In [1]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.stats import norm
import seaborn as sns
```

In [2]:
```
# 1. Generate synthetic wine data using Gaussian distributions
np.random.seed(42)
num_samples = 1000

# Synthetic features based on Gaussian assumptions
data = {
    "fixed_acidity": np.random.normal(7.0, 0.7, num_samples),
    "volatile_acidity": np.random.normal(0.5, 0.1, num_samples),
    "citric_acid": np.random.normal(0.3, 0.1, num_samples),
    "residual_sugar": np.random.normal(6.0, 1.5, num_samples),
    "chlorides": np.random.normal(0.05, 0.01, num_samples),
    "alcohol": np.random.normal(10.0, 1.0, num_samples)
}

# Generate wine quality based on a combination of other features
# Add randomness to simulate real-world data
wine_quality = (
    0.3 * data["alcohol"] -
    1.5 * data["volatile_acidity"] +
    0.8 * data["citric_acid"] +
    np.random.normal(0, 0.5, num_samples)
).round().astype(int)
```

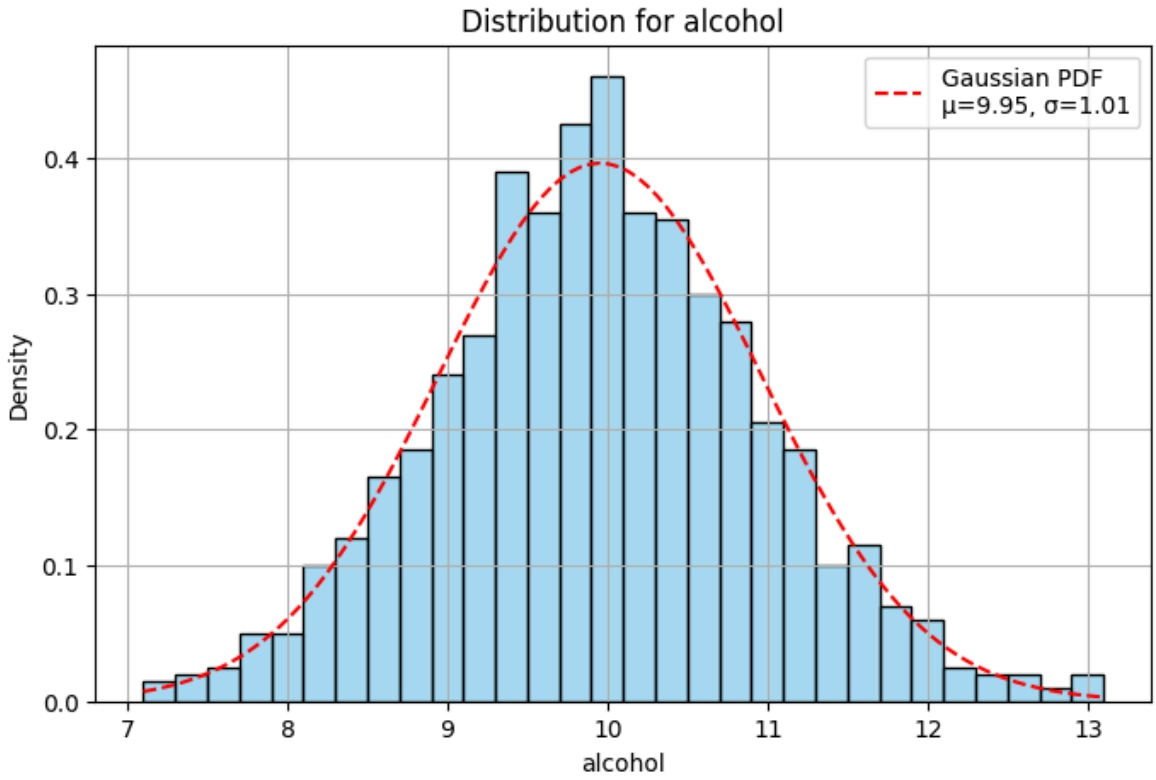
In [3]:
```
# Clamp wine quality between 3 and 8
wine_quality = np.clip(wine_quality, 3, 8)

# Add wine_quality to the dataset
data["wine_quality"] = wine_quality
```

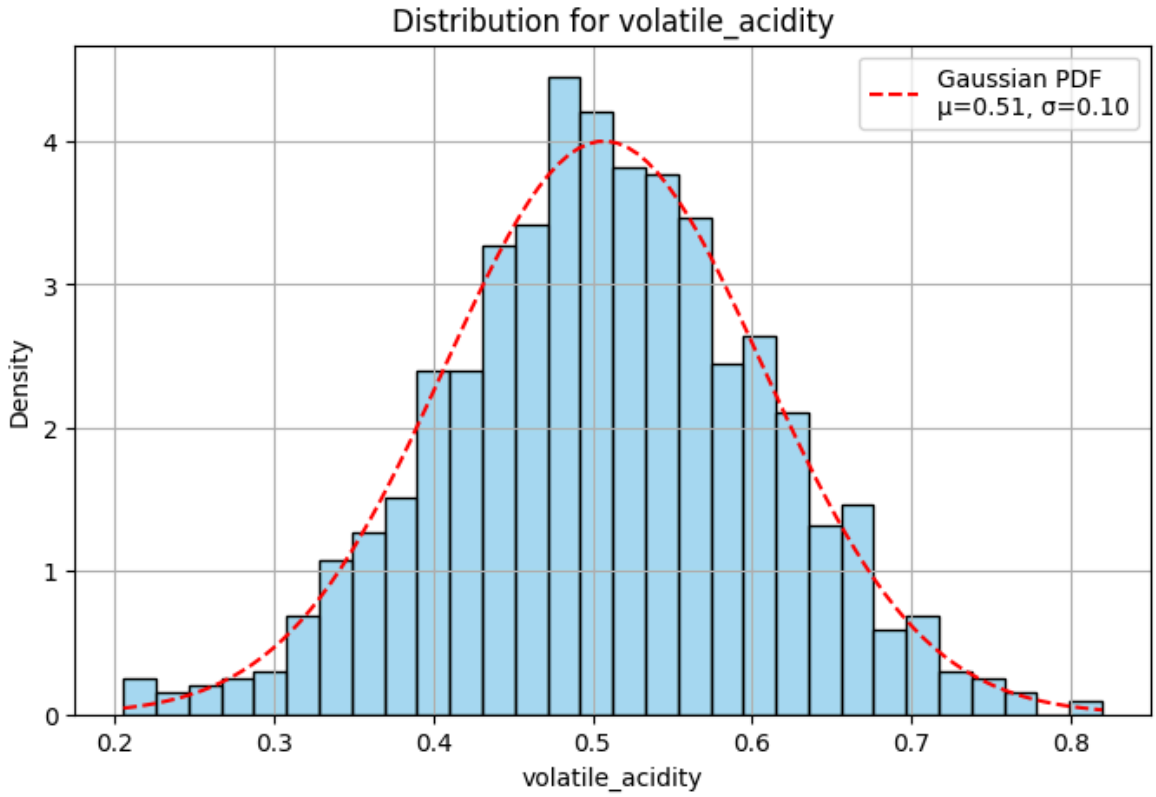
In [4]:
```
# Convert to DataFrame
df = pd.DataFrame(data)

# 2. Fit Gaussian models and 3. Compute statistical measures
print("Statistical Summary:")
print(df.describe())
```

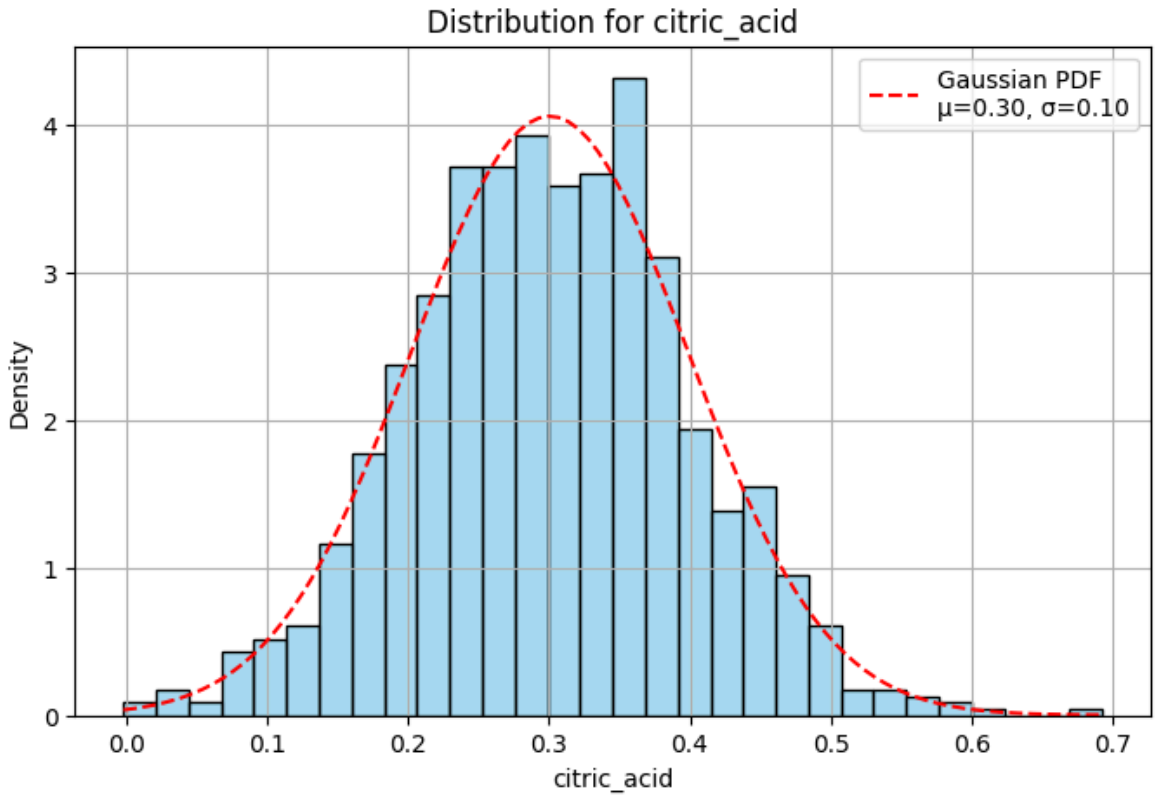
```
Statistical Summary:
       fixed_acidity  volatile_acidity  citric_acid  residual_sugar  \
count    1000.000000       1000.000000  1000.000000     1000.000000
mean        7.013532          0.507084     0.300583        5.971921
std         0.685451          0.099745     0.098345        1.540699
min         4.731113          0.205961    -0.001951        1.605827
25%         6.546687          0.439376     0.235200        4.893869
50%         7.017710          0.506308     0.299975        6.000277
75%         7.453561          0.572888     0.366092        7.000418
max         9.696912          0.819311     0.692624       10.864639

         chlorides      alcohol  wine_quality
count  1000.000000  1000.000000    1000.00000
mean      0.049507     9.953262       3.04600
std       0.009924     1.007389       0.20959
min       0.018233     7.100486       3.00000
25%       0.043174     9.306307       3.00000
50%       0.049818     9.957173       3.00000
75%       0.056391    10.612447       3.00000
max       0.081129    13.098299       4.00000
```

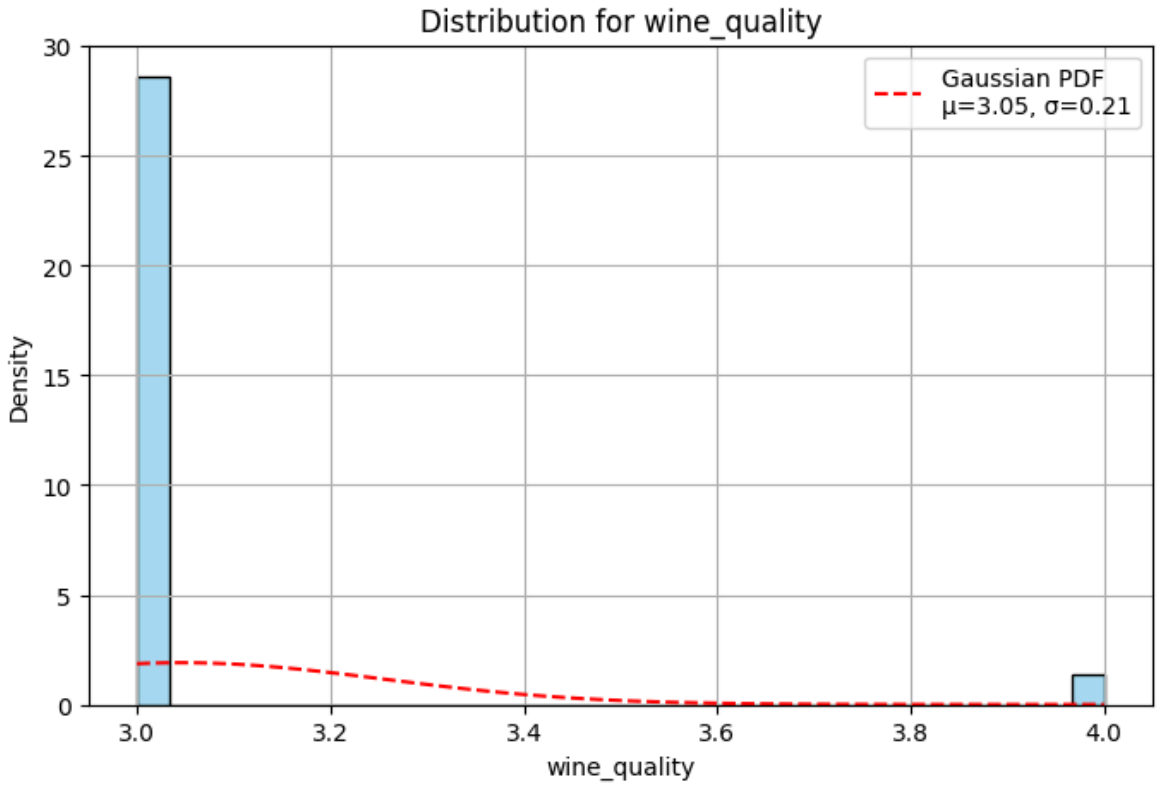
In [9]:

```python
#Visualizations - Histogram & PDF
features = ["alcohol", "volatile_acidity", "citric_acid", "wine_quality"]

for feature in features:
    mean = np.mean(df[feature])
    std = np.std(df[feature])
    x = np.linspace(df[feature].min(), df[feature].max(), 100)
    pdf = norm.pdf(x, mean, std)

    plt.figure(figsize=(8, 5))
    sns.histplot(df[feature], bins=30, kde=False, color='skyblue', stat="density
    plt.plot(x, pdf, 'r--', label=f'Gaussian PDF\nμ={mean:.2f}, σ={std:.2f}')
    plt.title(f'Distribution for {feature}')
    plt.xlabel(feature)
    plt.ylabel("Density")
    plt.legend()
    plt.grid(True)
    plt.show()
```

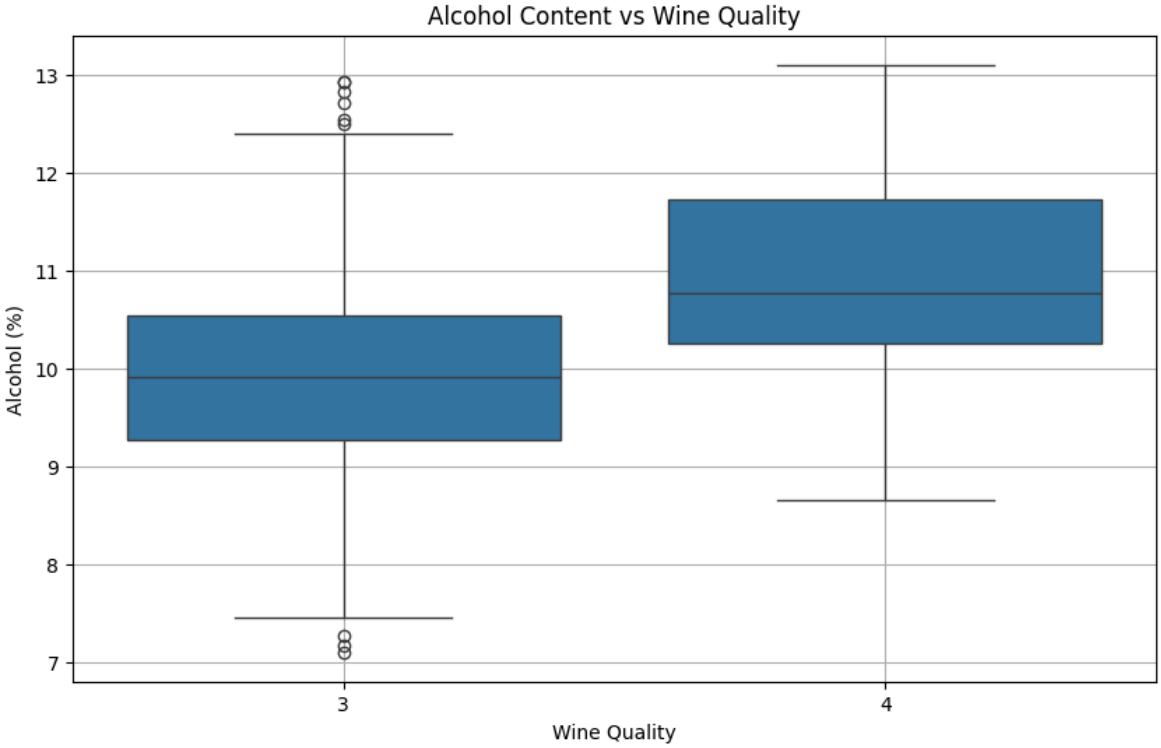

Distribution for alcohol
Gaussian PDF
μ=9.95, σ=1.01
Density
alcohol
0.0
0.1
0.2
0.3
0.4
7
8
9
10
11
12
13


Distribution for volatile_acidity
Gaussian PDF
μ=0.51, σ=0.10
Density
volatile_acidity
0
1
2
3
4
0.2
0.3
0.4
0.5
0.6
0.7
0.8

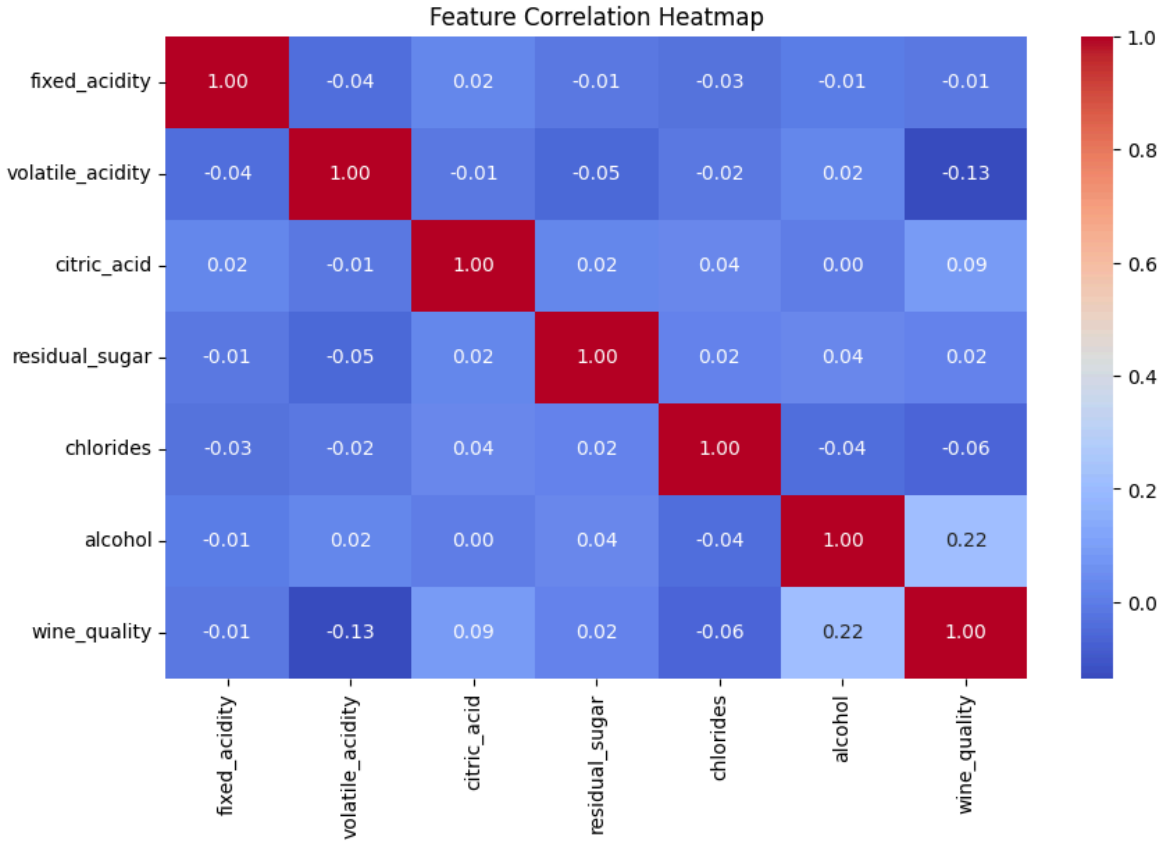




In [7]:
```python
# Analyze feature vs wine_quality
plt.figure(figsize=(10, 6))
sns.boxplot(x="wine_quality", y="alcohol", data=df)
plt.title("Alcohol Content vs Wine Quality")
plt.xlabel("Wine Quality")
plt.ylabel("Alcohol (%)")
plt.grid(True)
plt.show()
```



In [8]:
```
# Correlation heatmap
plt.figure(figsize=(10, 6))
sns.heatmap(df.corr(), annot=True, cmap="coolwarm", fmt=".2f")
plt.title("Feature Correlation Heatmap")
plt.show()
```



In [ ]: