Interactive Maps Exploring Relationships Between Fermented Vegetables and Covid-19 Mortality Rates

The original paper suggests that low COVID-19 death rates at the country level were linked to high fermented vegetable consumption in Europe. However, this conclusion was based on data from June 2020, an early stage of the three-year pandemic. I aim to explore whether this finding holds with the latest data using interactive maps. Additionally, I will visualize longitudinal trends in death rates or absolute death numbers.

Load modules

In [582…

```python
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import plotly.express as px
import plotly.io as pio
import kaleido # This package is required to save the map as a static image
```

Load and preprocess epidemiological data

Covid 19 mortality and population data

In [583…

```python
# Load Covid-19 death data
covid_death_df = pd.read_csv('time_series_covid19_deaths_global.csv')
```

In [584…

```python
covid_death_df.head()
```

Out[584…

	Province/State	Country/Region	Lat	Long	1/22/20	1/23/20	1/24/20	1/25/20
0	NaN	Afghanistan	33.93911	67.709953	0	0	0	0
1	NaN	Albania	41.15330	20.168300	0	0	0	0
2	NaN	Algeria	28.03390	1.659600	0	0	0	0
3	NaN	Andorra	42.50630	1.521800	0	0	0	0
4	NaN	Angola	-11.20270	17.873900	0	0	0	0

5 rows × 1147 columns

The Covid-19 death data contains geographic information in the first four columns, followed by daily death counts. I will aggregate the data to get the total number of deaths and death rates per country.

Aggregate yearly death counts for each country

In [585…

```
# Make wide table long
covid_death_df_long = covid_death_df.melt(id_vars=['Province/State', 'Country/Reg
```

In [586…

```
covid_death_df_long.shape
```

Out[586…

```
(330327, 6)
```

In [587…

```
covid_death_df_long['Date'].head()
```

Out[587…

```
0    1/22/20
1    1/22/20
2    1/22/20
3    1/22/20
4    1/22/20
Name: Date, dtype: object
```

In [588…

```
# Add year column based on last two digits of Date column
covid_death_df_long['Date'] = pd.to_datetime(covid_death_df_long['Date'], format=
```

In [589…

```
covid_death_df_long['Date'].head()
```

Out[589…

```
0   2020-01-22
1   2020-01-22
2   2020-01-22
3   2020-01-22
4   2020-01-22
Name: Date, dtype: datetime64[ns]
```

In [590…

```
# Check missing values in Date column
covid_death_df_long['Date'].isnull().sum()
```

Out[590…

```
0
```

In [591…

```
covid_death_df_long['Year'] = covid_death_df_long['Date'].dt.year
```

In [592…

```
# Aggregate deaths by country and year
covid_death_df_agg = covid_death_df_long.groupby(['Country/Region', 'Year'])['Dea
```

In [593…

```
covid_death_df_agg.head()
```

Out[593…

	Country/Region	Year	Deaths
0	Afghanistan	2020	296447
1	Afghanistan	2021	1778958
2	Afghanistan	2022	2810220
3	Afghanistan	2023	535810
4	Albania	2020	88375

In [594…

```
# Aggregate daily death counts to get total death count
covid_death_df['Total Deaths'] = covid_death_df.iloc[:, 4:].sum(axis=1)
```

In [595…

```
covid_death_df['Total Deaths'].describe()
```

Out[595…

```
count    2.890000e+02
mean     1.529348e+07
std      6.166454e+07
min      0.000000e+00
25%      2.474700e+04
50%      5.184140e+05
75%      5.035519e+06
max      7.138772e+08
Name: Total Deaths, dtype: float64
```

In [596…

```
# Inspect Country/Region column
covid_death_df['Country/Region'].value_counts()
```

Out[596…

```
Country/Region
China             34
Canada            16
United Kingdom    15
France            12
Australia          8
                  ..
Guinea             1
Guinea-Bissau      1
Guyana             1
Haiti              1
Zimbabwe           1
Name: count, Length: 201, dtype: int64
```

In [597…

```
# Inspect Province/State column
covid_death_df['Province/State'].value_counts()
```

Out[597…

```
Province/State
Australian Capital Territory    1
Saint Pierre and Miquelon       1
Reunion                         1
New Caledonia                   1
Mayotte                         1
                               ..
Gansu                           1
Fujian                          1
Chongqing                       1
Beijing                         1
Turks and Caicos Islands        1
Name: count, Length: 91, dtype: int64
```

There are multiple states or provinces within a country in the data. I will aggregate the data to the country level.

In [598…

```
# Aggregate total deaths by country
covid_death_country_df = covid_death_df.groupby('Country/Region')['Total Deaths']
```

In [599…

```
# Sort countries by total deaths in descending order
covid_death_country_df = covid_death_country_df.sort_values(by='Total Deaths', as
In [600…  covid_death_country_df.head()
```

Out[600…

	Country/Region	Total Deaths
186	US	713877215
24	Brazil	488181000
80	India	364921237
117	Mexico	241085189
147	Russia	220983590

```
In [601…  covid_death_country_df.tail()
```

Out[601…

	Country/Region	Total Deaths
5	Antarctica	0
185	Tuvalu	0
197	Winter Olympics 2022	0
170	Summer Olympics 2020	0
76	Holy See	0

```
In [602…  covid_death_country_df.rename(columns={'Country/Region': 'Country'}, inplace=True
```

The dataframe `covid_death_country_df` contains aggregated COVID-19 deaths at the country level from January 2020 to March 2023, used for the following visualization.

Population data for EU countries

```
In [603…  pop_df = pd.read_excel('demo_gind__custom_7680622_page_spreadsheet.xlsx', sheet_r
```

```
/opt/anaconda3/lib/python3.12/site-packages/openpyxl/styles/stylesheet.py:226: Us
erWarning:

Workbook contains no default style, apply openpyxl's default
```

```
In [604…  pop_df.head()
```

Out[604…

	TIME	2020	Unnamed: 2	2021	Unnamed: 4	2022	Unnamed: 6	2
0	GEO (Labels)	NaN	NaN	NaN	NaN	NaN	NaN	
1	European Economic Area (EU28 - 2013-2020 and I...	519811603	e	:	NaN	:	NaN	
2	European Union - 27 countries (from 2020)	447015600	e	445872542	b	445837374	bep	44880
3	Euro area – 20 countries (from 2023)	346625682	NaN	346699769	NaN	346969818	p	34966
4	Germany	83166711	NaN	83155031	NaN	83237124	NaN	8435

In [605…

```
# Clean up the population data
pop_df2 = pop_df[['TIME', '2020', '2021', '2022', '2023']]

# Drop the first row
pop_df2 = pop_df2.drop(0)

# Rename the first column to 'Country'
pop_df2.rename(columns={'TIME': 'Country'}, inplace=True)

pop_df2.head()
```

Out[605…

	Country	2020	2021	2022	2023
1	European Economic Area (EU28 - 2013-2020 and I...	519811603	:	:	:
2	European Union - 27 countries (from 2020)	447015600	445872542	445837374	448803078
3	Euro area – 20 countries (from 2023)	346625682	346699769	346969818	349665601
4	Germany	83166711	83155031	83237124	84358845
5	Germany including former GDR	83166711	83155031	83237124	84358845

Estimate death rates in 2020, 2021, 2022 and 2023 for EU countries

In [606…

```
covid_death_df_agg.head()
```

Out[606…

	Country/Region	Year	Deaths
0	Afghanistan	2020	296447
1	Afghanistan	2021	1778958
2	Afghanistan	2022	2810220
3	Afghanistan	2023	535810
4	Albania	2020	88375

In [607…

```
# Rename the first column to 'Country'
covid_death_df_agg.rename(columns={'Country/Region': 'Country'}, inplace=True)

covid_death_df_agg.head()
```

Out[607…

	Country	Year	Deaths
0	Afghanistan	2020	296447
1	Afghanistan	2021	1778958
2	Afghanistan	2022	2810220
3	Afghanistan	2023	535810
4	Albania	2020	88375

In [608…

```
covid_death_df_agg['Year'] = covid_death_df_agg['Year'].astype(int)
```

In [609…

```
# Make wide table long - pop_df2
pop_df2_long = pop_df2.melt(id_vars='Country', var_name='Year', value_name='Popul
```

In [610…

```
pop_df2_long.head()
```

Out[610…

	Country	Year	Population
0	European Economic Area (EU28 - 2013-2020 and I...	2020	519811603
1	European Union - 27 countries (from 2020)	2020	447015600
2	Euro area – 20 countries (from 2023)	2020	346625682
3	Germany	2020	83166711
4	Germany including former GDR	2020	83166711

In [611…

```
pop_df2_long['Year'] = pop_df2_long['Year'].astype(int)
```

In [612…

```
# Merge covid_death_df_agg to pop_df2_long on Country and Year columns
covid_death_pop_df = pop_df2_long.merge(covid_death_df_agg, on=['Country', 'Year'
```

In [613…

```
covid_death_pop_df.head()
```

Out[613…

	Country	Year	Population	Deaths
0	European Economic Area (EU28 - 2013-2020 and I...	2020	519811603	NaN
1	European Union - 27 countries (from 2020)	2020	447015600	NaN
2	Euro area – 20 countries (from 2023)	2020	346625682	NaN
3	Germany	2020	83166711	2890473.0
4	Germany including former GDR	2020	83166711	NaN

In [614…

```
# Create death rate column by dividing Deaths by Population
covid_death_pop_df['Deaths'] = pd.to_numeric(covid_death_pop_df['Deaths'], errors
covid_death_pop_df['Population'] = pd.to_numeric(covid_death_pop_df['Population']

# Fill NaN values with 0 to avoid division errors
covid_death_pop_df['Deaths'].fillna(0, inplace=True)
covid_death_pop_df['Population'].fillna(0, inplace=True)

# Calculate death rate
covid_death_pop_df['Death Rate'] = covid_death_pop_df['Deaths'] / covid_death_pop
```

```
/var/folders/b8/9ymtxc2j7rb00xx34s753cwc0000gn/T/ipykernel_81771/2787820439.py:6:
FutureWarning:

A value is trying to be set on a copy of a DataFrame or Series through chained as
signment using an inplace method.
The behavior will change in pandas 3.0. This inplace method will never work becau
se the intermediate object on which we are setting values always behaves as a cop
y.

For example, when doing 'df[col].method(value, inplace=True)', try using 'df.meth
od({col: value}, inplace=True)' or df[col] = df[col].method(value) instead, to pe
rform the operation inplace on the original object.



/var/folders/b8/9ymtxc2j7rb00xx34s753cwc0000gn/T/ipykernel_81771/2787820439.py:7:
FutureWarning:

A value is trying to be set on a copy of a DataFrame or Series through chained as
signment using an inplace method.
The behavior will change in pandas 3.0. This inplace method will never work becau
se the intermediate object on which we are setting values always behaves as a cop
y.

For example, when doing 'df[col].method(value, inplace=True)', try using 'df.meth
od({col: value}, inplace=True)' or df[col] = df[col].method(value) instead, to pe
rform the operation inplace on the original object.
```

In [615…

```
covid_death_pop_df.head()
```

Out[615…

	Country	Year	Population	Deaths	Death Rate
0	European Economic Area (EU28 - 2013-2020 and I...	2020	519811603.0	0.0	0.000000
1	European Union - 27 countries (from 2020)	2020	447015600.0	0.0	0.000000
2	Euro area – 20 countries (from 2023)	2020	346625682.0	0.0	0.000000
3	Germany	2020	83166711.0	2890473.0	0.034755
4	Germany including former GDR	2020	83166711.0	0.0	0.000000

Fermented vegetable consumption data

In [616…

```
# Read in fermented vegetable consumption data in xlsx format
food_df = pd.read_excel('Foodex 2 L4 dashboard.xlsx', skiprows=2)
```

In [617…

```
food_df.head()
```

Out[617…

	Survey's country	Survey start year	Survey name	Population Group (L2)	Exposure hierarchy (L1)	Exposure hierarchy (L2)	Exposure hierarchy (L3)	Exposure hierarchy (L4)
0	Austria	2010	Austrian Study on Nutritional Status 2010-12 -...	Adults	Vegetables and vegetable products	Processed or preserved vegetables and similar	Fermented or pickled vegetables	Fermented vegetables
1	Austria	2010	Austrian Study on Nutritional Status 2010-12 -...	Elderly	Vegetables and vegetable products	Processed or preserved vegetables and similar	Fermented or pickled vegetables	Fermented vegetables
2	Austria	2010	Austrian Study on Nutritional Status 2010-12 -...	Very elderly	Vegetables and vegetable products	Processed or preserved vegetables and similar	Fermented or pickled vegetables	Fermented vegetables
3	Austria	2010	Austrian Study on Nutritional Status 2010-12 -...	Adolescents	Vegetables and vegetable products	Processed or preserved vegetables and similar	Fermented or pickled vegetables	Fermented vegetables
4	Austria	2010	Austrian Study on Nutritional Status 2010-12 -...	Other children	Vegetables and vegetable products	Processed or preserved vegetables and similar	Fermented or pickled vegetables	Fermented vegetables

In [618…

```
# Investigate countries, years, and population columns
food_df.rename(columns={"Survey's country": 'Country'}, inplace=True)
food_df['Country'].value_counts()
```

Out[618…

```
Country
Netherlands                    15
France                         10
Latvia                         10
Germany                        10
Poland                          9
Austria                         8
Romania                         8
Hungary                         8
Estonia                         8
Belgium                         7
Croatia                         7
Serbia                          7
Montenegro                      6
Sweden                          6
Finland                         5
Slovenia                        5
United Kingdom                  4
Czechia                         3
Bosnia and Herzegovina          3
Bulgaria                        2
Portugal                        2
Republic of North Macedonia     2
Greece                          1
Name: count, dtype: int64
```

In [619…

```
# Survey start year
food_df['Survey start year'].value_counts()
```

Out[619…

```
Survey start year
2019    23
2012    17
2017    16
2007    15
2010    10
2014    10
2013     8
2018     8
2003     8
2006     6
2008     5
2021     4
2004     4
2011     3
2000     2
2001     2
2016     2
2015     2
1997     1
Name: count, dtype: int64
```

In [620…

```
# Population
food_df['Population Group (L2)'].value_counts()
```

Out[620…

```
Population Group (L2)
Adults                32
Elderly               24
Adolescents           24
Other children        23
Toddlers              16
Very elderly          13
Pregnant women         7
Vegetarians            4
Infants                2
Lactating women        1
Name: count, dtype: int64
```

Aggregated daily consumption of fermented vegetables in general population and over time by country.

In [621…

```
avg_consumption_country = food_df.groupby(by ='Country')['Mean'].mean().reset_inc

avg_consumption_country.rename(columns={'Mean': 'Average Consumption'}, inplace=T
```

In [622…

```
avg_consumption_country.describe() # Summary statistics
```

Out[622…

	Average Consumption
count	23.000000
mean	3.432499
std	3.132373
min	0.012646
25%	0.795268
50%	2.660731
75%	5.742800
max	10.636471

In [623…

```
avg_consumption_country.head()
```

Out[623…

	Country	Average Consumption
0	Austria	2.660731
1	Belgium	0.454854
2	Bosnia and Herzegovina	5.906935
3	Bulgaria	1.235104
4	Croatia	3.958930

Prepare for geographical data of EU countries.

In [624…

```
# Fetch GeoJSON for Europe
import requests
import json
```

In [625…

```
# URL for countries' GeoJSON data
url = "https://raw.githubusercontent.com/datasets/geo-countries/master/data/count

# Fetch the data
response = requests.get(url)
geojson_data = response.json()
```

In [626…

```
# Filter only EU countries
# eu_countries = ['Austria', 'Belgium', 'Bulgaria', 'Croatia', 'Cyprus', 'Czech R
```

In [627…

```
targeted_countries = food_df['Country'].unique().tolist()
print(len(targeted_countries))
```

```
23
```

In [628…

```
# Filter the geojson for EU
eu_geojson = {
    "type": "FeatureCollection",
    "features": [
        feature for feature in geojson_data["features"]
        if feature["properties"]["ADMIN"] in targeted_countries
    ]
}
```

In [629…

```
len(eu_geojson['features'])
```

Out[629…

```
20
```

Data frame for the interactive map

In [630…

```
# Identify EU countries in the eu_geojson
eu_countries_geojson = [feature['properties']['ADMIN'] for feature in eu_geojson[
```

In [631…

```
print(eu_countries_geojson)
```

```
['Austria', 'Belgium', 'Bulgaria', 'Bosnia and Herzegovina', 'Germany', 'Estoni
a', 'Finland', 'France', 'United Kingdom', 'Greece', 'Croatia', 'Hungary', 'Latvi
a', 'Montenegro', 'Netherlands', 'Poland', 'Portugal', 'Romania', 'Slovenia', 'Sw
eden']
```

In [632…

```
# Save en_countries_geojson as dataframe
eu_countries_df = pd.DataFrame(eu_countries_geojson, columns=['Country'])
```

In [633…

```
# Merge eu_countries_df with avg_consumption_country on Country
eu_avg_consumption_country = eu_countries_df.merge(avg_consumption_country, on='C
```

In [634…

```
eu_avg_consumption_country.head()
```

Out[634…

	Country	Average Consumption
0	Austria	2.660731
1	Belgium	0.454854
2	Bulgaria	1.235104
3	Bosnia and Herzegovina	5.906935
4	Germany	1.552563

In [635…

```
# Merge eu_avg_consumption_country with covid_death_pop_df on Country
eu_avg_consumption_covid_death_pop_df = eu_avg_consumption_country.merge(covid_de
```

In [636…

```
eu_avg_consumption_covid_death_pop_df.columns
```

Out[636…

```
Index(['Country', 'Average Consumption', 'Year', 'Population', 'Deaths',
       'Death Rate'],
      dtype='object')
```

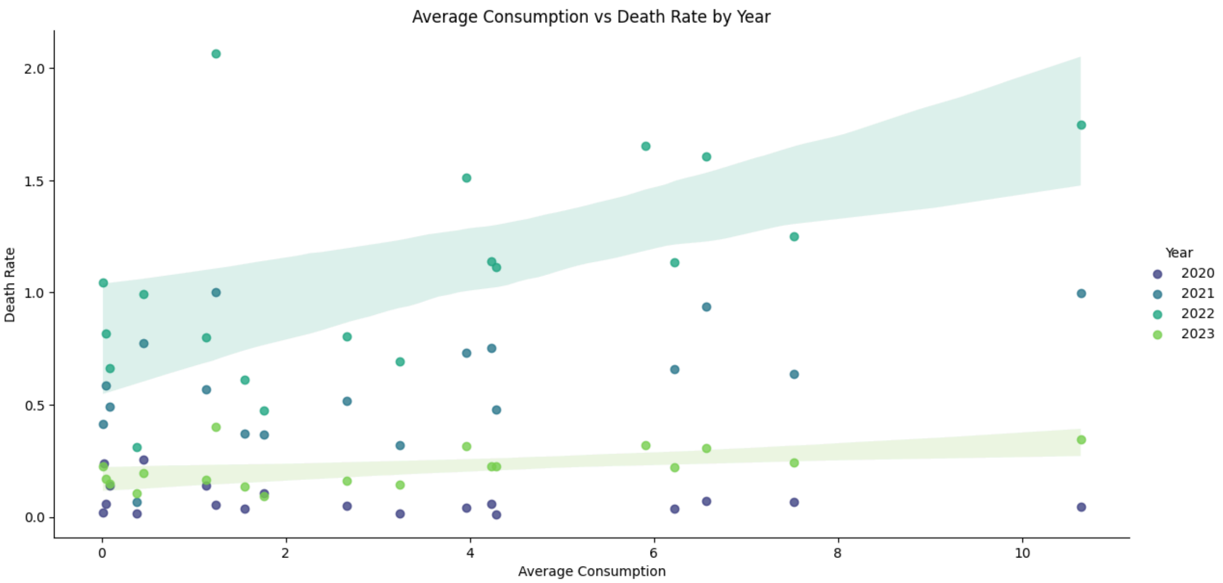
Visually assess the relationship between fermented vegetable consumption and COVID-19 death rates

In [637…

```
# Draw a scatter plot of Average Consumption vs Death Rate, stratified by Year
plt.figure(figsize=(12, 6))

# Add line of best fit by year
sns.lmplot(data=eu_avg_consumption_covid_death_pop_df, x='Average Consumption', y
plt.title('Average Consumption vs Death Rate by Year')

plt.show()
```

```
/opt/anaconda3/lib/python3.12/site-packages/numpy/lib/function_base.py:4655: Runt
imeWarning:

invalid value encountered in subtract
```

```
<Figure size 1200x600 with 0 Axes>
```



Bubble map of fermented vegetable consumption in EU countries

To change the colors of the areas (countries) separately from the bubbles, use px.choropleth() for the country colors and px.scatter_geo() for the bubbles, then overlay them using go.Figure().

In [638…

```
import plotly.express as px
import pandas as pd
import plotly.graph_objects as go
```

In [639…

```
eu_avg_consumption_covid_death_pop_df.columns
```

Out[639…

```
Index(['Country', 'Average Consumption', 'Year', 'Population', 'Deaths',
       'Death Rate'],
      dtype='object')
```

In [640…

```
eu_avg_consumption_covid_death_pop_df.head()
```

Out[640…

	Country	Average Consumption	Year	Population	Deaths	Death Rate
0	Austria	2.660731	2020	8901064.0	438345.0	0.049246
1	Austria	2.660731	2021	8932664.0	4607998.0	0.515859
2	Austria	2.660731	2022	8978929.0	7209848.0	0.802974
3	Austria	2.660731	2023	9104772.0	1476277.0	0.162143
4	Belgium	0.454854	2020	11522440.0	2931202.0	0.254391

In [641…

```
# Drop rows with Inf values in Death Rate column
eu_avg_consumption_covid_death_pop_df = eu_avg_consumption_covid_death_pop_df[eu_
```

In [642…

```
import pycountry

# List of EU countries
```

```
eu_countries = eu_avg_consumption_covid_death_pop_df['Country'].unique().tolist()

# Dictionary of country names and their corresponding alpha_3 codes
country_alpha3 = {}
for country in eu_countries:
    try:
        country_data = pycountry.countries.get(name=country)
        # print(country_data.alpha_3)
        country_alpha3[country] = country_data.alpha_3
    except:
        print(f"{country} not found")

print(country_alpha3)
```

```
{'Austria': 'AUT', 'Belgium': 'BEL', 'Bulgaria': 'BGR', 'Bosnia and Herzegovina':
'BIH', 'Germany': 'DEU', 'Estonia': 'EST', 'Finland': 'FIN', 'France': 'FRA', 'Un
ited Kingdom': 'GBR', 'Greece': 'GRC', 'Croatia': 'HRV', 'Hungary': 'HUN', 'Latvi
a': 'LVA', 'Montenegro': 'MNE', 'Netherlands': 'NLD', 'Poland': 'POL', 'Portuga
l': 'PRT', 'Romania': 'ROU', 'Slovenia': 'SVN', 'Sweden': 'SWE'}
```

In [643…

```
# Add ISO Alpha-3 codes to eu_avg_consumption_covid_death_pop_df
eu_avg_consumption_covid_death_pop_df['iso_alpha'] = eu_avg_consumption_covid_dea
```

In [644…

```
data_map_2020 = eu_avg_consumption_covid_death_pop_df[eu_avg_consumption_covid_de
```

In [645…

```
# Create a Choropleth map (for country colors) based on fermented vegetable consu
food_map = px.choropleth(
    data_map_2020,
    locations="iso_alpha",
    color="Average Consumption",
    hover_name="Country",
    scope="europe",
    projection="natural earth",
    color_continuous_scale='Plasma'
)

food_map.show()
```

In [646…

```
data_map_2020.head()
```

Out[646…

	Country	Average Consumption	Year	Population	Deaths	Death Rate	iso_alpha
0	Austria	2.660731	2020	8901064.0	438345.0	0.049246	AUT
4	Belgium	0.454854	2020	11522440.0	2931202.0	0.254391	BEL
8	Bulgaria	1.235104	2020	6569275.0	347789.0	0.052942	BGR
16	Germany	1.552563	2020	83166711.0	2890473.0	0.034755	DEU
20	Estonia	3.232856	2020	1328976.0	20833.0	0.015676	EST

In [647…

```
# df = px.data.gapminder().query("year==2007")
bubble_map = px.scatter_geo(data_map_2020,
                            locations="iso_alpha",
                            hover_name="Country",
                            size="Death Rate",
                            scope="europe",
                            projection="natural earth",
                            opacity=0.7, # Set opacity level for better visibilit
                            size_max=15,
                            color_continuous_scale=px.colors.sequential.Plasma)
bubble_map.show()
```

In [648…

```
# Combine both layers
fig = go.Figure(data=food_map.data + bubble_map.data)
```

In [649…

```
# Improve layout
fig.update_geos(
    scope="europe", # Only show European countries
    showcoastlines=False,
    showland=True,
    landcolor="lightgray",
    projection_scale=1.5)

fig.update_layout(
    coloraxis_colorbar_title="Fermented Vegetable Consumption",
    coloraxis_colorscale="RdYlBu" , # Change color scale
    width=1200,
    height=800,
    coloraxis_colorbar=dict(
        orientation="h",  # Set colorbar horizontal
        title="Fermented Vegetable Consumption",
        title_side="top",
        title_font_size=12,
        thickness=10,  # Adjust colorbar width
        len=0.5,  # Adjust colorbar height (relative size)
        x=0.25,  # Move colorbar horizontally
        y=0.95,  # Move colorbar vertically
    )
)

fig.update_layout(
    title=dict(
        text="Fermented Vegetable Consumption and Covid-19 Death Rate in Europe (
        x=0.5,  # Center the title
        y=0.98,  # Position it above the colorbar
        xanchor="center",  # Ensure proper centering
        yanchor="top",  # Anchor at the top
        font=dict(
            size=18,  # Increase font size for better readability
            family="Arial, sans-serif",  # Use a professional font
            color="black",  # Set color (adjust if needed)
            weight="bold"  # Bolden the title (alternative: use "<b>Title</b>" ir
        )
    )
)

fig.update_layout(
    coloraxis_colorbar=dict(
        orientation="h",  # Horizontal colorbar
        x=0.5, y=-0.15,  # Move below the map
        len=0.5, thickness=10
    )
)
```

```
fig.show()
```

In [650…

```
# Annotate country names on the map

import pandas as pd

# Create the DataFrame
country_data = pd.DataFrame({
    "Country": ["Austria", "Belgium", "Bulgaria", "Bosnia and Herzegovina", "Germ
    "ISO3": ["AUT", "BEL", "BGR", "BIH", "DEU", "EST", "FIN", "FRA", "GBR", "GRC'
    "Lat": [47.5162, 50.5039, 42.7339, 43.9159, 51.1657, 58.5953, 61.9241, 46.603
    "Lon": [14.5501, 4.4699, 25.4858, 17.6791, 10.4515, 25.0136, 25.7482, 1.8883,
})

# Display the DataFrame
print(country_data)
```

```
                   Country ISO3      Lat      Lon
0                  Austria  AUT  47.5162  14.5501
1                  Belgium  BEL  50.5039   4.4699
2                 Bulgaria  BGR  42.7339  25.4858
3   Bosnia and Herzegovina  BIH  43.9159  17.6791
4                  Germany  DEU  51.1657  10.4515
5                  Estonia  EST  58.5953  25.0136
6                  Finland  FIN  61.9241  25.7482
7                   France  FRA  46.6034   1.8883
8           United Kingdom  GBR  55.3781  -3.4360
9                   Greece  GRC  39.0742  21.8243
10                 Croatia  HRV  45.1000  15.2000
11                 Hungary  HUN  47.1625  19.5033
12                  Latvia  LVA  56.8796  24.6032
13              Montenegro  MNE  42.7087  19.3744
14             Netherlands  NLD  52.1326   5.2913
15                  Poland  POL  51.9194  19.1451
16                Portugal  PRT  39.3999  -8.2245
17                 Romania  ROU  45.9432  24.9668
18                Slovenia  SVN  46.1512  14.9955
19                  Sweden  SWE  60.1282  18.6435
```

In [651…

```
import plotly.graph_objects as go

# Create the country label layer (scattergeo)
country_labels = go.Scattergeo(
    locationmode="ISO-3",
    lon=country_data["Lon"],
    lat=country_data["Lat"],
    text=country_data["Country"],  # Display country names
    mode="text",  # Only text (no markers)
    textfont=dict(size=12, color="black", family="Arial", weight="bold"),  # Adju
    textposition="top center",
    showlegend=False
)

# Add to your existing Plotly figure
fig.add_trace(country_labels)
```

In [652…

```
# Add footnote
fig.update_layout(
    margin=dict(l=50, r=50, t=50, b=200)  # Increase bottom margin (b) for the fo
)

fig.add_annotation(
    text="Data source: The population data, Covid-19 mortality, and fermented foo
    "and European Food Safety Authority (EFSA) Comprehensive European Food Consum
    "The map is inspired by the preprint, Association between consumption of ferm
    xref="paper", yref="paper",
    x=0.5, y=-0.3,
    showarrow=False, # No arrow needed
    font=dict(size=12, color="grey", family="Arial"),
    align="left"
)

fig.show()
```

In [653…

```
# Save the Plotly figure as HTML file
pio.write_html(fig, file='index.html', auto_open=True)
```