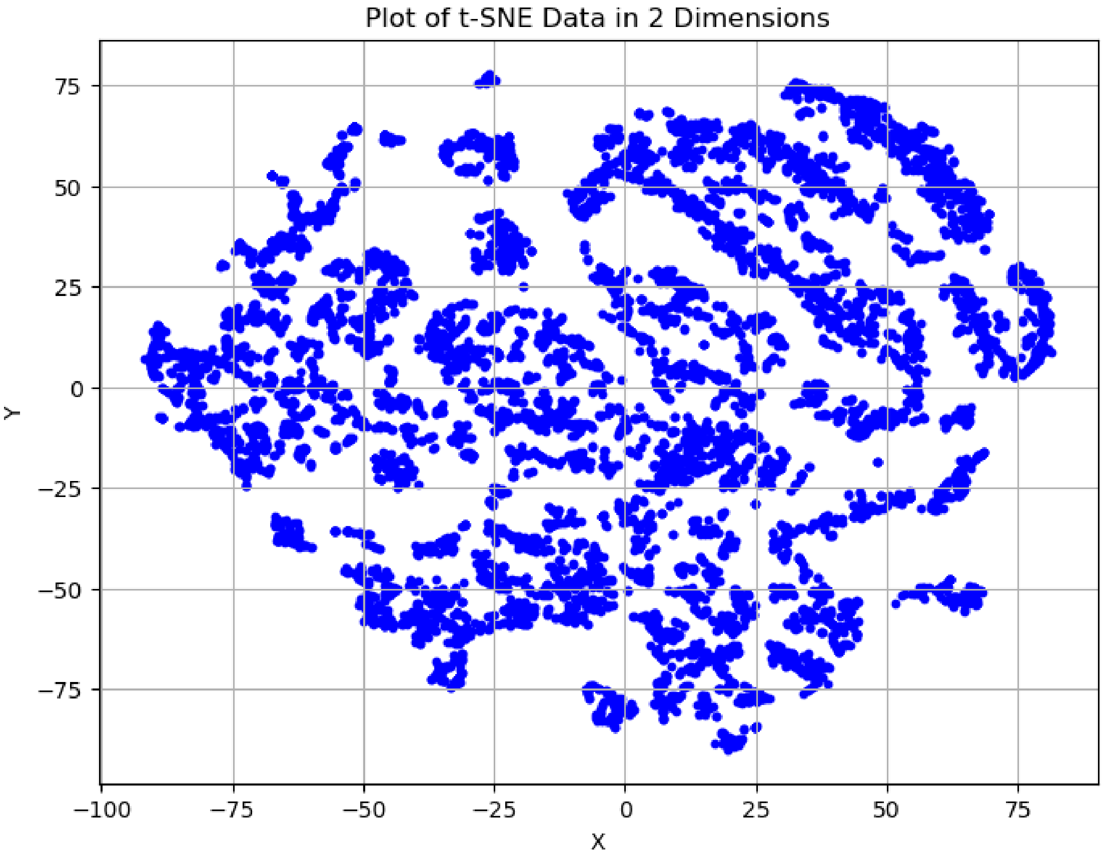
0.1 Dimensionality Reduction

[16]:
```python
from clustering_function import dimensionality_reduction,scatter_plot_clustering
```

[17]:
```python
# Reduced to 2 dimensions using tsne
```

```
X_tsne_reduced, tsne_x_data, tsne_y_data, reduction_method =␣
 ↪dimensionality_reduction(X, 't-SNE', n_components=2)
```

[18]:
```
scatter_plot_clustering(tsne_x_data, tsne_y_data, reduction_method)
```



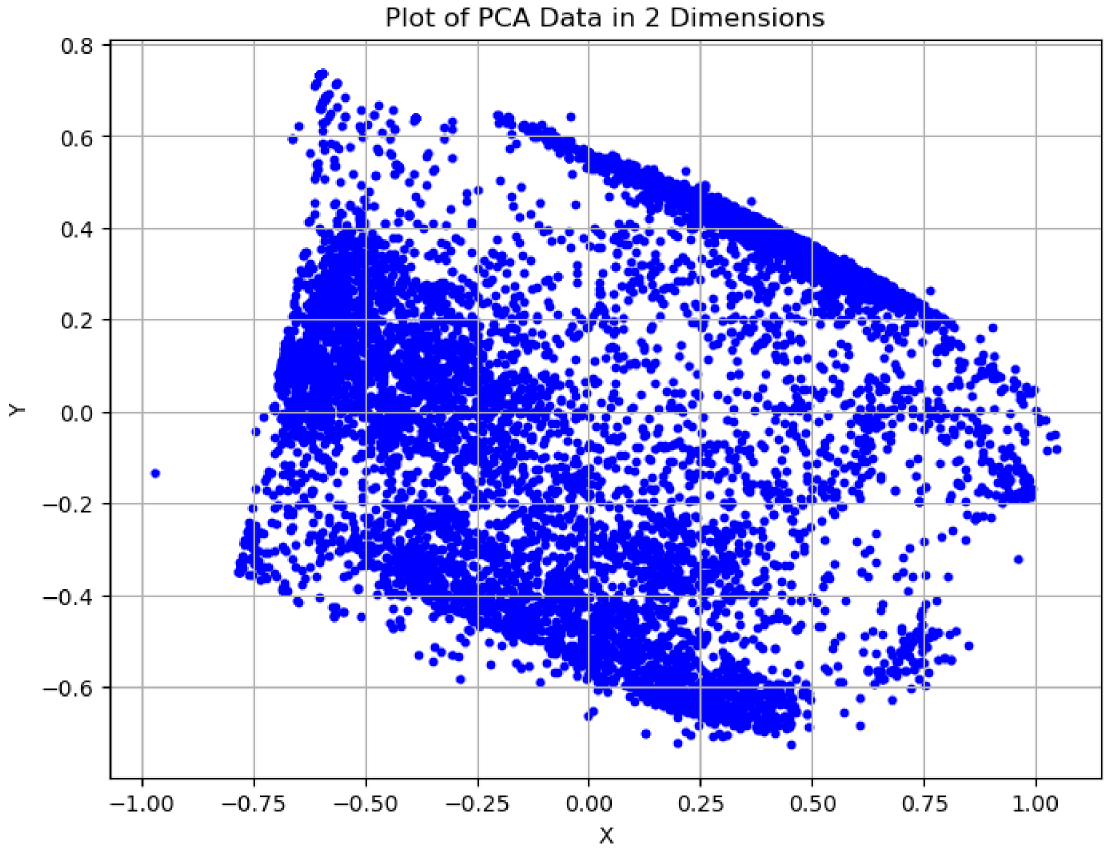
[19]:
```
X_tsne_reduced
```

[19]:
```
array([[ -2.8866012 ,  25.033136  ],
       [ 10.356084  ,   0.31811064],
       [-28.60716   ,  33.482193  ],
       …,
       [-60.97991   ,  -6.97665   ],
       [-50.850197  , -45.544563  ],
       [  2.5995357 , -35.31806   ]], dtype=float32)
```

[20]:
```
pd.DataFrame(X_tsne_reduced).to_csv("../Dataset/Dataset_for_reduced_data/
 ↪median_reduced.csv")
```

[21]:
```
# Reduced to 2 dimensions using pca
X_pca_reduced, pca_x_data, pca_y_data, reduction_method =␣
 ↪dimensionality_reduction(X, 'PCA', n_components=2)
```

[22]:
```
scatter_plot_clustering(pca_x_data, pca_y_data, reduction_method)
```



[23]:
```
X_pca_reduced
```

[23]:
```
array([[-0.28583447,  0.23920712],
       [ 0.11334472, -0.07742649],
       [-0.48422218, -0.01451935],
       …,
       [-0.58623631,  0.0718748 ],
       [-0.62047369, -0.2098833 ],
       [ 0.04574319, -0.51445591]])
```

0.2 K Means: Optimal number of clusters

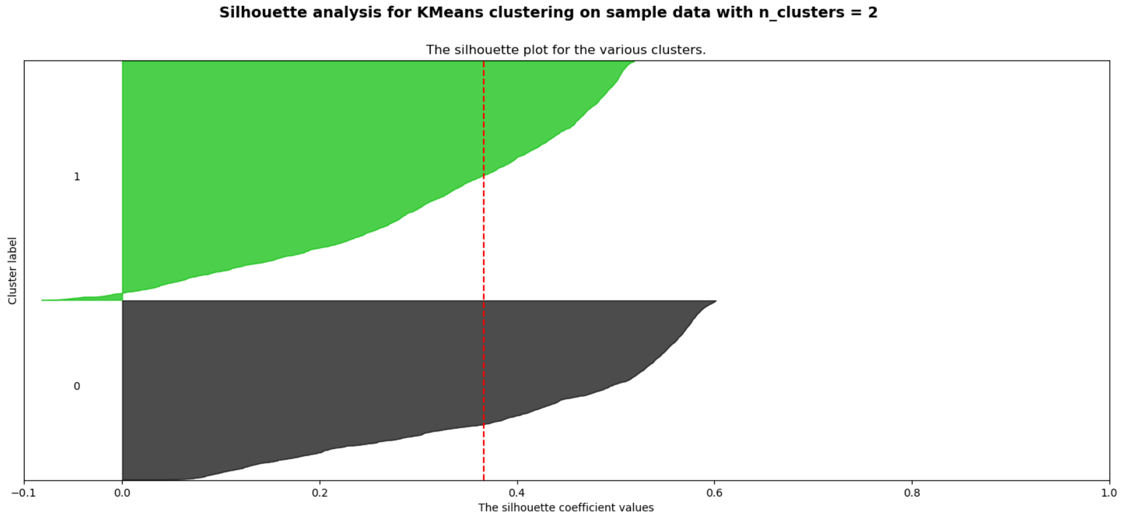
Silhoutte Analysis

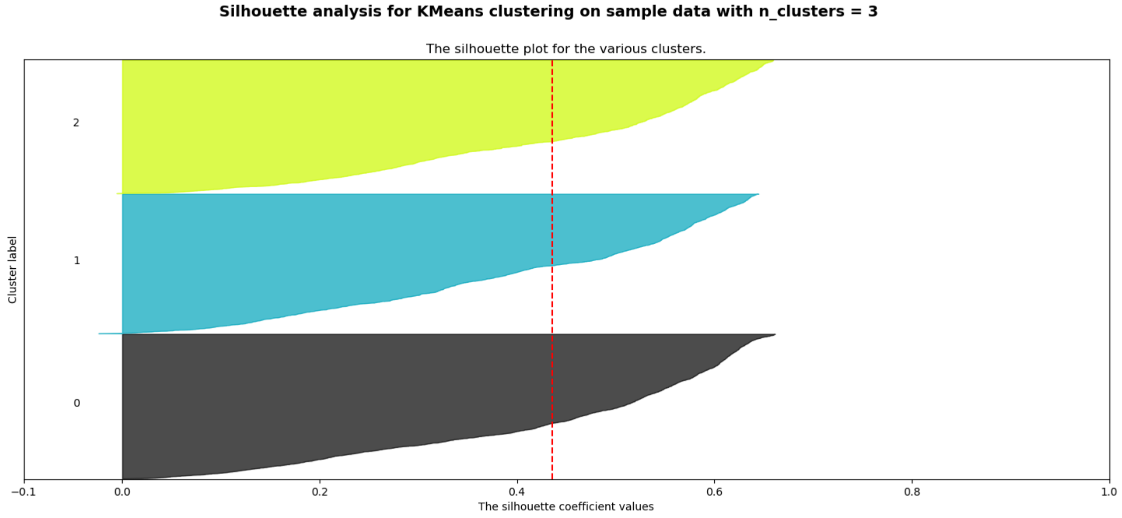
[24]:
```
from clustering_function import plot_silhouette_analysis
```

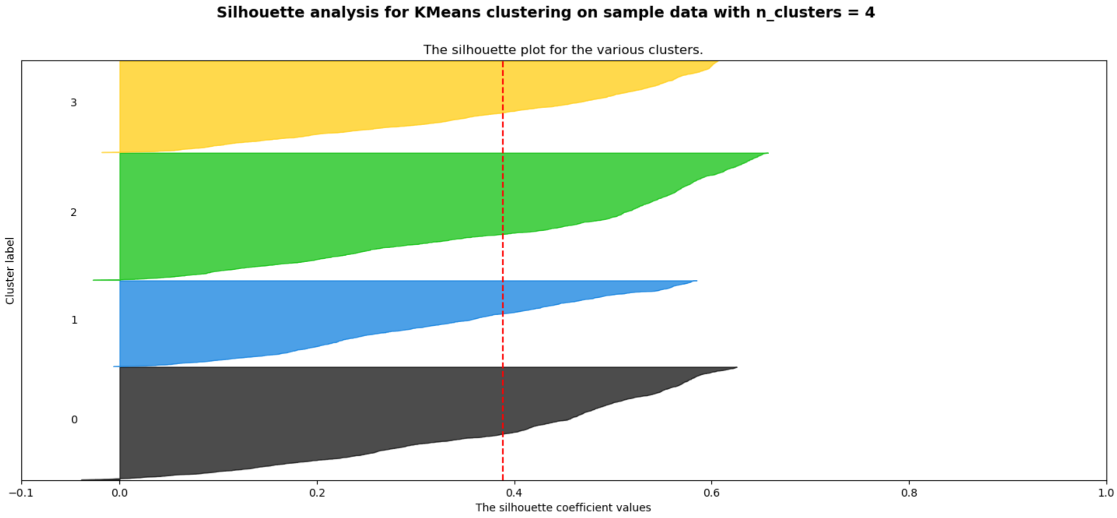
[25]:

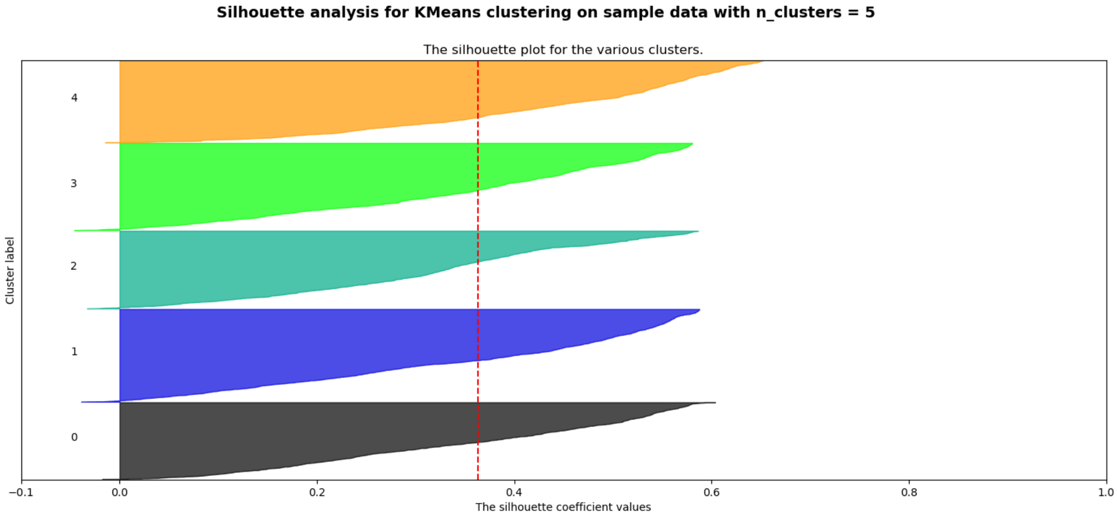
```
tsne_list_num_clusters = list(range(2,8))
plot_silhouette_analysis(X_tsne_reduced, tsne_list_num_clusters)
```

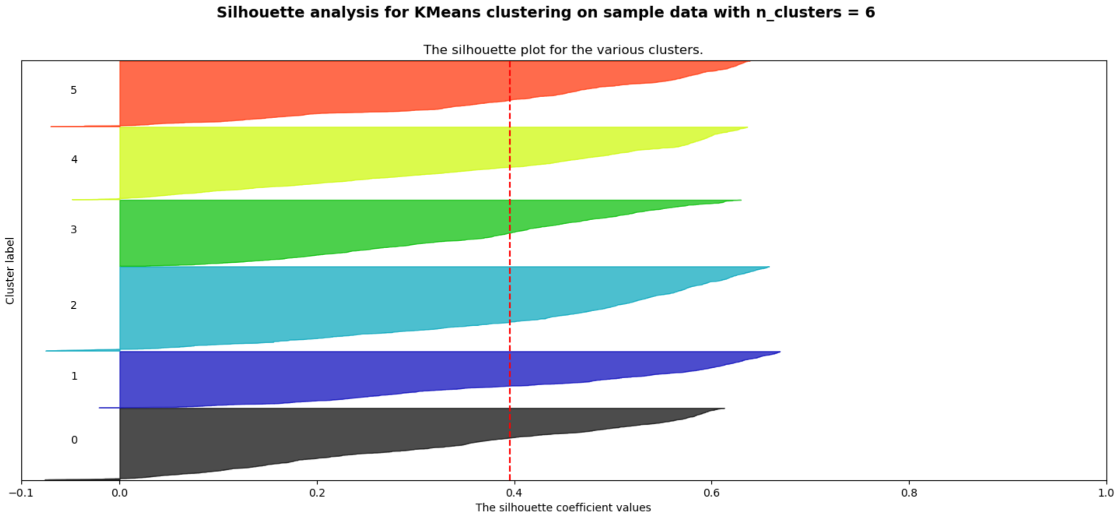
```
For n_clusters = 2 The average silhouette_score is : 0.36614758
For n_clusters = 3 The average silhouette_score is : 0.43591416
For n_clusters = 4 The average silhouette_score is : 0.3885924
For n_clusters = 5 The average silhouette_score is : 0.36350286
For n_clusters = 6 The average silhouette_score is : 0.39561477
For n_clusters = 7 The average silhouette_score is : 0.39939517
```

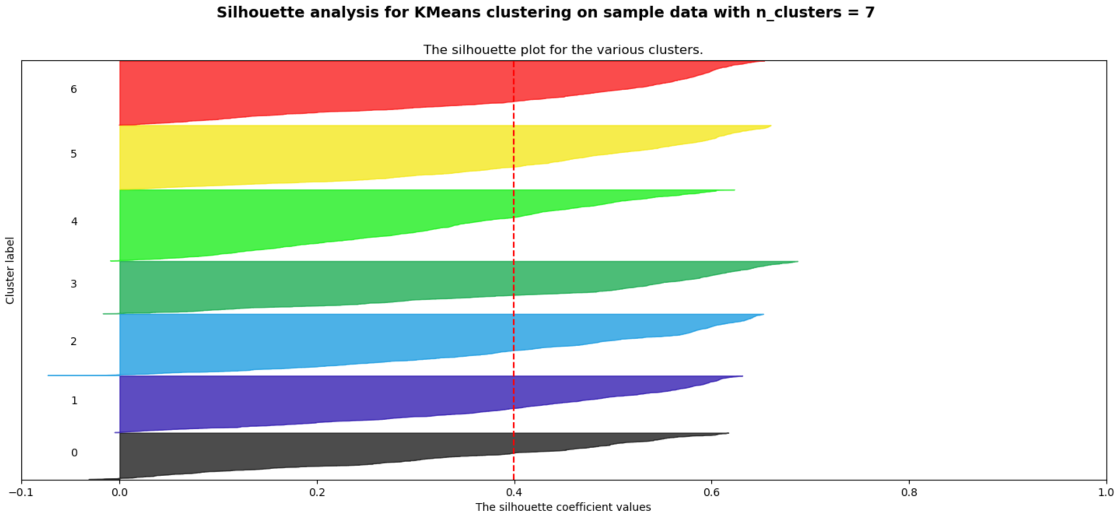





Silhouette analysis for KMeans clustering on sample data with n_clusters = 4
The silhouette plot for the various clusters.
Cluster label
3
2
1
0
−0.1
0.0
0.2
0.4
0.6
0.8
1.0
The silhouette coefficient values


Silhouette analysis for KMeans clustering on sample data with n_clusters = 5
The silhouette plot for the various clusters.
Cluster label
4
3
2
1
0
−0.1
0.0
0.2
0.4
0.6
0.8
1.0
The silhouette coefficient values



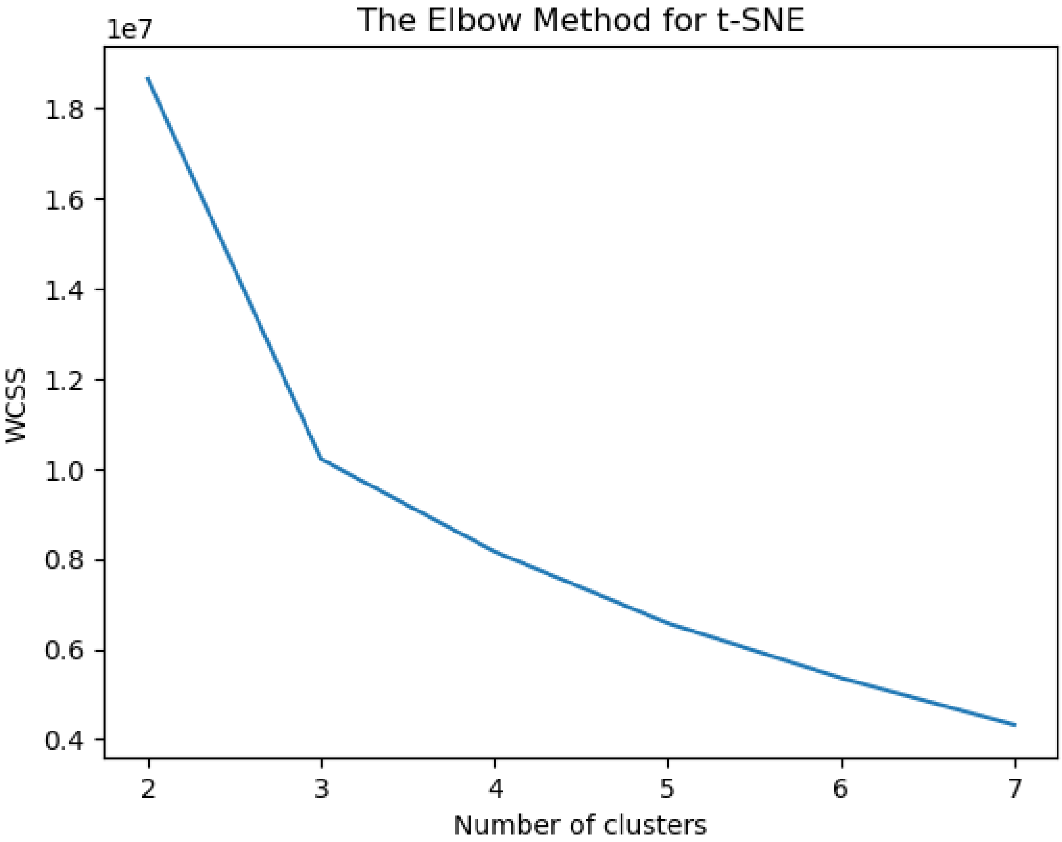


3 clusters seems to be the best number of cluster according to Silhouette Analysis.

Elbow Method

```
[26]: from clustering_function import elbow_method_analysis
```

```
[27]: elbow_method_analysis(X_tsne_reduced)
```



Given that the elbow point falls at 3, the elbow method also suggests that 3 clusters will be the ideal number of clusters for K-Means.

0.3 Clustering

```
[28]: # Trackers throughout each model
      scores = {} # to track the silhoutte score of the tuned model
      food_groups = {} # to track the counts of each group
```

```
[29]: X_with_labels = X.copy()
      X_with_labels
```

```
[29]:       Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
      0          0.685223         0.421947    0.644650        0.122492
      1          0.770972         0.539328    0.673774        0.444529
      2          0.624253         0.633388    0.203973        0.020652
      3          0.466968         0.380891    0.074901        0.056849
      4          0.513760         0.468498    0.074901        0.056849
      …             …               …            …              …
      8785       0.654500         0.583869    0.396246        0.175712
```

```
8786       0.654500         0.583869    0.396246        0.175712
8787       0.642026         0.626764    0.305234        0.000000
8788       0.817624         0.893283    0.324179        0.024556
8789       0.889955         0.936086    0.535802        0.513582

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                           0.022900                        0.022872
1                           0.297219                        0.227549
2                           0.242826                        0.122122
3                           0.017754                        0.019922
4                           0.017754                        0.019922
…                              …                              …
8785                        0.066435                        0.008176
8786                        0.066435                        0.008176
8787                        0.000000                        0.000000
8788                        0.002465                        0.005934
8789                        0.373303                        0.259528

      Saturated Fatty Acids(g)
0                     0.030388
1                     0.212894
2                     0.003042
3                     0.014394
4                     0.014394
…                        …
8785                  0.129330
8786                  0.129330
8787                  0.000000
8788                  0.009211
8789                  0.275650

[8790 rows x 7 columns]
```

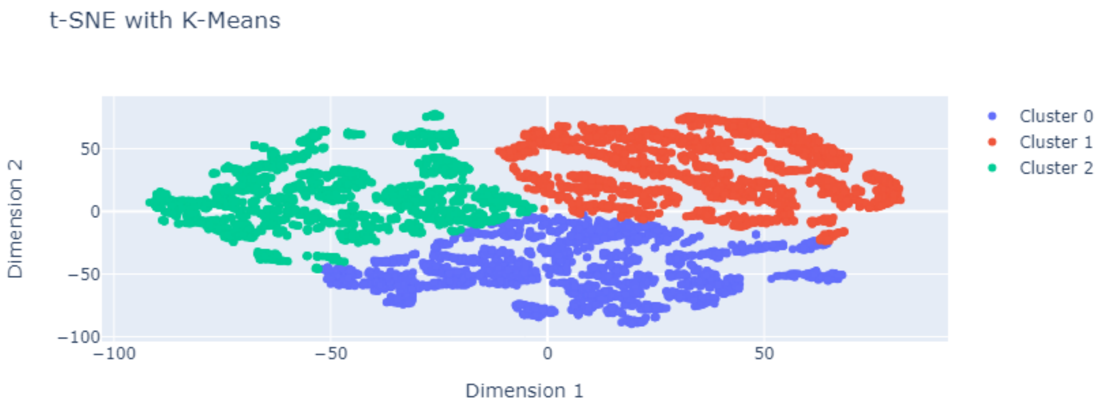
0.4 K Means Clustering

[30]:

```
from clustering_function import perform_kmeans_clustering, plot_clusters
```

[31]:

```
tsne_clust_labels, kmean_model = perform_kmeans_clustering(X_tsne_reduced, 3)
plot_clusters(X_tsne_reduced, tsne_clust_labels, 'K-Means')
```



[32]:
```
# export model
with open('../Model_fitted/Kmeans_model_median_pkl', 'wb') as files:
    pickle.dump(kmean_model, files)
```

[33]:
```
X_with_labels['kmeans_tsne'] = tsne_clust_labels
scores['kmeans_tsne'] = (silhouette_score(X_tsne_reduced,␣
 ↪X_with_labels['kmeans_tsne']))

X_with_labels
```

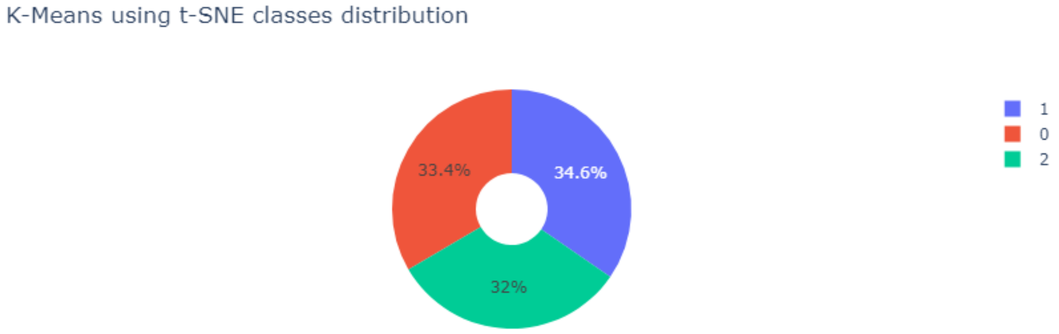
[33]:
```
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0          0.685223         0.421947    0.644650        0.122492
1          0.770972         0.539328    0.673774        0.444529
2          0.624253         0.633388    0.203973        0.020652
3          0.466968         0.380891    0.074901        0.056849
4          0.513760         0.468498    0.074901        0.056849
…               …              …           …             …
8785       0.654500         0.583869    0.396246        0.175712
8786       0.654500         0.583869    0.396246        0.175712
8787       0.642026         0.626764    0.305234        0.000000
8788       0.817624         0.893283    0.324179        0.024556
8789       0.889955         0.936086    0.535802        0.513582

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                           0.022900                        0.022872
1                           0.297219                        0.227549
2                           0.242826                        0.122122
3                           0.017754                        0.019922
4                           0.017754                        0.019922
…                              …                               …
```

```
8785                        0.066435                        0.008176
8786                        0.066435                        0.008176
8787                        0.000000                        0.000000
8788                        0.002465                        0.005934
8789                        0.373303                        0.259528

      Saturated Fatty Acids(g)  kmeans_tsne
0                     0.030388            1
1                     0.212894            1
2                     0.003042            2
3                     0.014394            2
4                     0.014394            2
…                          …          …
8785                  0.129330            2
8786                  0.129330            2
8787                  0.000000            2
8788                  0.009211            0
8789                  0.275650            0

[8790 rows x 8 columns]
```

```
[34]: from clustering_function import get_food_groups, plot_cluster_distribution
```

```
[35]: food_groups, value_counts = get_food_groups(X_with_labels['kmeans_tsne'],␣
        ↪'KMeans_tsne',food_groups)
```

```
[36]: plot_cluster_distribution(value_counts, 'K-Means')
```



```
[37]: kmeans_tsne = X_with_labels.groupby('kmeans_tsne')
```

[38]:

```
n = kmeans_tsne['kmeans_tsne'].count().count() # number of cluster
for i in range(0,n):
    display(kmeans_tsne.get_group(i))
```

```
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
5          0.913731         0.870851    0.476131        0.745258
7          0.916054         0.866962    0.491577        0.753711
8          0.875881         0.808581    0.437893        0.696246
12         0.904365         0.529205    0.512571        0.822403
13         0.862406         0.577933    0.329815        0.756303
…             …              …         …             …
8725       0.859472         0.591069    0.577721        0.718901
8745       0.859894         0.897421    0.719463        0.181414
8748       0.858196         0.937465    0.463454        0.219193
8788       0.817624         0.893283    0.324179        0.024556
8789       0.889955         0.936086    0.535802        0.513582

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
5                           0.676104                        0.443583
7                           0.684742                        0.451553
8                           0.626129                        0.398092
12                          0.632893                        0.671998
13                          0.615989                        0.517992
…                              …                             …
8725                        0.444714                        0.657667
8745                        0.024320                        0.103539
8748                        0.080576                        0.140080
8788                        0.002465                        0.005934
8789                        0.373303                        0.259528

      Saturated Fatty Acids(g)  kmeans_tsne
5                     0.348734            0
7                     0.355775            0
8                     0.308817            0
12                    0.494853            0
13                    0.473315            0
…                        …          …
8725                  0.360711            0
8745                  0.063870            0
8748                  0.000000            0
8788                  0.009211            0
8789                  0.275650            0

[2937 rows x 8 columns]

      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0          0.685223         0.421947    0.644650        0.122492
1          0.770972         0.539328    0.673774        0.444529
```

```
14          0.816493          0.139076    0.695060        0.644735
100         0.786376          0.000000    0.756312        0.513785
101         0.717455          0.000000    0.681411        0.382380
…             …              …         …             …
8749        0.769417          0.000000    0.762047        0.442852
8750        0.733270          0.000000    0.708751        0.396735
8771        0.632419          0.346116    0.532774        0.232190
8772        0.601603          0.330664    0.537600        0.071353
8773        0.673693          0.347863    0.512571        0.388237

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                           0.022900                        0.022872
1                           0.297219                        0.227549
14                          0.511857                        0.352783
100                         0.351960                        0.293664
101                         0.175770                        0.224155
…                              …                             …
8749                        0.242826                        0.122122
8750                        0.246740                        0.204303
8771                        0.089229                        0.016934
8772                        0.011634                        0.002758
8773                        0.257480                        0.088905

      Saturated Fatty Acids(g)  kmeans_tsne
0                     0.030388            1
1                     0.212894            1
14                    0.395637            1
100                   0.254692            1
101                   0.180514            1
…                        …          …
8749                  0.208383            1
8750                  0.180322            1
8771                  0.175470            1
8772                  0.024208            1
8773                  0.267429            1

[3041 rows x 8 columns]
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
2          0.624253         0.633388    0.203973        0.020652
3          0.466968         0.380891    0.074901        0.056849
4          0.513760         0.468498    0.074901        0.056849
6          0.670663         0.503637    0.457547        0.324453
9          0.721842         0.757620    0.153183        0.055176
…             …              …         …             …
8783       0.556031         0.463708    0.351950        0.035864
8784       0.656199         0.583869    0.396246        0.175712
8785       0.654500         0.583869    0.396246        0.175712
```

```
8786       0.654500         0.583869    0.396246        0.175712
8787       0.642026         0.626764    0.305234        0.000000

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
2                           0.242826                        0.122122
3                           0.017754                        0.019922
4                           0.017754                        0.019922
6                           0.222082                        0.060118
9                           0.242826                        0.122122
…                              …                             …
8783                        0.010777                        0.001153
8784                        0.061346                        0.007953
8785                        0.066435                        0.008176
8786                        0.066435                        0.008176
8787                        0.000000                        0.000000

      Saturated Fatty Acids(g)  kmeans_tsne
2                     0.003042            2
3                     0.014394            2
4                     0.014394            2
6                     0.180322            2
9                     0.208383            2
…                        …          …
8783                  0.024012            2
8784                  0.122689            2
8785                  0.129330            2
8786                  0.129330            2
8787                  0.000000            2

[2812 rows x 8 columns]
```

0.4.1 Insights

[39]:
```
kmeans_tsne.get_group(0).describe()
```

[39]:
```
       Energy (Kcal)  Carbohydrate(g)   Protein(g)  Total Lipid(g)  \
count    2937.000000      2937.000000  2937.000000     2937.000000
mean        0.863727         0.805301     0.460011        0.526370
std         0.053829         0.193784     0.165270        0.210419
min         0.656199         0.000000     0.000000        0.000000
25%         0.829515         0.733767     0.383500        0.377123
50%         0.869298         0.876045     0.478997        0.544657
75%         0.901848         0.929653     0.560456        0.674634
max         1.000000         0.986273     0.964519        1.000000

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     2937.000000                     2937.000000
```

```
mean                           0.329947                           0.299584
std                            0.199535                           0.199596
min                            0.000000                           0.000000
25%                            0.192959                           0.138181
50%                            0.317862                           0.255735
75%                            0.448099                           0.421787
max                            0.984335                           1.000000

       Saturated Fatty Acids(g)  kmeans_tsne
count               2937.000000       2937.0
mean                   0.302195          0.0
std                    0.180595          0.0
min                    0.000000          0.0
25%                    0.142837          0.0
50%                    0.307050          0.0
75%                    0.430294          0.0
max                    0.903884          0.0
```

Cluster 0: It appears that this cluster contains foods heavy in lipids and energy. The energy value minimum of 0.656 is the greatest minimum value observed across all clusters.

```
[40]: kmeans_tsne.get_group(1).describe()
```

```
[40]:        Energy (Kcal)  Carbohydrate(g)   Protein(g)  Total Lipid(g)  \
count    3041.000000      3041.000000  3041.000000     3041.000000
mean        0.773320         0.078428     0.679336        0.500426
std         0.068658         0.149217     0.116332        0.179250
min         0.509238         0.000000     0.000000        0.000000
25%         0.729216         0.000000     0.660090        0.380891
50%         0.770972         0.000000     0.698659        0.496306
75%         0.810708         0.079011     0.739935        0.618189
max         1.000000         0.751628     1.000000        1.000000

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     3041.000000                     3041.000000
mean                         0.344084                        0.163226
std                          0.166106                        0.114097
min                          0.000000                        0.000000
25%                          0.233872                        0.079265
50%                          0.335200                        0.124698
75%                          0.454211                        0.220889
max                          1.000000                        0.649514

       Saturated Fatty Acids(g)  kmeans_tsne
count               3041.000000       3041.0
mean                   0.316879          1.0
std                    0.169445          0.0
min                    0.000000          1.0
```

```
25%                 0.200476          1.0
50%                 0.294946          1.0
75%                 0.419823          1.0
max                 1.000000          1.0
```

Cluster 1: This cluster predominantly consists of low-carb foods, with approximately half of the data falling into this category. The statistical analysis reveals that this cluster exhibits the highest Q1 range for protein, reaching 0.66. Consequently, it can be inferred that Cluster 1 is primarily composed of protein-rich foods.

```
[41]: kmeans_tsne.get_group(2).describe()
```

```
[41]:       Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
      count    2812.000000      2812.000000  2812.000000     2812.000000
      mean        0.588109         0.521628    0.209455        0.108504
      std         0.137224         0.183761    0.138160        0.114048
      min         0.000000         0.000000    0.000000        0.000000
      25%         0.526545         0.416072    0.097559        0.020652
      50%         0.604032         0.527693    0.209686        0.063415
      75%         0.669125         0.633970    0.306923        0.168863
      max         0.881455         1.000000    0.715473        0.606244

             Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
      count                     2812.000000                     2812.000000
      mean                         0.076733                        0.054543
      std                          0.097881                        0.057750
      min                          0.000000                        0.000000
      25%                          0.002687                        0.009289
      50%                          0.014187                        0.030898
      75%                          0.143674                        0.112947
      max                          0.565610                        0.363535

             Saturated Fatty Acids(g)  kmeans_tsne
      count               2812.000000       2812.0
      mean                   0.062648          2.0
      std                    0.082691          0.0
      min                    0.000000          2.0
      25%                    0.003903          2.0
      50%                    0.016230          2.0
      75%                    0.104264          2.0
      max                    0.373856          2.0
```

Cluster 2: The maximum values for the fatty acids in this cluster were the lowest among all the cluster. Hence can conclude that this cluster is food that low in fatty acids. This suggests that this cluster may consists of healthy food.

0.5 Agglomerative Clustering

```
[42]: from clustering_function import tuning_agglomerative, perform_agg_clustering
```

```
[43]: agg_param_grid = {
            'n_clusters': [2, 3, 4, 5, 6],
            'linkage': ['ward'],
            'affinity' : ['euclidean']
        }
```

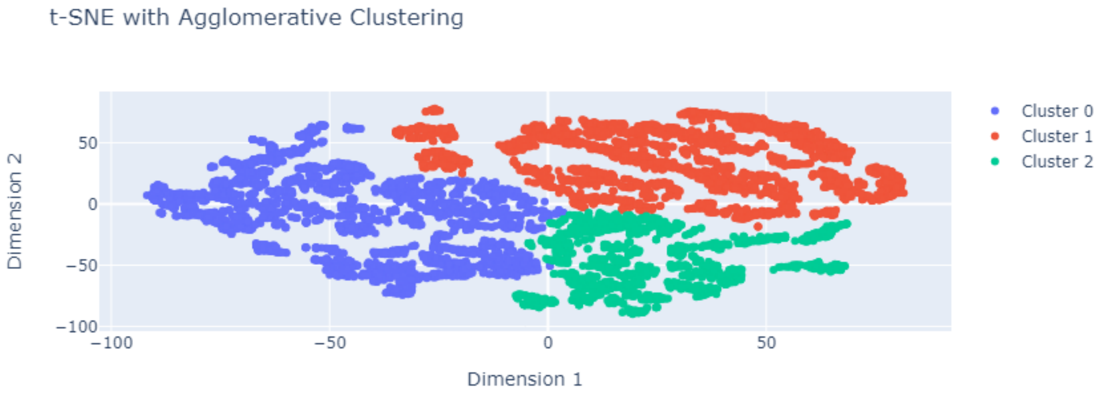
```
[44]: tuning_agglomerative(X_tsne_reduced, agg_param_grid)
```

```
Best silhouette score: 0.38080552
Best parameters: {'affinity': 'euclidean', 'linkage': 'ward', 'n_clusters': 3}
```

```
[45]: Agg_tsne_clust_labels,agg_model = perform_agg_clustering(X_tsne_reduced, 3)
```

```
[46]: # export model
      with open('../Model_fitted/Agg_model_median_pkl', 'wb') as files:
          pickle.dump(agg_model, files)
```

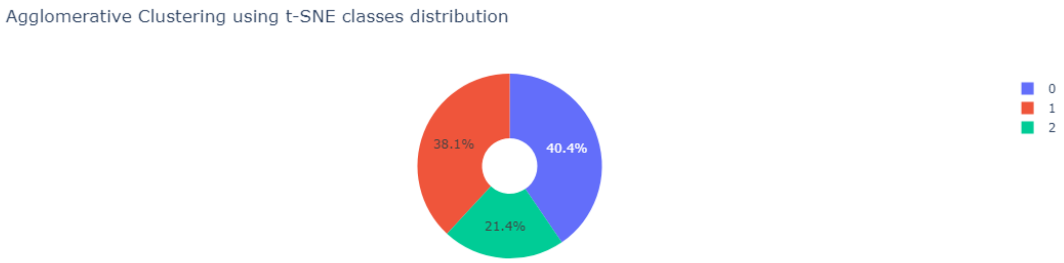
```
[47]: plot_clusters(X_tsne_reduced, Agg_tsne_clust_labels, "Agglomerative Clustering")
```



```
[48]: X_with_labels['Agg_tsne'] = Agg_tsne_clust_labels
      scores['Agg_tsne'] = (silhouette_score(X_tsne_reduced,␣
       ↪X_with_labels['Agg_tsne']))
```

```
[49]: food_groups, value_counts = get_food_groups(X_with_labels['Agg_tsne'],␣
       ↪'Agglomerative_tsne',food_groups)
```

```
[50]: plot_cluster_distribution(value_counts, 'Agglomerative Clustering')
```



```
[51]: Aggtsne = X_with_labels.groupby('Agg_tsne')
```

```
[52]: n = Aggtsne['Agg_tsne'].count().count() # number of cluster
      for i in range(0,n):
          display(Aggtsne.get_group(i))
```

```
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
3          0.466968         0.380891    0.074901        0.056849
4          0.513760         0.468498    0.074901        0.056849
6          0.670663         0.503637    0.457547        0.324453
10         0.857339         0.957418    0.221928        0.113698
15         0.836114         0.000000    0.000000        0.000000
…               …             …          …               …
8784       0.656199         0.583869    0.396246        0.175712
8785       0.654500         0.583869    0.396246        0.175712
8786       0.654500         0.583869    0.396246        0.175712
8787       0.642026         0.626764    0.305234        0.000000
8788       0.817624         0.893283    0.324179        0.024556

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
3                           0.017754                        0.019922
4                           0.017754                        0.019922
6                           0.222082                        0.060118
10                          0.242826                        0.122122
15                          0.000000                        0.000000
…                              …                               …
8784                        0.061346                        0.007953
8785                        0.066435                        0.008176
8786                        0.066435                        0.008176
8787                        0.000000                        0.000000
8788                        0.002465                        0.005934

      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne
3                     0.014394            2         0
```

```
4                     0.014394            2         0
6                     0.180322            2         0
10                    0.208383            2         0
15                    0.000000            2         0
…                        …          …       …
8784                  0.122689            2         0
8785                  0.129330            2         0
8786                  0.129330            2         0
8787                  0.000000            2         0
8788                  0.009211            0         0

[3555 rows x 9 columns]
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0          0.685223         0.421947    0.644650        0.122492
1          0.770972         0.539328    0.673774        0.444529
2          0.624253         0.633388    0.203973        0.020652
9          0.721842         0.757620    0.153183        0.055176
11         0.622139         0.616810    0.093208        0.030283
…             …              …         …             …
8749       0.769417         0.000000    0.762047        0.442852
8750       0.733270         0.000000    0.708751        0.396735
8771       0.632419         0.346116    0.532774        0.232190
8772       0.601603         0.330664    0.537600        0.071353
8773       0.673693         0.347863    0.512571        0.388237

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                           0.022900                        0.022872
1                           0.297219                        0.227549
2                           0.242826                        0.122122
9                           0.242826                        0.122122
11                          0.242826                        0.122122
…                              …                             …
8749                        0.242826                        0.122122
8750                        0.246740                        0.204303
8771                        0.089229                        0.016934
8772                        0.011634                        0.002758
8773                        0.257480                        0.088905

      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne
0                     0.030388            1         1
1                     0.212894            1         1
2                     0.003042            2         1
9                     0.208383            2         1
11                    0.208383            2         1
…                        …          …       …
8749                  0.208383            1         1
8750                  0.180322            1         1
```

```
8771                  0.175470            1         1
8772                  0.024208            1         1
8773                  0.267429            1         1

[3350 rows x 9 columns]
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
5          0.913731         0.870851    0.476131        0.745258   
7          0.916054         0.866962    0.491577        0.753711   
8          0.875881         0.808581    0.437893        0.696246   
12         0.904365         0.529205    0.512571        0.822403   
13         0.862406         0.577933    0.329815        0.756303   
…             …              …             …             …
8629       0.807727         0.732959    0.581346        0.493436   
8659       0.882545         0.914725    0.526799        0.531641   
8696       0.883985         0.813507    0.761901        0.617939   
8725       0.859472         0.591069    0.577721        0.718901   
8789       0.889955         0.936086    0.535802        0.513582   

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
5                           0.676104                        0.443583   
7                           0.684742                        0.451553   
8                           0.626129                        0.398092   
12                          0.632893                        0.671998   
13                          0.615989                        0.517992   
…                              …                              …
8629                        0.340380                        0.173271   
8659                        0.385713                        0.213847   
8696                        0.438754                        0.386834   
8725                        0.444714                        0.657667   
8789                        0.373303                        0.259528   

      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne  
5                     0.348734            0         2  
7                     0.355775            0         2  
8                     0.308817            0         2  
12                    0.494853            0         2  
13                    0.473315            0         2  
…                        …          …       …
8629                  0.327419            0         2  
8659                  0.356463            0         2  
8696                  0.261418            0         2  
8725                  0.360711            0         2  
8789                  0.275650            0         2  

[1885 rows x 9 columns]
```

0.5.1 Insights

[53]:

```
Aggtsne.get_group(0).describe()
```

[53]:

```
       Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
count    3555.000000      3555.000000 3555.000000     3555.000000
mean        0.666548         0.633652    0.295738        0.174720
std         0.167766         0.234432    0.188526        0.153656
min         0.000000         0.000000    0.000000        0.000000
25%         0.568816         0.466745    0.142881        0.039505
50%         0.669125         0.620550    0.286992        0.134466
75%         0.823148         0.857315    0.447489        0.304672
max         0.947569         1.000000    0.964519        0.924243

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     3555.000000                     3555.000000
mean                         0.082623                        0.076877
std                          0.097304                        0.080969
min                          0.000000                        0.000000
25%                          0.003798                        0.011719
50%                          0.035946                        0.043492
75%                          0.145836                        0.122122
max                          0.565610                        0.487236

       Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne
count               3555.000000  3555.000000    3555.0
mean                   0.079875     1.381997       0.0
std                    0.100300     0.924141       0.0
min                    0.000000     0.000000       0.0
25%                    0.006255     0.000000       0.0
50%                    0.034351     2.000000       0.0
75%                    0.129330     2.000000       0.0
max                    0.756575     2.000000       0.0
```

Cluster 0: Among all the food clusters, this one has the lowest fat content, with lipids and three fatty acids each around value of 0.3 (excluding maximum value). This implies that there may be healthy foods in this food cluster.

[54]:

```
Aggtsne.get_group(1).describe()
```

[54]:

```
       Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
count    3350.000000      3350.000000 3350.000000     3350.000000
mean        0.749137         0.123298    0.635710        0.448678
std         0.087602         0.193661    0.179329        0.205318
min         0.376881         0.000000    0.000000        0.000000
25%         0.709449         0.000000    0.635389        0.331135
50%         0.759726         0.000000    0.692396        0.467998
75%         0.802205         0.225788    0.736299        0.594092
```

```
max         0.999674         0.795036    1.000000        1.000000

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     3350.000000                     3350.000000
mean                         0.328621                        0.156111
std                          0.152704                        0.103982
min                          0.000000                        0.000000
25%                          0.242826                        0.084296
50%                          0.304128                        0.122122
75%                          0.436242                        0.204303
max                          0.923391                        0.629091

       Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne
count               3350.000000  3350.000000    3350.0
mean                   0.288747     1.104478       1.0
std                    0.158963     0.311726       0.0
min                    0.000000     0.000000       1.0
25%                    0.187612     1.000000       1.0
50%                    0.267911     1.000000       1.0
75%                    0.390189     1.000000       1.0
max                    0.786175     2.000000       1.0
```

Cluster 1: This cluster seems to be a low-carb meal cluster, as Q1 and Q2 have carbohydrate values of 0. The greatest value of carbohydrates was about 0.75g (after log tansform and min max scaled), which is the lowest among all clusters.

```
[55]: Aggtsne.get_group(2).describe()
```

```
[55]:        Energy (Kcal)  Carbohydrate(g)   Protein(g)  Total Lipid(g)  \
      count  1885.000000      1885.000000  1885.000000     1885.000000
      mean      0.882231         0.745255     0.437626        0.662416
      std       0.054809         0.247276     0.183585        0.141062
      min       0.712934         0.000000     0.000000        0.348732
      25%       0.840996         0.681925     0.367857        0.554266
      50%       0.891665         0.842390     0.462898        0.641729
      75%       0.914315         0.908793     0.566303        0.729697
      max       1.000000         0.979258     0.898049        1.000000

             Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
      count                     1885.000000                     1885.000000
      mean                         0.443810                        0.389048
      std                          0.170806                        0.194710
      min                          0.000000                        0.000000
      25%                          0.328592                        0.246133
      50%                          0.418181                        0.367389
      75%                          0.528850                        0.506677
      max                          1.000000                        1.000000
```

```
       Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne
count               1885.000000  1885.000000    1885.0
mean                   0.411717     0.027586       2.0
std                    0.154498     0.163827       0.0
min                    0.000000     0.000000       2.0
25%                    0.307695     0.000000       2.0
50%                    0.391984     0.000000       2.0
75%                    0.497368     0.000000       2.0
max                    1.000000     1.000000       2.0
```

Cluster 2: This cluster may consist of foods high in energy because the first quartile of data was around 0.84, the highest of all the clusters. Based on the three fatty acid compositions, this cluster indicates that the meal in this cluster is maximal in fat. The fact that this food cluster has the highest value of total lipids among all clusters serves as additional support.

0.6 GMM

[56]:
```
from clustering_function import gmm_bic_score, perform_gmm_clustering
from sklearn.mixture import GaussianMixture
from sklearn.model_selection import GridSearchCV
```

[57]:
```
gmm_param_grid = {
    "n_components": range(1, 6),
    "covariance_type": ["spherical", "tied", "diag", "full"],
}
grid_search = GridSearchCV(
    GaussianMixture(), param_grid=gmm_param_grid, scoring=gmm_bic_score
)
```

[58]:
```
grid_search.fit(X_tsne_reduced)
Gmm_tsne_results = grid_search.cv_results_
```

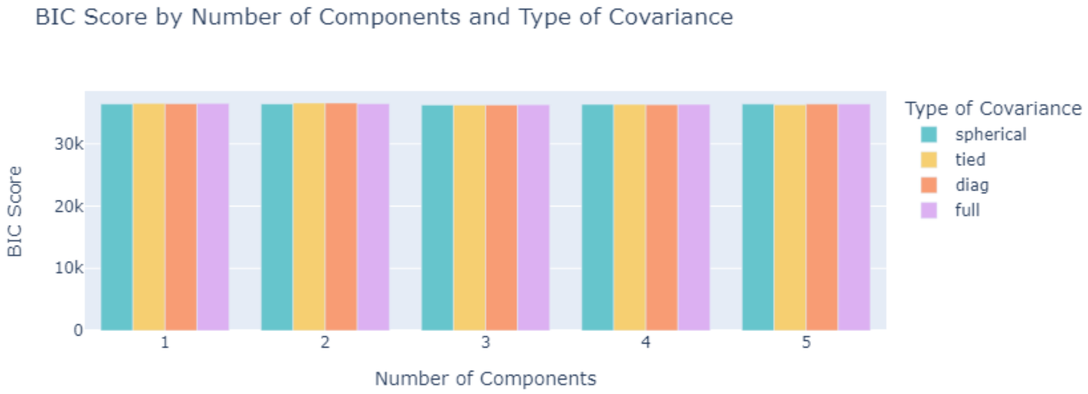
[59]:
```
Gmm_tsne_df = pd.DataFrame(Gmm_tsne_results)[
    ["param_n_components", "param_covariance_type", "mean_test_score"]
]
Gmm_tsne_df["mean_test_score"] = -Gmm_tsne_df["mean_test_score"]
Gmm_tsne_df = Gmm_tsne_df.rename(
    columns={
        "param_n_components": "Number of Components",
        "param_covariance_type": "Type of Covariance",
        "mean_test_score": "BIC Score",
    }
)
Gmm_tsne_df.sort_values(by="BIC Score").head()
```

[59]:
```
   Number of Components Type of Covariance     BIC Score
7                     3               tied  36259.642277
2                     3          spherical  36277.982784
```

```
12                        3                diag   36285.380930
9                         5                tied   36307.227321
17                        3                full   36333.090942
```

[60]:

```python
fig = px.bar(Gmm_tsne_df, x="Number of Components", y="BIC Score",
                  color="Type of Covariance", barmode="group",
                  title="BIC Score by Number of Components and Type of␣
 ↪Covariance",
                  color_discrete_sequence=px.colors.qualitative.Pastel)
fig.show()
```



[61]:

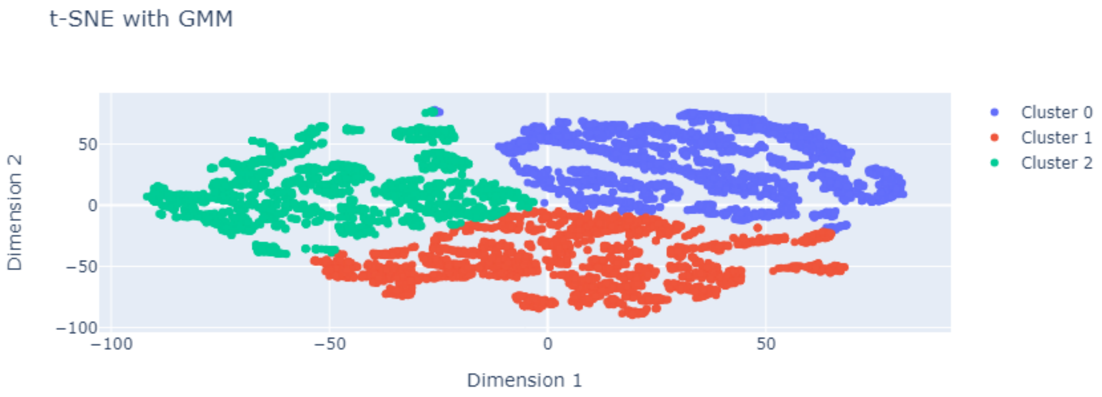
```python
Gmm_tsne_labels,gmm_model = perform_gmm_clustering(X_tsne_reduced, 3, 'tied')
```

[62]:

```python
# export model
with open('../Model_fitted/Gmm_model_median_pkl', 'wb') as files:
    pickle.dump(gmm_model, files)
```

[63]:

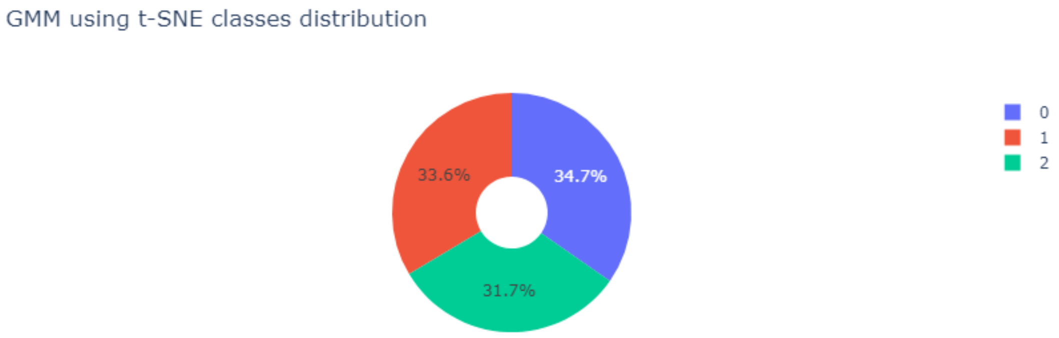
```python
plot_clusters(X_tsne_reduced, Gmm_tsne_labels, "GMM")
```


t-SNE with GMM

```
[64]: X_with_labels['Gmm_tsne'] = Gmm_tsne_labels
      scores['Gmm_tsne'] = (silhouette_score(X_tsne_reduced,␣
        ↪X_with_labels['Gmm_tsne']))
```

```
[65]: food_groups, value_counts = get_food_groups(X_with_labels['Gmm_tsne'],␣
        ↪'GMM_tsne',food_groups)
```

```
[66]: plot_cluster_distribution(value_counts, 'GMM')
```


GMM using t-SNE classes distribution

```
[67]: GmmTsne = X_with_labels.groupby('Gmm_tsne')
```

```
[68]: n = GmmTsne['Gmm_tsne'].count().count() # number of cluster
      for i in range(0,n):
          display(GmmTsne.get_group(i))
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0          0.685223         0.421947    0.644650        0.122492
1          0.770972         0.539328    0.673774        0.444529
14         0.816493         0.139076    0.695060        0.644735
52         0.654500         0.288696    0.015061        0.000000
53         0.656199         0.334863    0.015061        0.000000
…             …                …          …              …
8749       0.769417         0.000000    0.762047        0.442852
8750       0.733270         0.000000    0.708751        0.396735
8771       0.632419         0.346116    0.532774        0.232190
8772       0.601603         0.330664    0.537600        0.071353
8773       0.673693         0.347863    0.512571        0.388237

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                           0.022900                        0.022872
1                           0.297219                        0.227549
14                          0.511857                        0.352783
52                          0.242826                        0.122122
53                          0.242826                        0.122122
…                              …                               …
8749                        0.242826                        0.122122
8750                        0.246740                        0.204303
8771                        0.089229                        0.016934
8772                        0.011634                        0.002758
8773                        0.257480                        0.088905

      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne  Gmm_tsne
0                     0.030388            1         1         0
1                     0.212894            1         1         0
14                    0.395637            1         1         0
52                    0.208383            2         1         0
53                    0.208383            2         1         0
…                        …            …         …         …
8749                  0.208383            1         1         0
8750                  0.180322            1         1         0
8771                  0.175470            1         1         0
8772                  0.024208            1         1         0
8773                  0.267429            1         1         0

[3048 rows x 10 columns]
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
5          0.913731         0.870851    0.476131        0.745258
7          0.916054         0.866962    0.491577        0.753711
8          0.875881         0.808581    0.437893        0.696246
12         0.904365         0.529205    0.512571        0.822403
13         0.862406         0.577933    0.329815        0.756303
…             …                …          …              …
```

```
8725       0.859472         0.591069    0.577721        0.718901
8745       0.859894         0.897421    0.719463        0.181414
8748       0.858196         0.937465    0.463454        0.219193
8788       0.817624         0.893283    0.324179        0.024556
8789       0.889955         0.936086    0.535802        0.513582

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
5                           0.676104                        0.443583
7                           0.684742                        0.451553
8                           0.626129                        0.398092
12                          0.632893                        0.671998
13                          0.615989                        0.517992
…                              …                             …
8725                        0.444714                        0.657667
8745                        0.024320                        0.103539
8748                        0.080576                        0.140080
8788                        0.002465                        0.005934
8789                        0.373303                        0.259528

      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne  Gmm_tsne
5                     0.348734            0         2         1
7                     0.355775            0         2         1
8                     0.308817            0         2         1
12                    0.494853            0         2         1
13                    0.473315            0         2         1
…                        …          …       …       …
8725                  0.360711            0         2         1
8745                  0.063870            0         0         1
8748                  0.000000            0         0         1
8788                  0.009211            0         0         1
8789                  0.275650            0         2         1

[2954 rows x 10 columns]
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
2          0.624253         0.633388    0.203973        0.020652
3          0.466968         0.380891    0.074901        0.056849
4          0.513760         0.468498    0.074901        0.056849
6          0.670663         0.503637    0.457547        0.324453
9          0.721842         0.757620    0.153183        0.055176
…             …              …         …             …
8783       0.556031         0.463708    0.351950        0.035864
8784       0.656199         0.583869    0.396246        0.175712
8785       0.654500         0.583869    0.396246        0.175712
8786       0.654500         0.583869    0.396246        0.175712
8787       0.642026         0.626764    0.305234        0.000000

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
2                           0.242826                        0.122122
3                           0.017754                        0.019922
4                           0.017754                        0.019922
6                           0.222082                        0.060118
9                           0.242826                        0.122122
…                              …                               …
8783                        0.010777                        0.001153
8784                        0.061346                        0.007953
8785                        0.066435                        0.008176
8786                        0.066435                        0.008176
8787                        0.000000                        0.000000

      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne  Gmm_tsne
2                     0.003042            2         1         2
3                     0.014394            2         0         2
4                     0.014394            2         0         2
6                     0.180322            2         0         2
9                     0.208383            2         1         2
…                        …           …       …       …
8783                  0.024012            2         0         2
8784                  0.122689            2         0         2
8785                  0.129330            2         0         2
8786                  0.129330            2         0         2
8787                  0.000000            2         0         2

[2788 rows x 10 columns]
```

0.6.1 Insights

[69]:
```
GmmTsne.get_group(0).describe()
```

[69]:
```
       Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
count    3048.000000      3048.000000 3048.000000     3048.000000
mean        0.771972         0.080391    0.678424        0.496158
std         0.067737         0.150926    0.118400        0.179918
min         0.509238         0.000000    0.000000        0.000000
25%         0.728185         0.000000    0.659228        0.378260
50%         0.770197         0.000000    0.698562        0.494544
75%         0.810117         0.088216    0.739855        0.615169
max         1.000000         0.751628    1.000000        1.000000

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     3048.000000                     3048.000000
mean                         0.341405                        0.161836
std                          0.162391                        0.111637
min                          0.000000                        0.000000
25%                          0.234012                        0.079388
```

```
50%                          0.332745                        0.124023
75%                          0.452313                        0.219573
max                          0.971727                        0.629091

       Saturated Fatty Acids(g)  kmeans_tsne     Agg_tsne  Gmm_tsne
count               3048.000000  3048.000000  3048.000000    3048.0
mean                   0.314871     1.003937     1.013123       0.0
std                    0.167912     0.076759     0.116669       0.0
min                    0.000000     0.000000     0.000000       0.0
25%                    0.200410     1.000000     1.000000       0.0
50%                    0.292086     1.000000     1.000000       0.0
75%                    0.416816     1.000000     1.000000       0.0
max                    1.000000     2.000000     2.000000       0.0
```

Cluster 0: With a maximum value of 1 and the highest reported protein Q1 of 0.659, this cluster appears to have categorized foods based on protein.

[70]:
```
GmmTsne.get_group(1).describe()
```

[70]:
```
       Energy (Kcal)  Carbohydrate(g)   Protein(g)  Total Lipid(g)  \
count    2954.000000      2954.000000  2954.000000     2954.000000
mean        0.864490         0.803388     0.457639        0.526275
std         0.053960         0.199434     0.167634        0.214055
min         0.656199         0.000000     0.000000        0.000000
25%         0.830033         0.733840     0.382104        0.376456
50%         0.869694         0.876045     0.478997        0.545270
75%         0.902165         0.929949     0.560277        0.675738
max         1.000000         0.986273     0.964519        1.000000

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     2954.000000                     2954.000000
mean                         0.331457                        0.299671
std                          0.202784                        0.200190
min                          0.000000                        0.000000
25%                          0.192767                        0.137161
50%                          0.318110                        0.255697
75%                          0.450811                        0.422187
max                          1.000000                        1.000000

       Saturated Fatty Acids(g)  kmeans_tsne     Agg_tsne  Gmm_tsne
count               2954.000000  2954.000000  2954.000000    2954.0
mean                   0.302524     0.012525     1.249492       1.0
std                    0.182657     0.145524     0.968016       0.0
min                    0.000000     0.000000     0.000000       1.0
25%                    0.140432     0.000000     0.000000       1.0
50%                    0.307614     0.000000     2.000000       1.0
75%                    0.431911     0.000000     2.000000       1.0
max                    0.903884     2.000000     2.000000       1.0
```

Cluster 1: This is a high-energy cluster with the first quartile of the data lying at 0.83 (the highest among all clusters).

```
[71]: GmmTsne.get_group(2).describe()
```

```
[71]:        Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
count      2788.000000      2788.000000  2788.000000     2788.000000
mean          0.586628         0.520892    0.210258        0.109738
std           0.136497         0.181437    0.137622        0.114633
min           0.000000         0.000000    0.000000        0.000000
25%           0.522406         0.418991    0.101826        0.020652
50%           0.601603         0.529017    0.211846        0.065026
75%           0.669125         0.633388    0.307622        0.170102
max           0.881090         1.000000    0.715473        0.606244

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     2788.000000                     2788.000000
mean                         0.075846                        0.054205
std                          0.097338                        0.057715
min                          0.000000                        0.000000
25%                          0.002465                        0.009067
50%                          0.013975                        0.030392
75%                          0.139711                        0.108327
max                          0.565610                        0.363535

       Saturated Fatty Acids(g)  kmeans_tsne     Agg_tsne  Gmm_tsne
count               2788.000000  2788.000000  2788.000000    2788.0
mean                   0.062396     1.997131     0.122310       2.0
std                    0.082646     0.075715     0.327702       0.0
min                    0.000000     0.000000     0.000000       2.0
25%                    0.003903     2.000000     0.000000       2.0
50%                    0.016230     2.000000     0.000000       2.0
75%                    0.103413     2.000000     0.000000       2.0
max                    0.373856     2.000000     1.000000       2.0
```

Cluster 2: Foods that fall under this category are thought to be lower in fat, or more healthful overall. This is due to the fact that 75% of the nutritional data for fats are less than 0.20 (0.17, 0.13, 0.11, 0.10 for lipid and 3 fatty acids, respectively).

0.7 K-Medoids

```
[72]: from clustering_function import tuning_kmedoids, perform_kmd_clustering
```

```
[73]: kmd_param_grid = {
          'n_clusters': [3, 4],
          'method': ['alternate', 'pam'],
          'init' : ['random', 'heuristic', 'k-medoids++', 'build']
      }
```

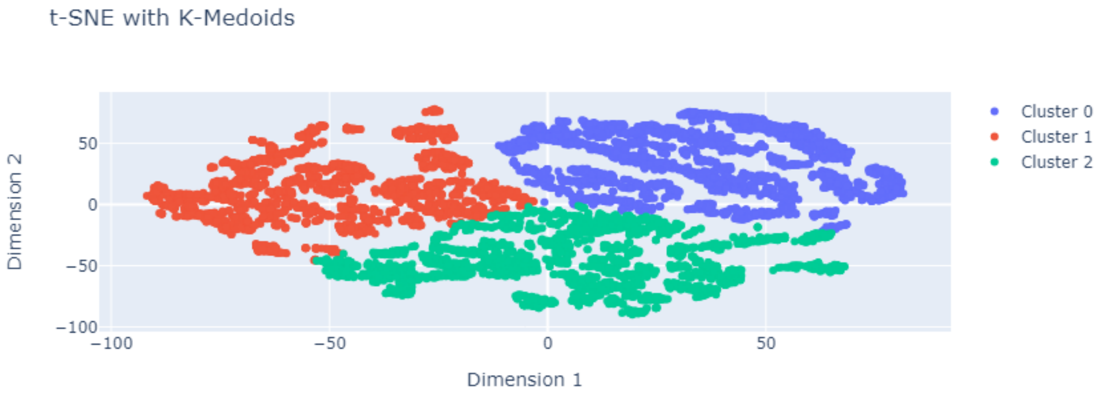
[74]:
```
tuning_kmedoids(X_tsne_reduced, kmd_param_grid)
```

```
Best silhouette score: 0.4359154
Best parameters: {'init': 'random', 'method': 'alternate', 'n_clusters': 3}
```

[75]:
```
Kmd_tsne_labels,kmd_model = perform_kmd_clustering(X_tsne_reduced, 3, 'random',␣
  ↪'alternate')
```

[76]:
```
# export model
with open('../Model_fitted/Kmd_model_median_pkl', 'wb') as files:
    pickle.dump(kmd_model, files)
```

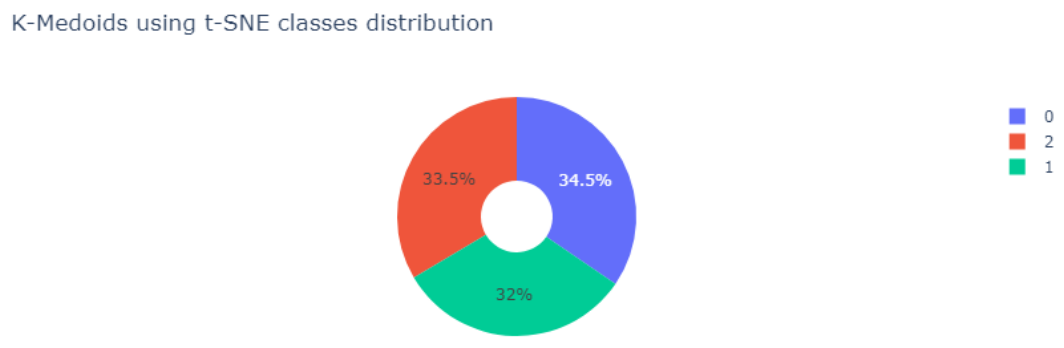
[77]:
```
plot_clusters(X_tsne_reduced, Kmd_tsne_labels, "K-Medoids")
```



[78]:
```
X_with_labels['Kmd_tsne'] = Kmd_tsne_labels
scores['Kmd_tsne'] = (silhouette_score(X_tsne_reduced,␣
  ↪X_with_labels['Kmd_tsne']))
```

[79]:
```
food_groups, value_counts = get_food_groups(X_with_labels['Kmd_tsne'],␣
  ↪'KMedoids_tsne',food_groups)
```

[80]:
```
plot_cluster_distribution(value_counts, 'K-Medoids')
```



```
[81]: Kmdtsne = X_with_labels.groupby('Kmd_tsne')
```

```
[82]: n = Kmdtsne['Kmd_tsne'].count().count() # number of cluster
      for i in range(0,n):
          display(Kmdtsne.get_group(i))
```

```
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
0          0.685223         0.421947    0.644650        0.122492
1          0.770972         0.539328    0.673774        0.444529
14         0.816493         0.139076    0.695060        0.644735
100        0.786376         0.000000    0.756312        0.513785
101        0.717455         0.000000    0.681411        0.382380
…              …               …          …              …
8749       0.769417         0.000000    0.762047        0.442852
8750       0.733270         0.000000    0.708751        0.396735
8771       0.632419         0.346116    0.532774        0.232190
8772       0.601603         0.330664    0.537600        0.071353
8773       0.673693         0.347863    0.512571        0.388237

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
0                           0.022900                        0.022872
1                           0.297219                        0.227549
14                          0.511857                        0.352783
100                         0.351960                        0.293664
101                         0.175770                        0.224155
…                             …                              …
8749                        0.242826                        0.122122
8750                        0.246740                        0.204303
8771                        0.089229                        0.016934
8772                        0.011634                        0.002758
8773                        0.257480                        0.088905
```

```
      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne  Gmm_tsne  Kmd_tsne
0                     0.030388            1         1         0         0
1                     0.212894            1         1         0         0
14                    0.395637            1         1         0         0
100                   0.254692            1         1         0         0
101                   0.180514            1         1         0         0
…                        …           …        …        …        …
8749                  0.208383            1         1         0         0
8750                  0.180322            1         1         0         0
8771                  0.175470            1         1         0         0
8772                  0.024208            1         1         0         0
8773                  0.267429            1         1         0         0

[3035 rows x 11 columns]
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
2          0.624253         0.633388    0.203973        0.020652
3          0.466968         0.380891    0.074901        0.056849
4          0.513760         0.468498    0.074901        0.056849
6          0.670663         0.503637    0.457547        0.324453
9          0.721842         0.757620    0.153183        0.055176
…             …               …          …              …
8783       0.556031         0.463708    0.351950        0.035864
8784       0.656199         0.583869    0.396246        0.175712
8785       0.654500         0.583869    0.396246        0.175712
8786       0.654500         0.583869    0.396246        0.175712
8787       0.642026         0.626764    0.305234        0.000000

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
2                           0.242826                        0.122122
3                           0.017754                        0.019922
4                           0.017754                        0.019922
6                           0.222082                        0.060118
9                           0.242826                        0.122122
…                              …                               …
8783                        0.010777                        0.001153
8784                        0.061346                        0.007953
8785                        0.066435                        0.008176
8786                        0.066435                        0.008176
8787                        0.000000                        0.000000

      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne  Gmm_tsne  Kmd_tsne
2                     0.003042            2         1         2         1
3                     0.014394            2         0         2         1
4                     0.014394            2         0         2         1
6                     0.180322            2         0         2         1
9                     0.208383            2         1         2         1
```

```
…                        …          …       …       …       …
8783                  0.024012            2         0         2         1
8784                  0.122689            2         0         2         1
8785                  0.129330            2         0         2         1
8786                  0.129330            2         0         2         1
8787                  0.000000            2         0         2         1

[2809 rows x 11 columns]
      Energy (Kcal)  Carbohydrate(g)  Protein(g)  Total Lipid(g)  \
5          0.913731         0.870851    0.476131        0.745258
7          0.916054         0.866962    0.491577        0.753711
8          0.875881         0.808581    0.437893        0.696246
12         0.904365         0.529205    0.512571        0.822403
13         0.862406         0.577933    0.329815        0.756303
…             …              …         …             …
8725       0.859472         0.591069    0.577721        0.718901
8745       0.859894         0.897421    0.719463        0.181414
8748       0.858196         0.937465    0.463454        0.219193
8788       0.817624         0.893283    0.324179        0.024556
8789       0.889955         0.936086    0.535802        0.513582

      Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
5                           0.676104                        0.443583
7                           0.684742                        0.451553
8                           0.626129                        0.398092
12                          0.632893                        0.671998
13                          0.615989                        0.517992
…                              …                              …
8725                        0.444714                        0.657667
8745                        0.024320                        0.103539
8748                        0.080576                        0.140080
8788                        0.002465                        0.005934
8789                        0.373303                        0.259528

      Saturated Fatty Acids(g)  kmeans_tsne  Agg_tsne  Gmm_tsne  Kmd_tsne
5                     0.348734            0         2         1         2
7                     0.355775            0         2         1         2
8                     0.308817            0         2         1         2
12                    0.494853            0         2         1         2
13                    0.473315            0         2         1         2
…                        …          …       …       …       …
8725                  0.360711            0         2         1         2
8745                  0.063870            0         0         1         2
8748                  0.000000            0         0         1         2
8788                  0.009211            0         0         1         2
8789                  0.275650            0         2         1         2
```

```
[2946 rows x 11 columns]
```

0.7.1 Insights

[83]:
```
Kmdtsne.get_group(0).describe()
```

[83]:
```
       Energy (Kcal)  Carbohydrate(g)   Protein(g)  Total Lipid(g)  \
count    3035.000000      3035.000000  3035.000000     3035.000000
mean        0.773084         0.077875     0.680102        0.499991
std         0.068356         0.147989     0.114427        0.178727
min         0.509238         0.000000     0.000000        0.000000
25%         0.729216         0.000000     0.660434        0.380891
50%         0.770972         0.000000     0.698948        0.496306
75%         0.810708         0.079011     0.739975        0.617939
max         1.000000         0.693086     1.000000        1.000000

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     3035.000000                     3035.000000
mean                         0.343654                        0.162658
std                          0.165132                        0.113367
min                          0.000000                        0.000000
25%                          0.233992                        0.079183
50%                          0.335200                        0.124428
75%                          0.453866                        0.220577
max                          0.971727                        0.629151

       Saturated Fatty Acids(g)  kmeans_tsne     Agg_tsne     Gmm_tsne  \
count               3035.000000       3035.0  3035.000000  3035.000000
mean                   0.316777          1.0     1.015815     0.002636
std                    0.169271          0.0     0.127396     0.051282
min                    0.000000          1.0     0.000000     0.000000
25%                    0.200476          1.0     1.000000     0.000000
50%                    0.294946          1.0     1.000000     0.000000
75%                    0.419582          1.0     1.000000     0.000000
max                    1.000000          1.0     2.000000     1.000000

       Kmd_tsne
count    3035.0
mean        0.0
std         0.0
min         0.0
25%         0.0
50%         0.0
75%         0.0
max         0.0
```

Cluster 0: This food group is low in carbs and high in protein, as seen by the values of the two nutrients, which are 0.66 and 0.74 for protein and 0 to 0.08 for carbohydrates, respectively.

[84]:

```
Kmdtsne.get_group(1).describe()
```

[84]:

```
       Energy (Kcal)  Carbohydrate(g)   Protein(g)  Total Lipid(g)  \
count    2809.000000      2809.000000  2809.000000     2809.000000   
mean        0.587818         0.521159     0.209288        0.108545   
std         0.137008         0.183297     0.138021        0.114077   
min         0.000000         0.000000     0.000000        0.000000   
25%         0.526545         0.415357     0.097559        0.020652   
50%         0.604032         0.527693     0.209252        0.063415   
75%         0.669125         0.633504     0.306923        0.168863   
max         0.881455         1.000000     0.715473        0.606244   

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     2809.000000                     2809.000000   
mean                         0.076722                        0.054554   
std                          0.097866                        0.057752   
min                          0.000000                        0.000000   
25%                          0.002687                        0.009289   
50%                          0.014187                        0.030898   
75%                          0.143644                        0.112947   
max                          0.565610                        0.363535   

       Saturated Fatty Acids(g)  kmeans_tsne     Agg_tsne     Gmm_tsne  \
count               2809.000000       2809.0  2809.000000  2809.000000   
mean                   0.062696          2.0     0.126735     1.985760   
std                    0.082720          0.0     0.332736     0.157245   
min                    0.000000          2.0     0.000000     0.000000   
25%                    0.003903          2.0     0.000000     2.000000   
50%                    0.016230          2.0     0.000000     2.000000   
75%                    0.104467          2.0     0.000000     2.000000   
max                    0.373856          2.0     1.000000     2.000000   

       Kmd_tsne  
count    2809.0  
mean        1.0  
std         0.0  
min         1.0  
25%         1.0  
50%         1.0  
75%         1.0  
max         1.0  
```

Cluster 1: Foods in this cluster have the lowest fat content, making them considered healthful.

[85]:

```
Kmdtsne.get_group(2).describe()
```

[85]:

```
       Energy (Kcal)  Carbohydrate(g)   Protein(g)  Total Lipid(g)  \
count    2946.000000      2946.000000  2946.000000     2946.000000   
```

```
mean        0.863782         0.804548     0.459572        0.526301
std         0.053978         0.195272     0.165836        0.211173
min         0.656199         0.000000     0.000000        0.000000
25%         0.829515         0.733345     0.383500        0.377123
50%         0.869298         0.876045     0.478997        0.544305
75%         0.901848         0.929653     0.560591        0.674634
max         1.000000         0.986273     0.964519        1.000000

       Monounsaturated Fatty Acids(g)  Polyunsaturated Fatty Acids(g)  \
count                     2946.000000                     2946.000000
mean                         0.330171                        0.299632
std                          0.200416                        0.199654
min                          0.000000                        0.000000
25%                          0.192767                        0.137799
50%                          0.317862                        0.256499
75%                          0.448238                        0.421787
max                          1.000000                        1.000000

       Saturated Fatty Acids(g)  kmeans_tsne     Agg_tsne     Gmm_tsne  \
count               2946.000000  2946.000000  2946.000000  2946.000000
mean                   0.302040     0.004073     1.249491     0.999321
std                    0.180888     0.078073     0.966963     0.058268
min                    0.000000     0.000000     0.000000     0.000000
25%                    0.140891     0.000000     0.000000     1.000000
50%                    0.306539     0.000000     2.000000     1.000000
75%                    0.430340     0.000000     2.000000     1.000000
max                    0.903884     2.000000     2.000000     2.000000

       Kmd_tsne
count    2946.0
mean        2.0
std         0.0
min         2.0
25%         2.0
50%         2.0
75%         2.0
max         2.0
```

Cluster 3: This food cluster appeared to be food that provides more energy due to high carbohydrate composition (around 0.73 to 0.98) as compared to other food clusters.

[86]:
```
scores
```

[86]:
```
{'kmeans_tsne': 0.43591416,
 'Agg_tsne': 0.38080552,
 'Gmm_tsne': 0.43544555,
 'Kmd_tsne': 0.4359154}
```

When the median strategy was used to fill in the missing values in the dataset, it was found that the K-Medoids model was the most successful clustering method, with the highest silhouette score 0.43606 recorded.

[ ]: