Exploring Red Wines by OZGUN BALABAN

Overview

In this project a sample set of red wines are analyzed for 12 different variables. I selected red wines as a study since I am curious in learning what makes of a good wine. We will first start with summarizing the data and identifying every parameter. In a data study it is important to make a background study to understand the phenomena.

Summary of the data

```
summary(red)
```

```
##        X          fixed.acidity   volatile.acidity  citric.acid
##  Min.   :   1.0   Min.   : 4.60   Min.   :0.1200   Min.   :0.000
##  1st Qu.: 400.5   1st Qu.: 7.10   1st Qu.:0.3900   1st Qu.:0.090
##  Median : 800.0   Median : 7.90   Median :0.5200   Median :0.260
##  Mean   : 800.0   Mean   : 8.32   Mean   :0.5278   Mean   :0.271
##  3rd Qu.:1199.5   3rd Qu.: 9.20   3rd Qu.:0.6400   3rd Qu.:0.420
##  Max.   :1599.0   Max.   :15.90   Max.   :1.5800   Max.   :1.000
##  residual.sugar     chlorides       free.sulfur.dioxide
##  Min.   : 0.900   Min.   :0.01200   Min.   : 1.00
##  1st Qu.: 1.900   1st Qu.:0.07000   1st Qu.: 7.00
##  Median : 2.200   Median :0.07900   Median :14.00
##  Mean   : 2.539   Mean   :0.08747   Mean   :15.87
##  3rd Qu.: 2.600   3rd Qu.:0.09000   3rd Qu.:21.00
##  Max.   :15.500   Max.   :0.61100   Max.   :72.00
##  total.sulfur.dioxide    density             pH          sulphates
##  Min.   :  6.00       Min.   :0.9901   Min.   :2.740   Min.   :0.3300
##  1st Qu.: 22.00       1st Qu.:0.9956   1st Qu.:3.210   1st Qu.:0.5500
##  Median : 38.00       Median :0.9968   Median :3.310   Median :0.6200
##  Mean   : 46.47       Mean   :0.9967   Mean   :3.311   Mean   :0.6581
##  3rd Qu.: 62.00       3rd Qu.:0.9978   3rd Qu.:3.400   3rd Qu.:0.7300
##  Max.   :289.00       Max.   :1.0037   Max.   :4.010   Max.   :2.0000
##     alcohol         quality
##  Min.   : 8.40   Min.   :3.000
##  1st Qu.: 9.50   1st Qu.:5.000
##  Median :10.20   Median :6.000
##  Mean   :10.42   Mean   :5.636
##  3rd Qu.:11.10   3rd Qu.:6.000
##  Max.   :14.90   Max.   :8.000
```

Analyzing the data, we have 1599 observations with 13 variables. These are;
X -> unique id
fixed.acidity -> acid produced in the body from sources other than CO2
volatile.acidity -> acids produced by yeast and bacteria
citric.acid -> rarely found in wine, can be used to boost wine acidity
residual.sugar -> determines sweetnees of the wine
chlorides -> saltiness of the wine (not a good thing)
free.sulfur.dioxide -> sulfur oxide prevents bacteria growth
total.sulfur.dioxide -> total amount

density -> density of the wine - 1 is same as water
pH -> acidity level (it is alkaline if over 7 but all the values in set under 7)
sulphates -> an additive to prevent wine fault
alcohol -> alcohol level of the wine
quality -> scores by sommeliers higher is better

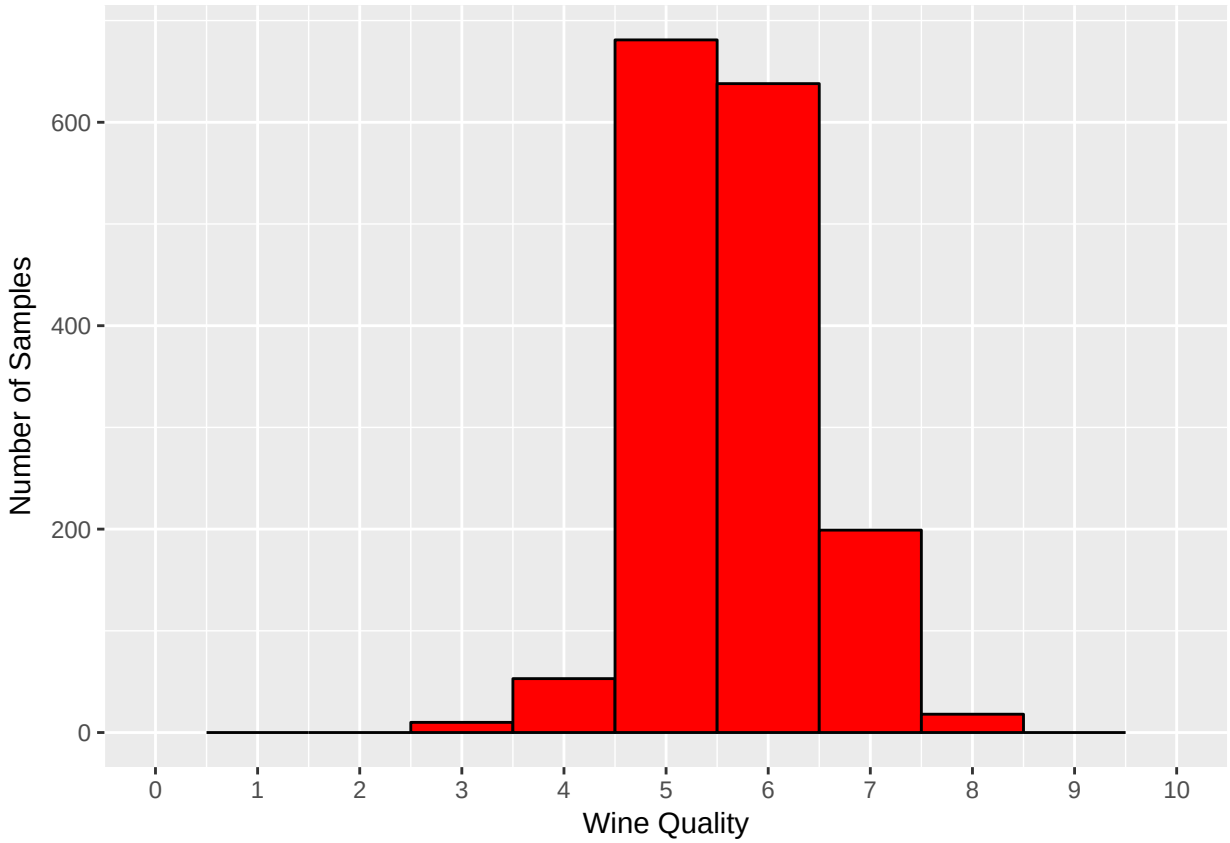
This listing of the parameters reveals some interesting relations. Acidity is one of the important things in wine. There are different opinions as to what level of volatile acidity is appropriate for higher quality wine. Although too high a concentration is sure to leave an undesirable, 'vinegar' tasting wine, some wine's acetic acid levels are developed to create a more 'complex', desirable taste. The renowned 1947 Cheval Blanc is widely recognized to contain high levels of volatile acidity.

Sugar level is also important in the 'taste' of the wine. Too much sugar might hide the complexity of the flavors. So looking on these parameters it is important to find out how these affect the overall taste. Some interesting questions that can be asked;

Univariate Plots Section

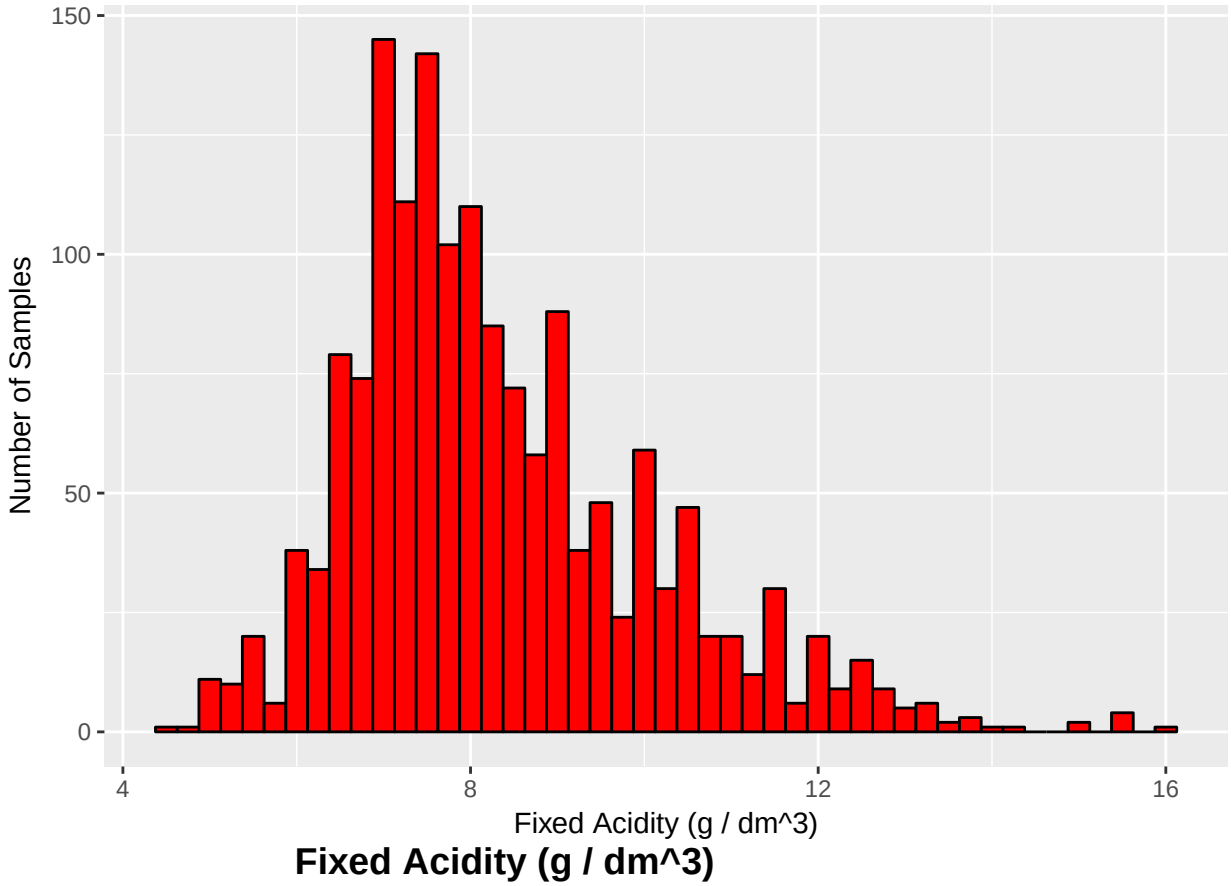
Wine Quality

Wine quality is supplied by tasters. It can be in the range from 0 to 10. Plotting the wine quality;

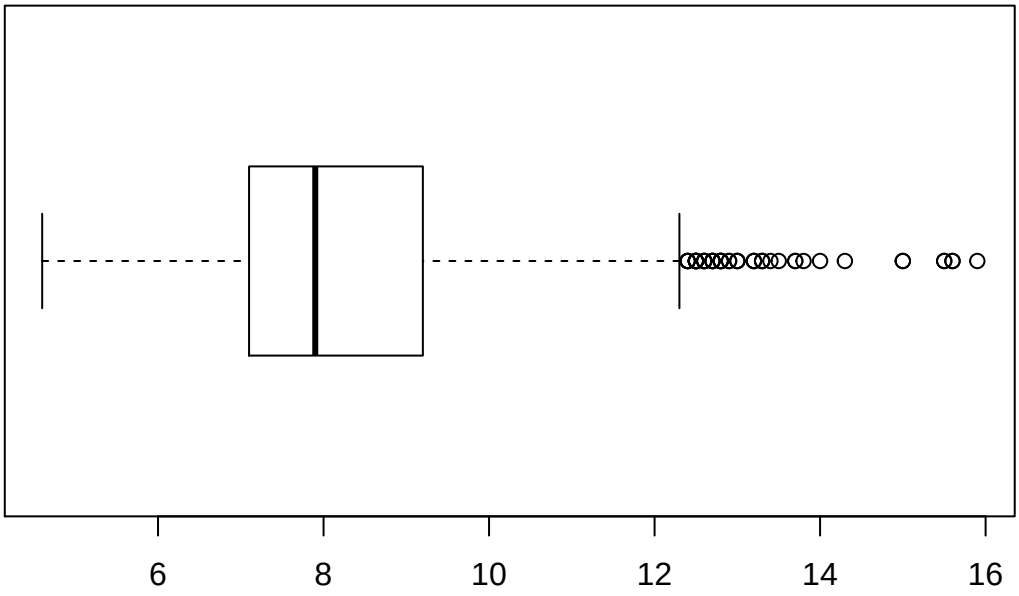


There is no outliers here. Minimum value is 3, maximum value is 8. We can see most of the wines are stacked around 5-6 and a little bit of 7.

Fixed Acidity

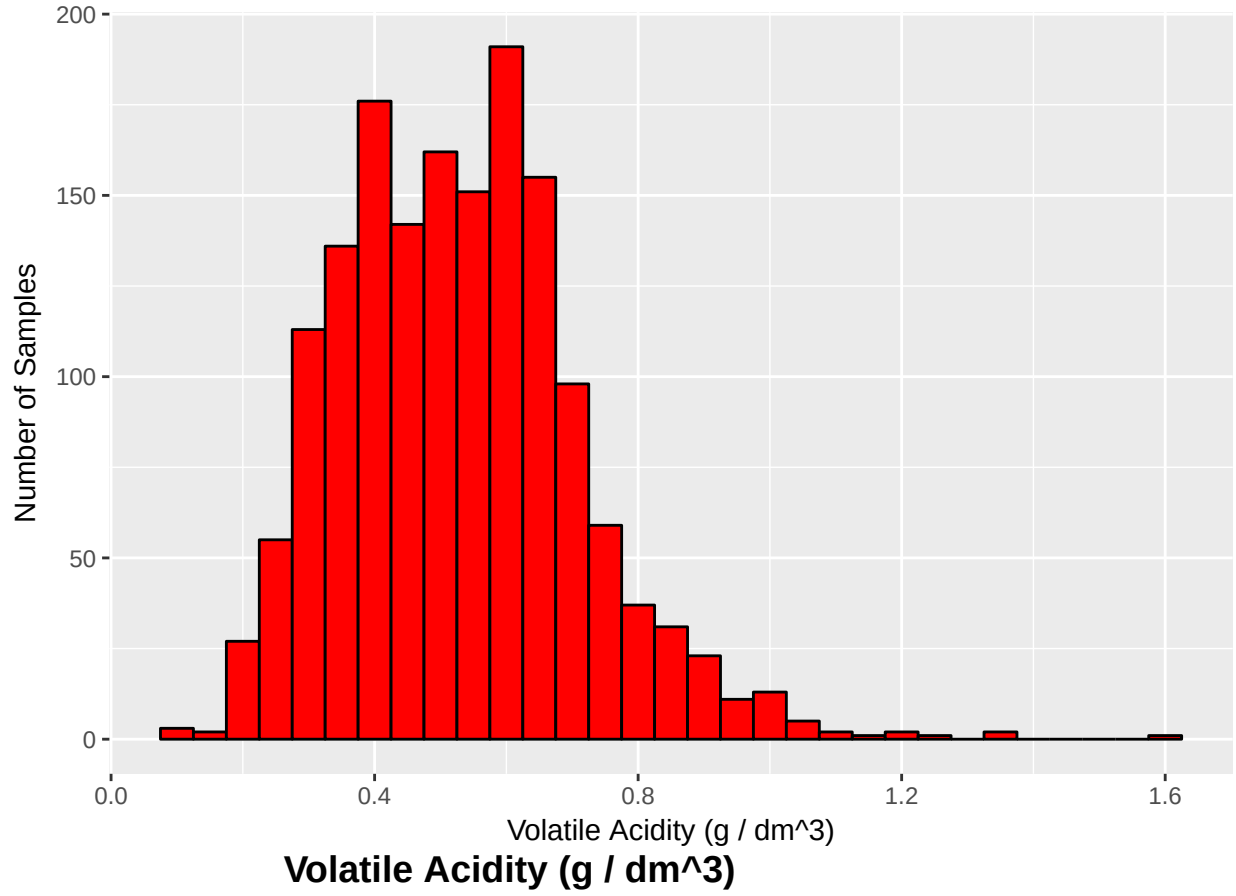


Fixed Acidity (g / dm^3)

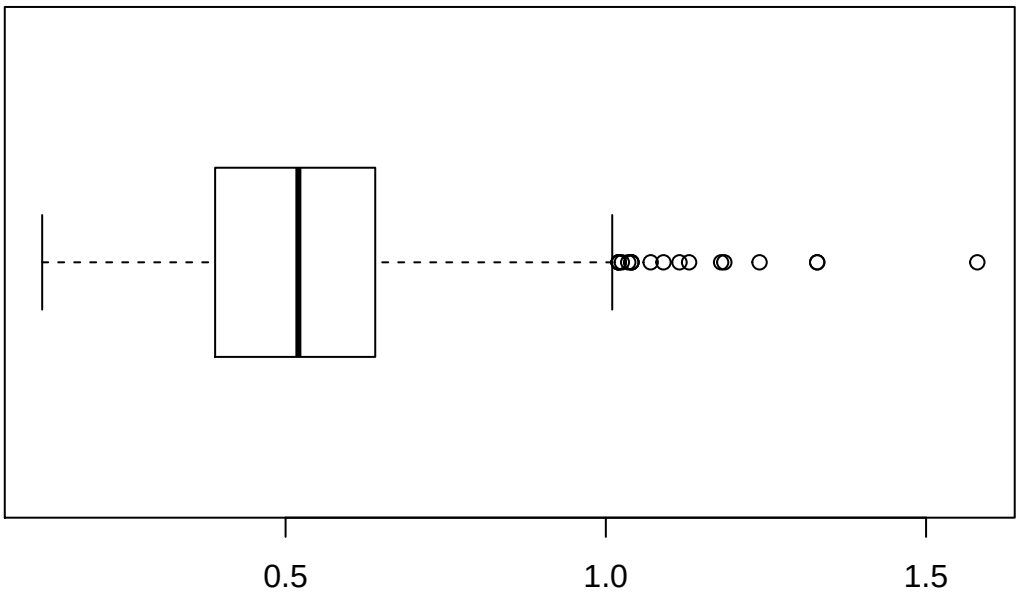


Here we see the mean around 8. There are few outliers in the right side of the data. From this graph we can conclude wines are generally more acidic than basic.

Volatile Acidity

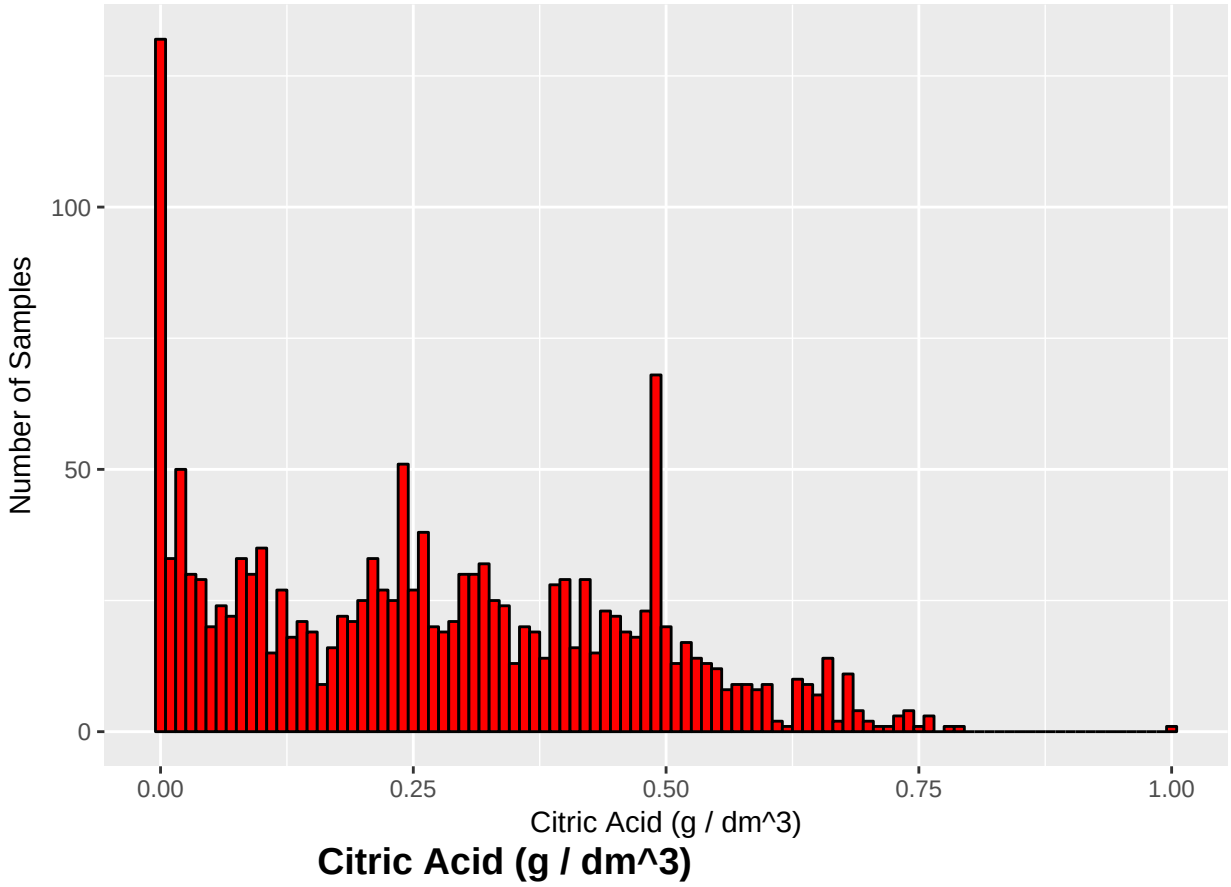


Volatile Acidity (g / dm^3)

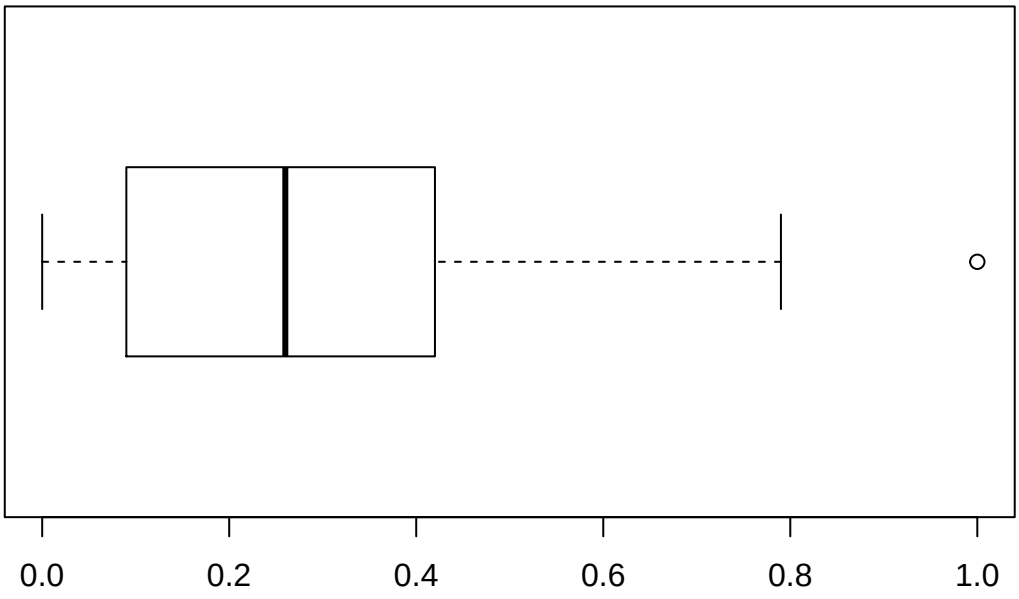


The mean here is around 0.5. There are some outliers again in the right side.

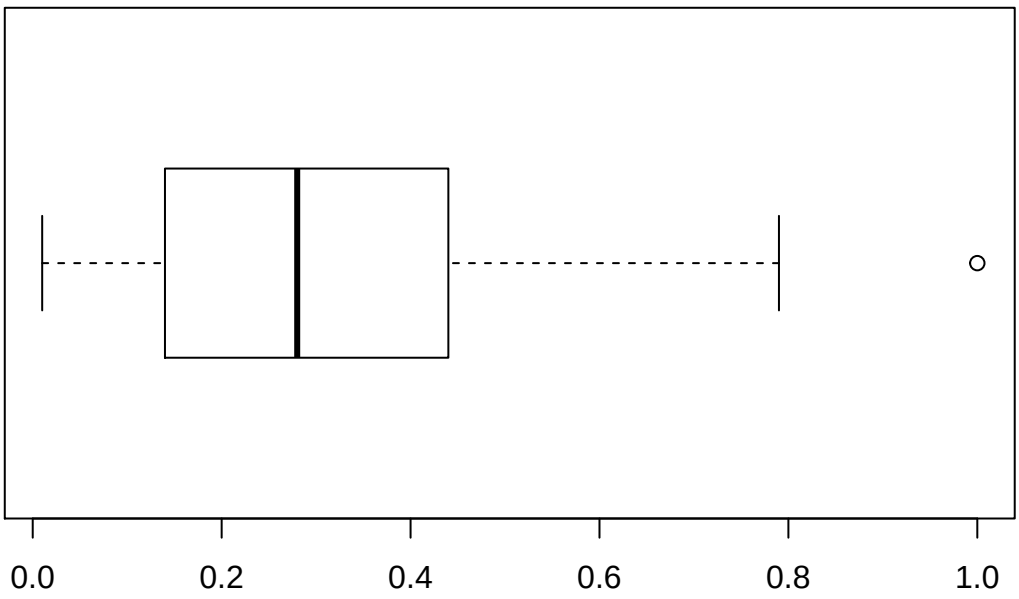
Citric Acid



Citric Acid (g / dm^3)



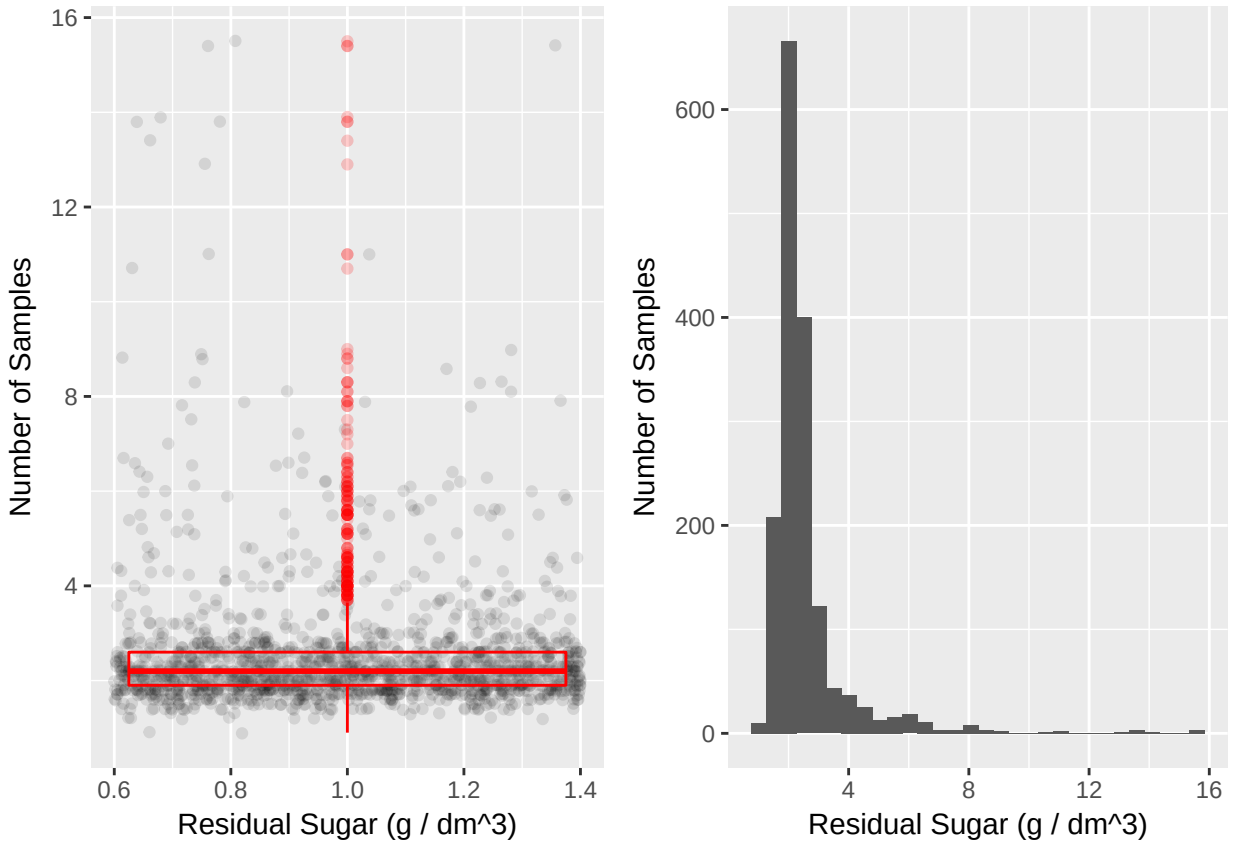

```
## [1] 132
```



From the previous observation we know that citric acid is rarely used to adjust acidity of wines. We have 132 wines with no citric acid. Searching on internet reveals that in EU using citric acid is banned. So it would be nice if we had the data of the origin of the wines used in this study.

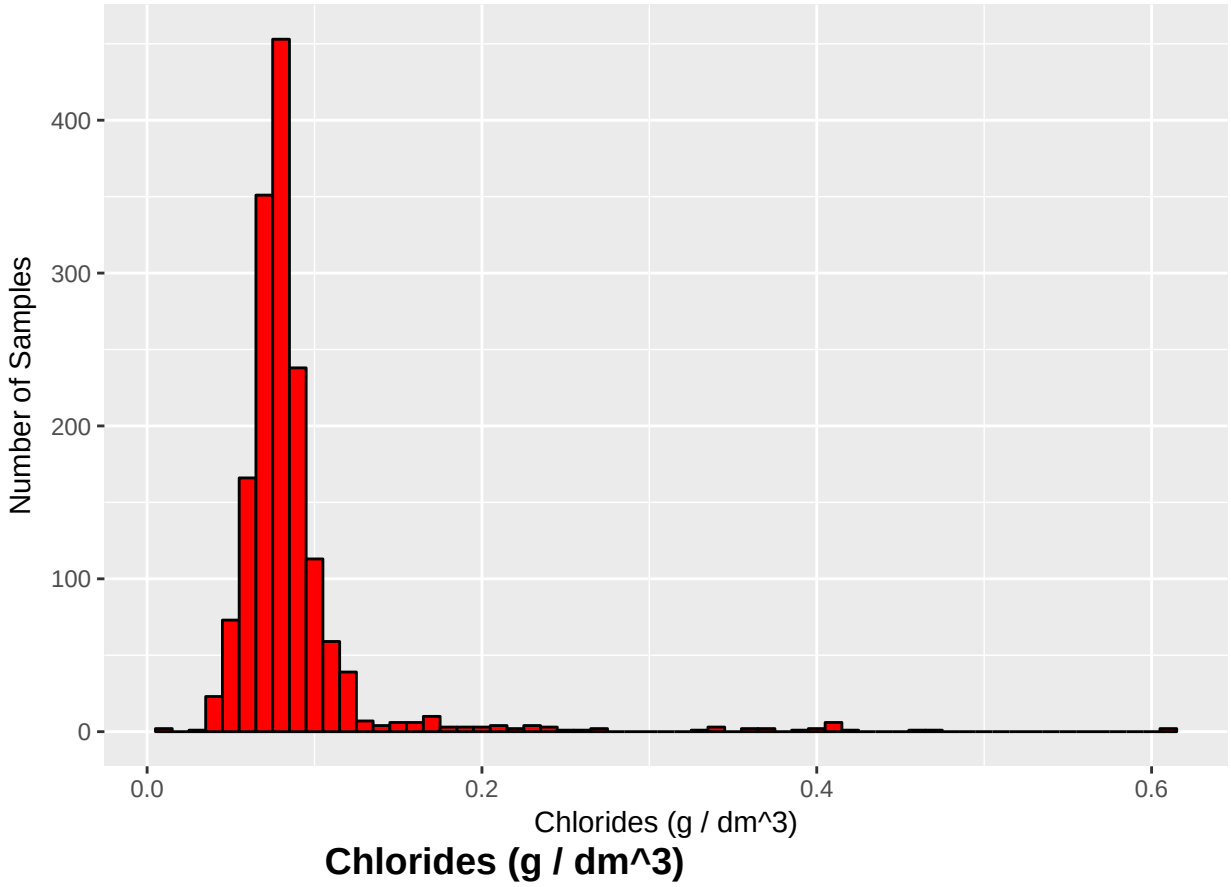
Residual Sugar

```
grid.arrange(ggplot(red, aes( x = 1, y = residual.sugar ) ) +
               geom_jitter(alpha = 0.1 )  + xlab('Residual Sugar (g / dm^3)')+
  ylab("Number of Samples") +
               geom_boxplot(alpha = 0.2, color = 'red' ) ,
             ggplot(red, aes( x = residual.sugar  ) ) +
    xlab('Residual Sugar (g / dm^3)')+
  ylab("Number of Samples") +
                  geom_histogram(bins=30 ),ncol=2)
```

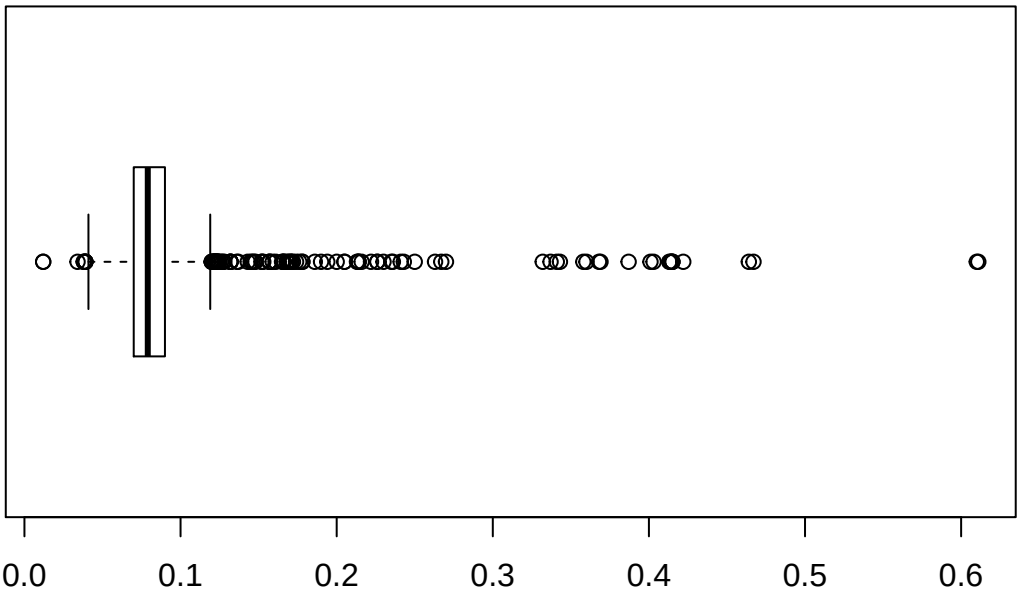


Residual sugar has many outliers. Removing the outliers I plotted again. Sugar level will probably influence the taste of wine. So many outliers also mean that sugar level is open to varied taste and experimentation. People generaly have varied opinions about sweet wines.

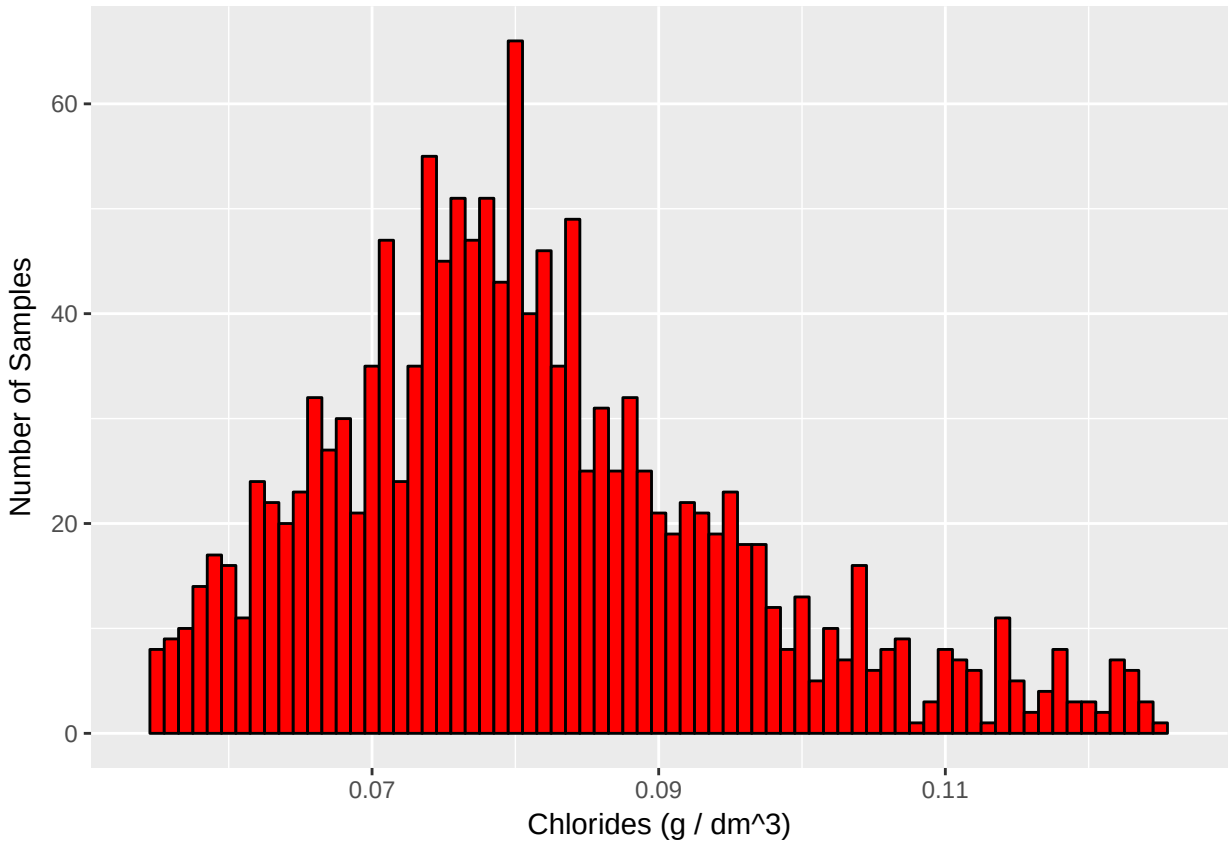
Chlorides



Chlorides (g / dm^3)

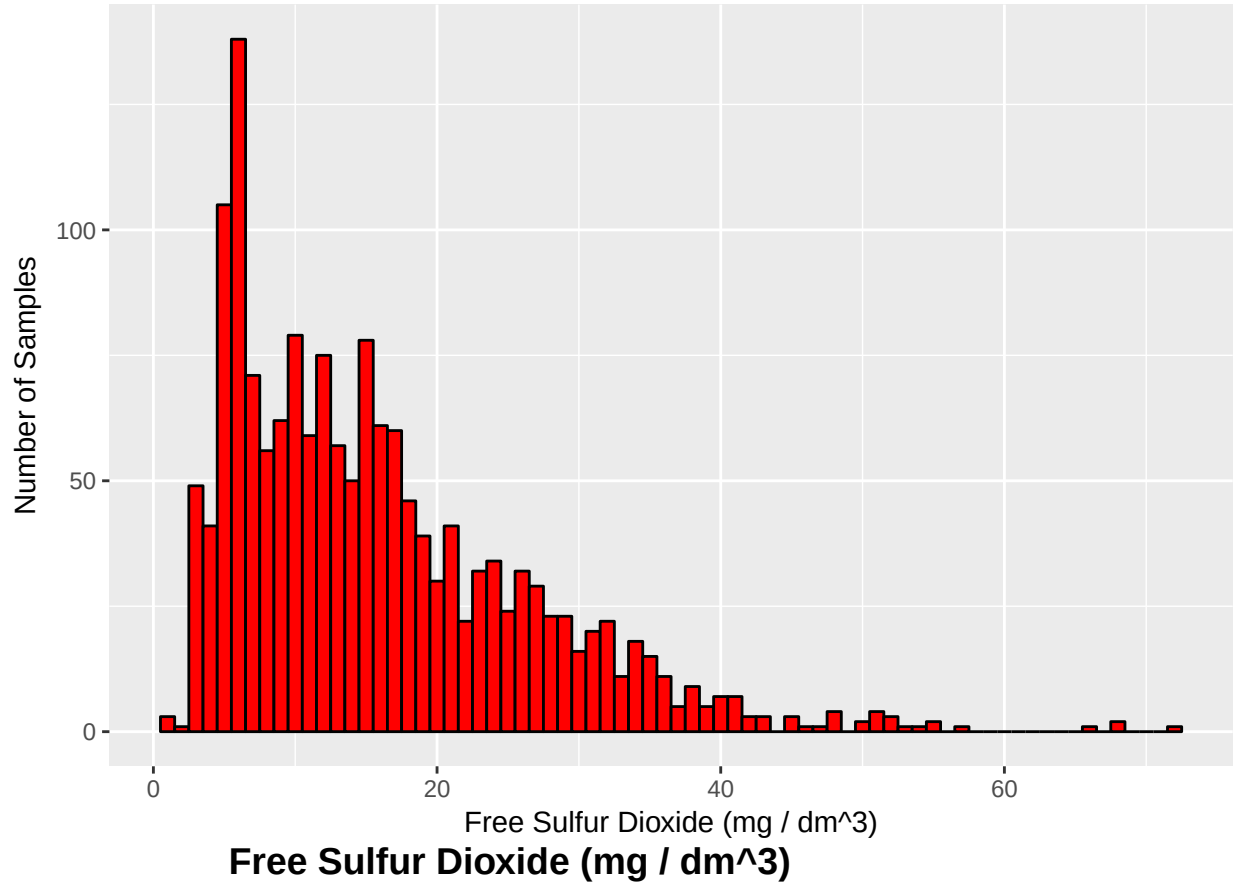


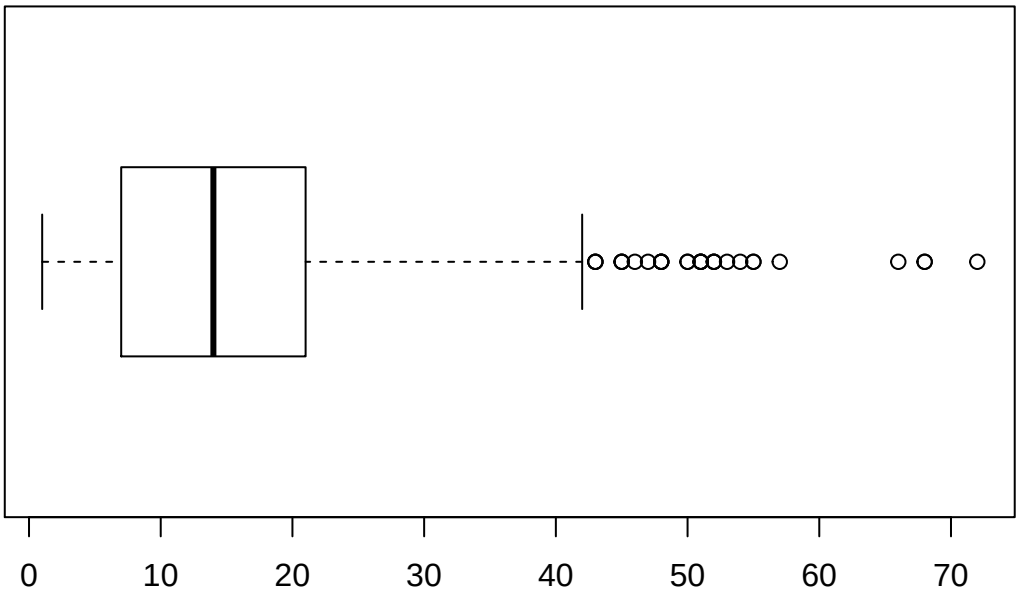

```
## Warning: Removed 158 rows containing non-finite values (stat_bin).
```



Chlorides have many outliers as well. Removing the extreme values, I plot it again. Chlorides give unwanted salty smell but in turn it protects the wine, so too much Chloride might make the wine taste bad but it might stop spoilage.

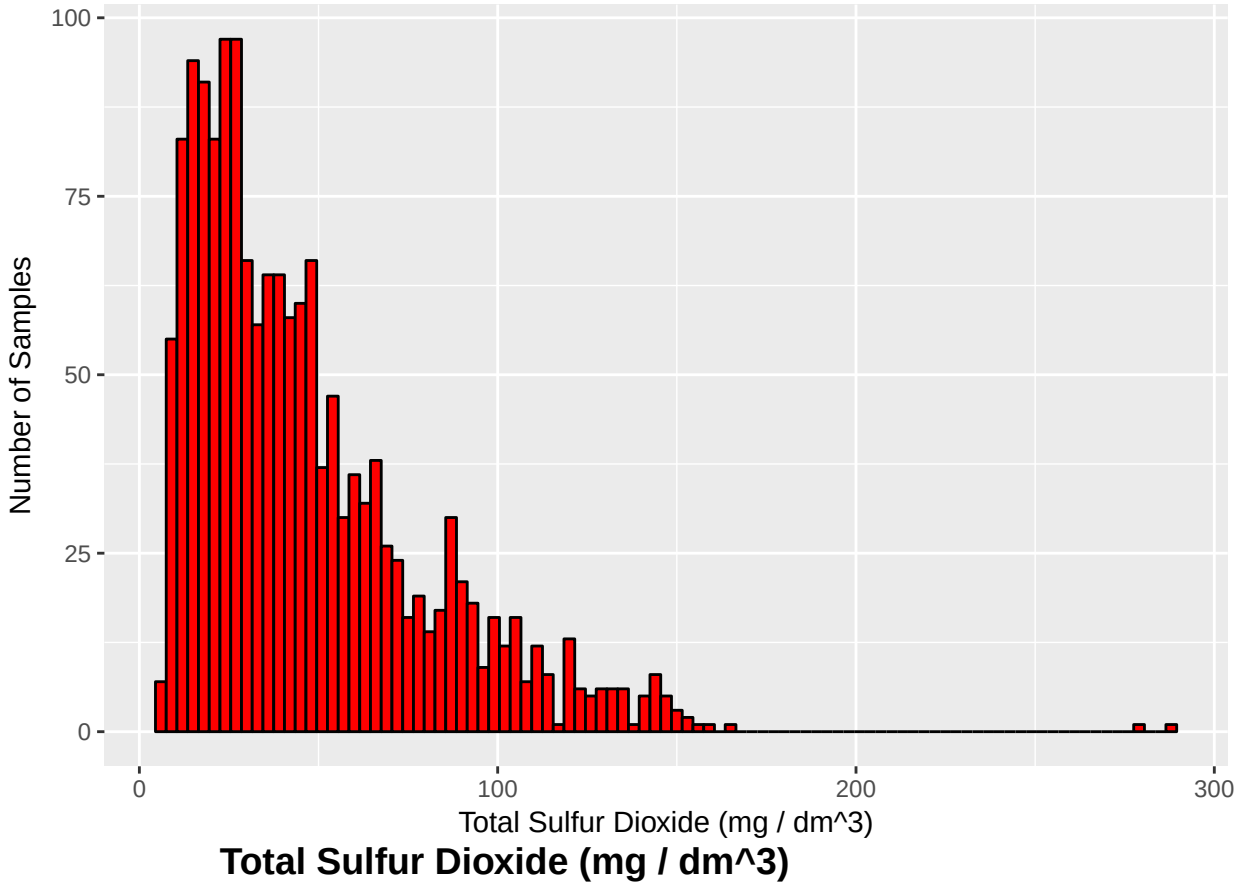
Free Sulfur Dioxide



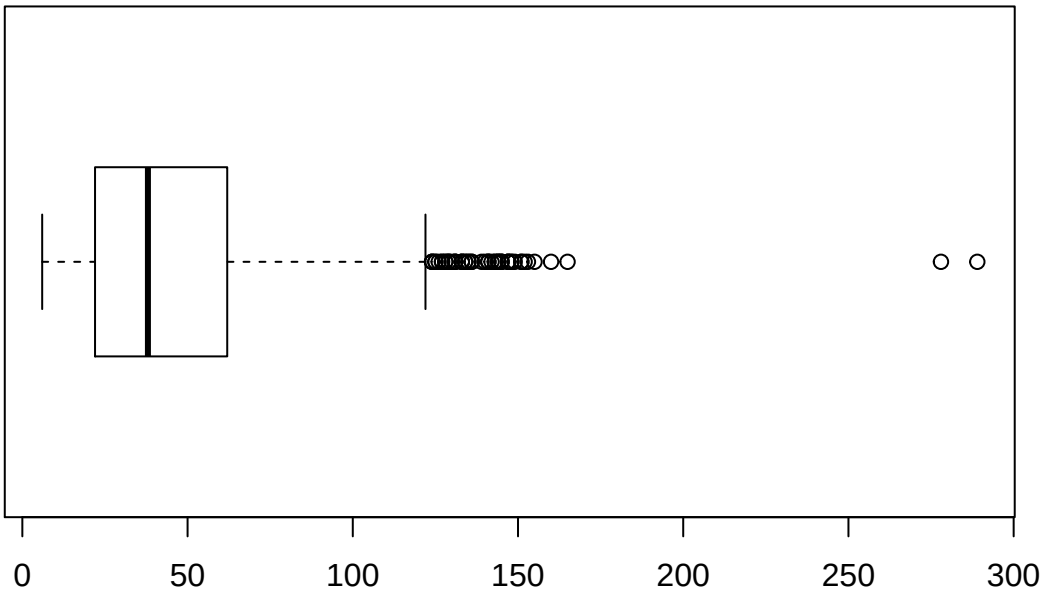


Average Free Sulfur Dioxide is around 15 with few outliers. Though outliers can be quite away from the mean value.

Total Sulfur Dioxide

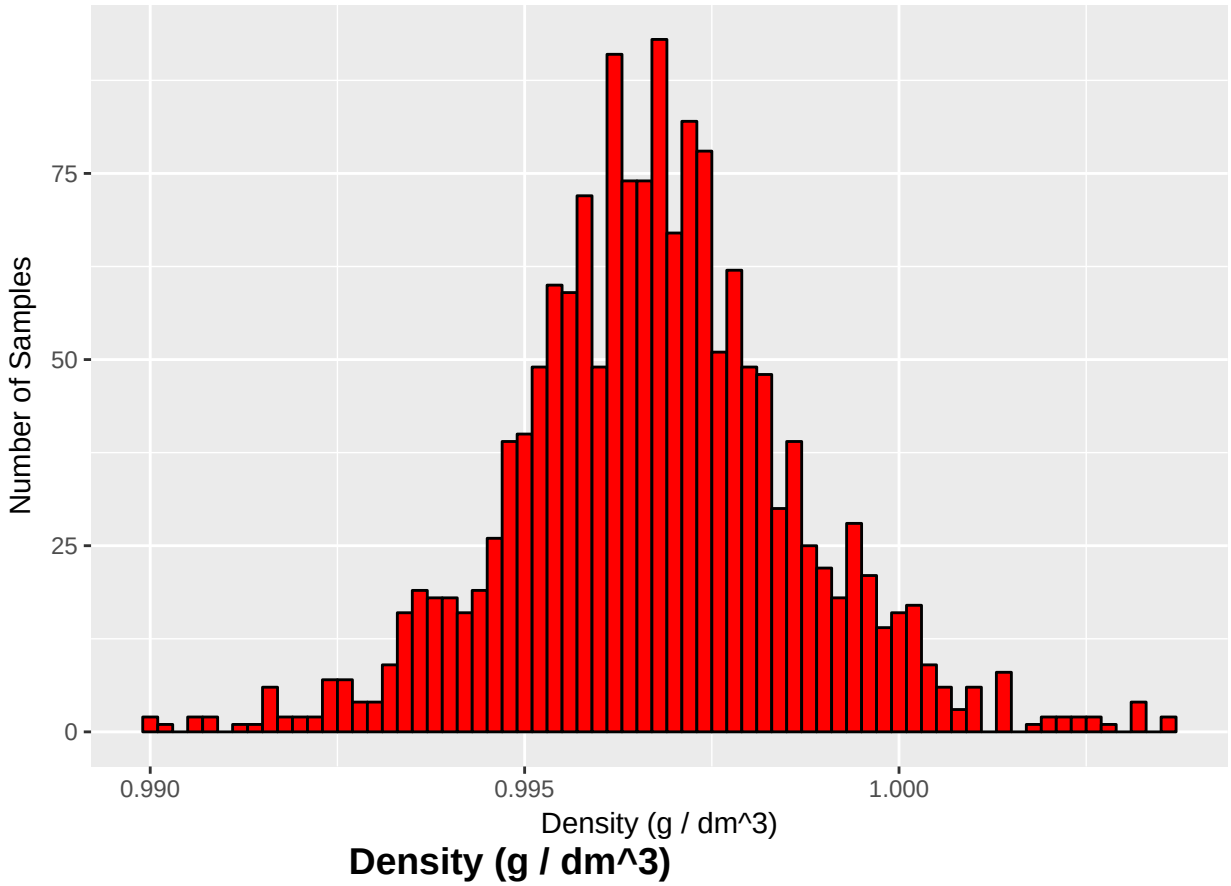


Total Sulfur Dioxide (mg / dm^3)

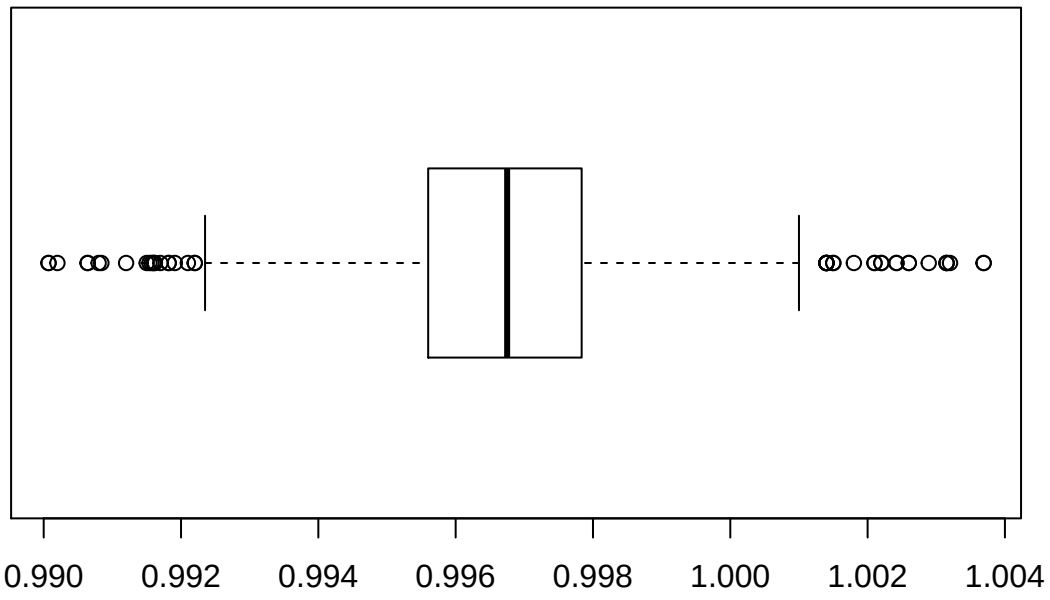


Total Sulfur Dioxide has many outliers on the right hand side of the data. And there are two points that are extremely away from the mean value.

Density

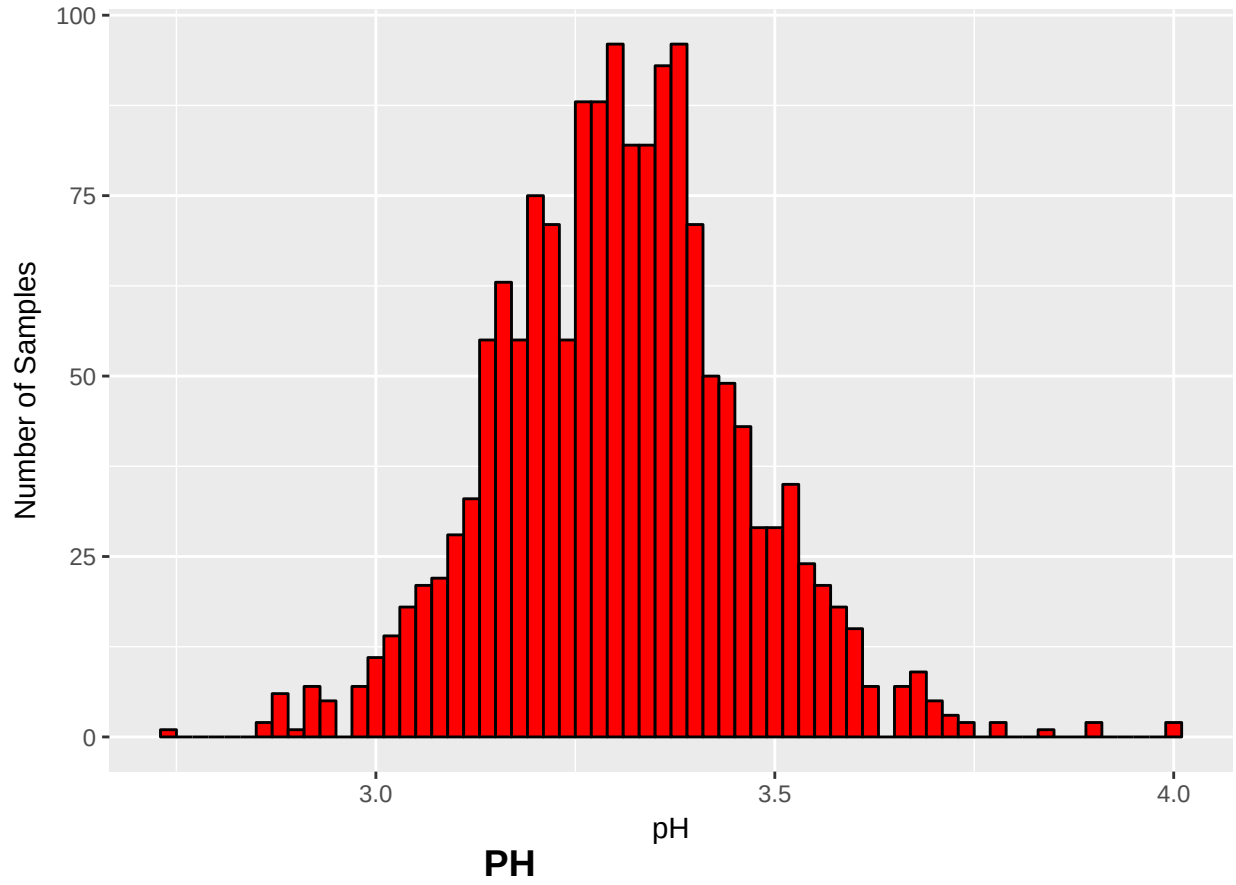


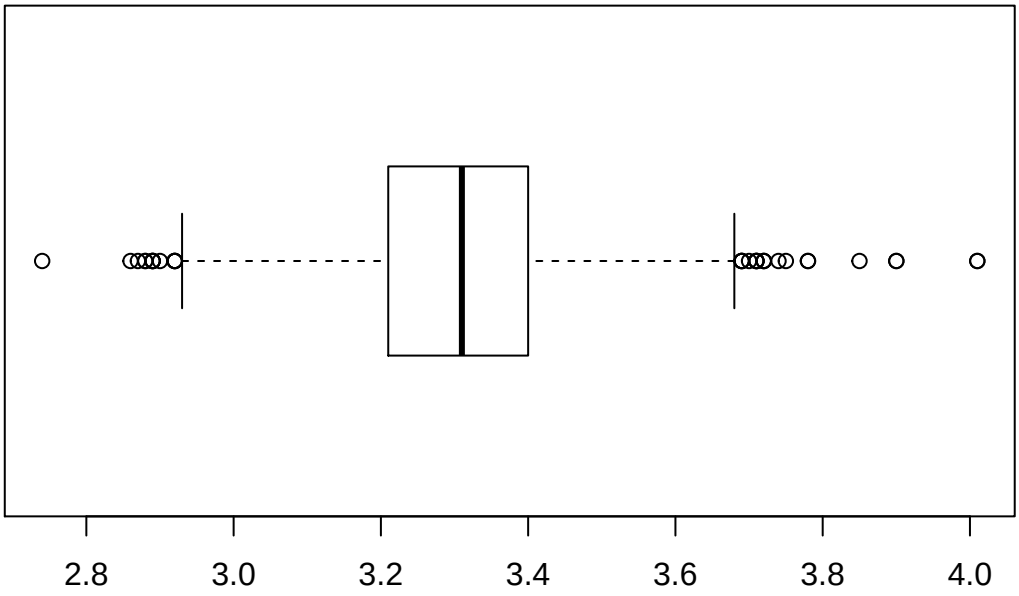
Density (g / dm^3)



Density values look very uniformly distributed, even the distances around the points are close, so I dont think it has a big effect on the taste.

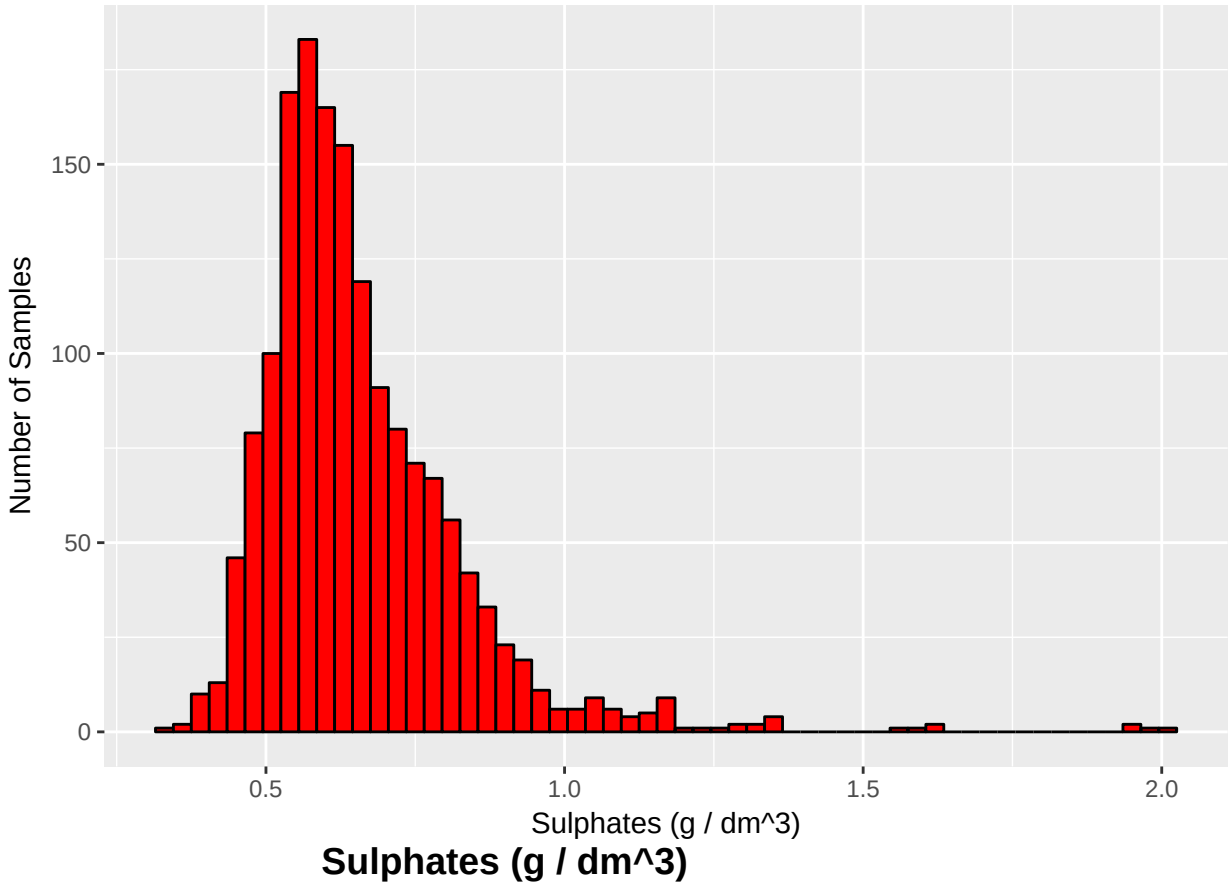
pH



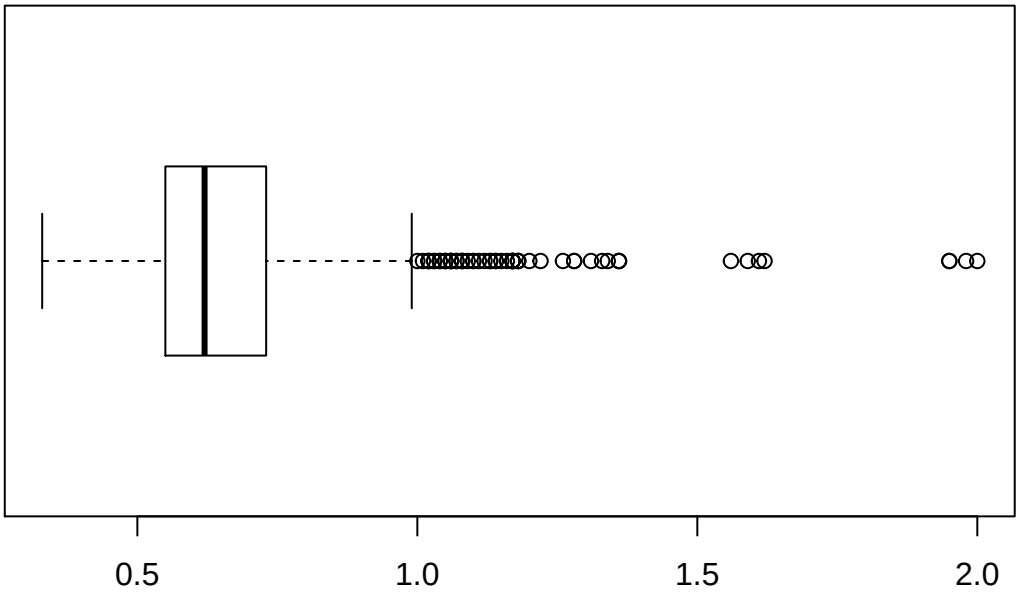


Observing Ph values we can see its mean is around 3.3 and it has few outliers. We can also observe since any pH lower than 7 is acidic, all the wines in this study is acidic. Since it is well spread towards both right and left, I wonder if this effects the taste.

Sulphates

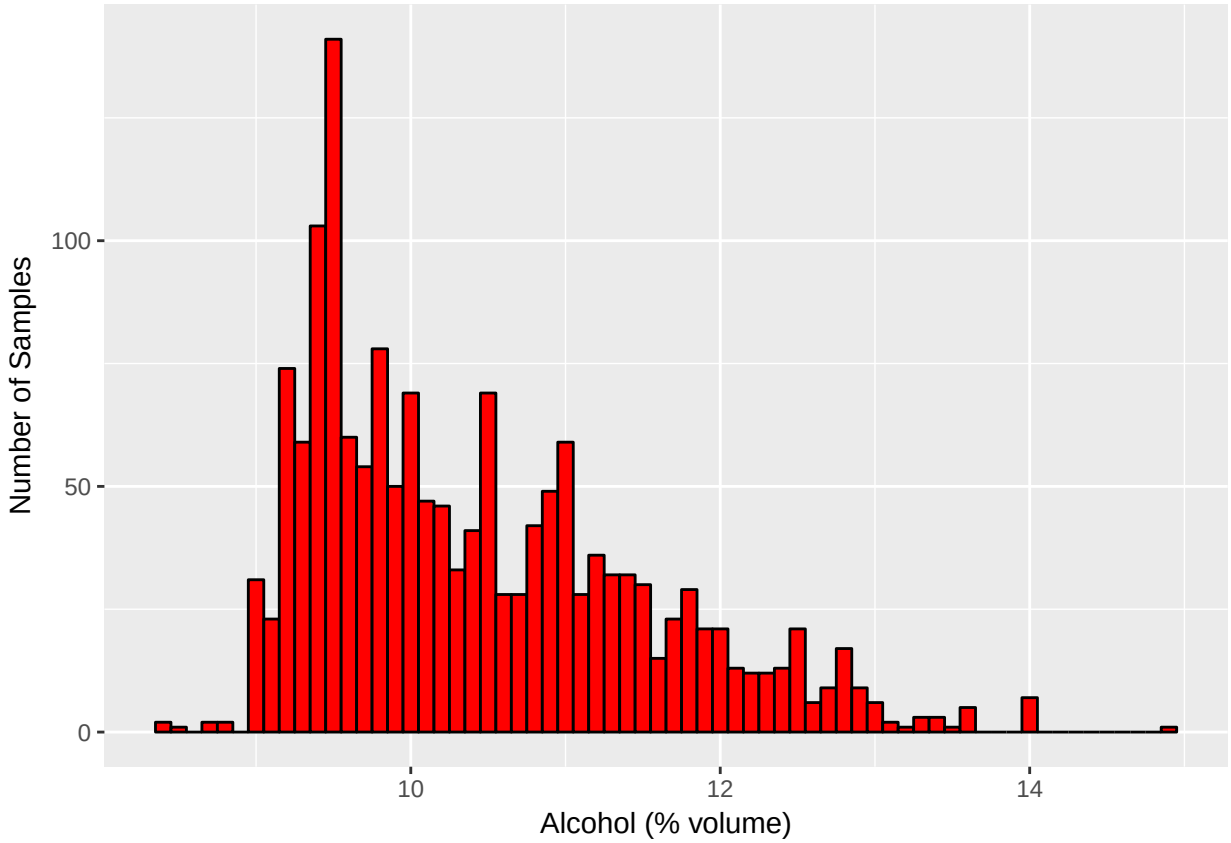


Sulphates (g / dm^3)

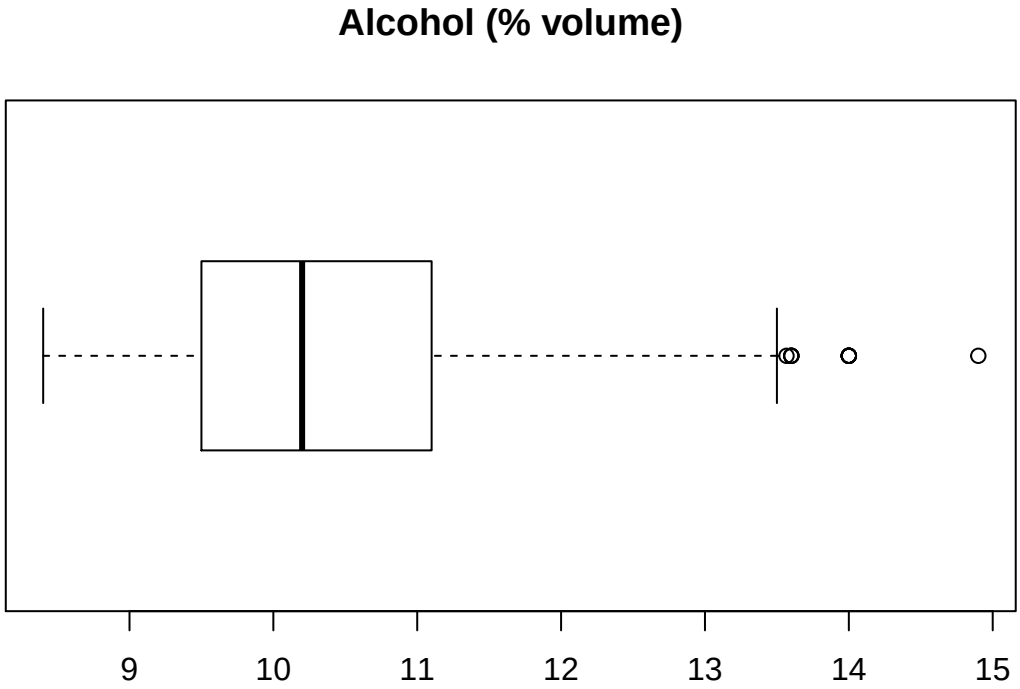


Many outliers on the right side, Sulphates are naturally occuring molecules, because of the fermentation. Too much sulpahtes might give a foul taste as well.

Alcohol




```
## [1] 8.4
## [1] 14.9
## [1] 10.42298
```



Observing alcohol level shows minimum alcohol level is 8.4 and maximum level is 14.9 with mean around 10.4.

Univariate Analysis

For a successful data analysis, univariate analysis of different parameters is crucial. In this stage we can already notice there is a lot variance in certian variables whereas some are same for most of the wines such as densities. Having a univariate analysis at the beginning of a study, makes it easier to understand the context.

What is the structure of your dataset?

```
str(red)
```

```
## 'data.frame':    1599 obs. of  13 variables:
##  $ X                   : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ fixed.acidity       : num  7.4 7.8 7.8 11.2 7.4 7.4 7.9 7.3 7.8 7.5 ...
##  $ volatile.acidity    : num  0.7 0.88 0.76 0.28 0.7 0.66 0.6 0.65 0.58 0.5 ...
##  $ citric.acid         : num  0 0 0.04 0.56 0 0 0.06 0 0.02 0.36 ...
##  $ residual.sugar      : num  1.9 2.6 2.3 1.9 1.9 1.8 1.6 1.2 2 6.1 ...
##  $ chlorides           : num  0.076 0.098 0.092 0.075 0.076 0.075 0.069 0.065 0.073 0.071 ...
##  $ free.sulfur.dioxide : num  11 25 15 17 11 13 15 15 9 17 ...
##  $ total.sulfur.dioxide: num  34 67 54 60 34 40 59 21 18 102 ...
##  $ density             : num  0.998 0.997 0.997 0.998 0.998 ...
##  $ pH                  : num  3.51 3.2 3.26 3.16 3.51 3.51 3.3 3.39 3.36 3.35 ...
##  $ sulphates           : num  0.56 0.68 0.65 0.58 0.56 0.56 0.46 0.47 0.57 0.8 ...
##  $ alcohol             : num  9.4 9.8 9.8 9.8 9.4 9.4 9.4 10 9.5 10.5 ...
##  $ quality             : int  5 5 5 6 5 5 5 7 7 5 ...
```

What is/are the main feature(s) of interest in your dataset?

In this study I am more interested in how different factors effect taste of wine.

What other features in the dataset do you think will help support your investigation into your feature(s) of interest?

Many features of the data will be related. Analizing the features with respect to quality we find this relationship;

```
##                              [,1]
## fixed.acidity         0.12405165
## volatile.acidity     -0.39055778
## citric.acid           0.22637251
## residual.sugar        0.01373164
## chlorides            -0.12890656
## free.sulfur.dioxide  -0.05065606
## total.sulfur.dioxide -0.18510029
## density              -0.17491923
## pH                   -0.05773139
## sulphates             0.25139708
## alcohol               0.47616632
```

So Fixed Acidity, Citric Acid, Residual Sugar, Sulphates and Alcohol is positively corelated. Alcohol has a strong corelation. Whereas Volatile Acidity, Chlorides, Free Sulfur Dioxide, Total Sulfur Dioxide, Density and pH is negatively corelated. Volatile Acidity has strong negative corelation.

Did you create any new variables from existing variables in the dataset?

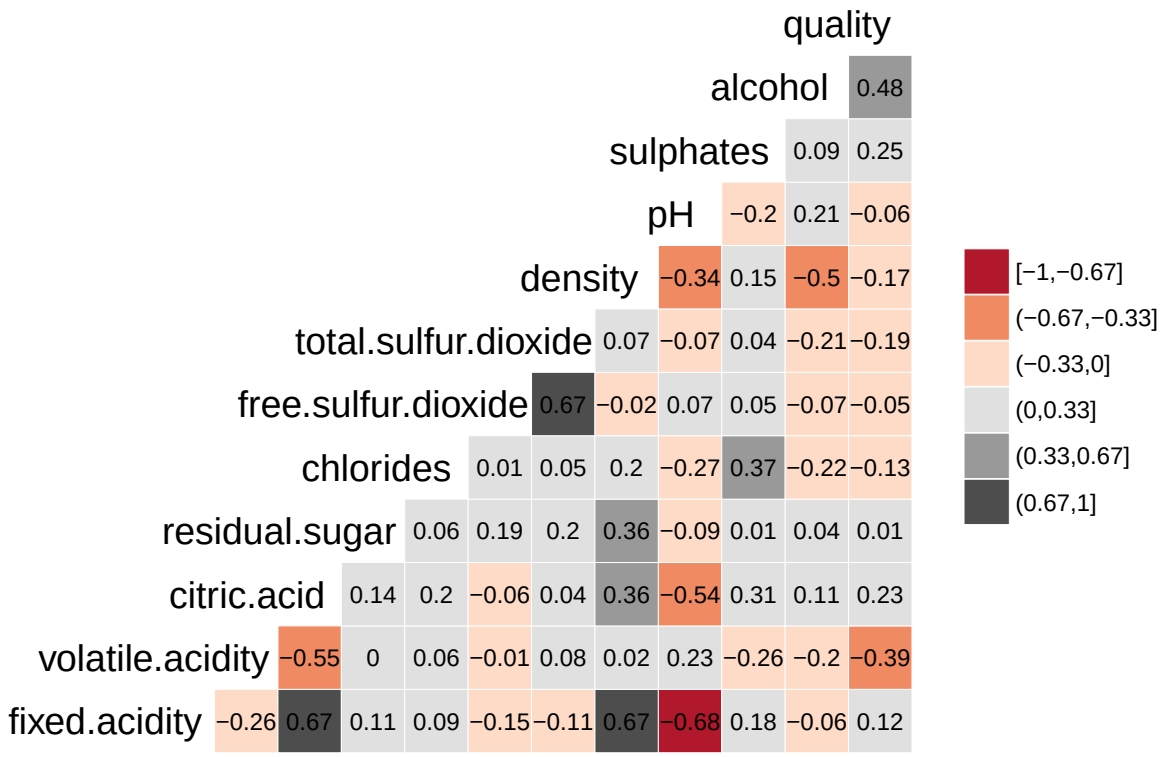
No, no new variable is created.

Of the features you investigated, were there any unusual distributions? Did you perform any operations on the data to tidy, adjust, or change the form of the data? If so, why did you do this?

As explained in previous section, Residual sugar and chlorides have outliers, those are plotted again after removing the top and bottom extremes. Citric acid has many zero values.

Bivariate Plots Section

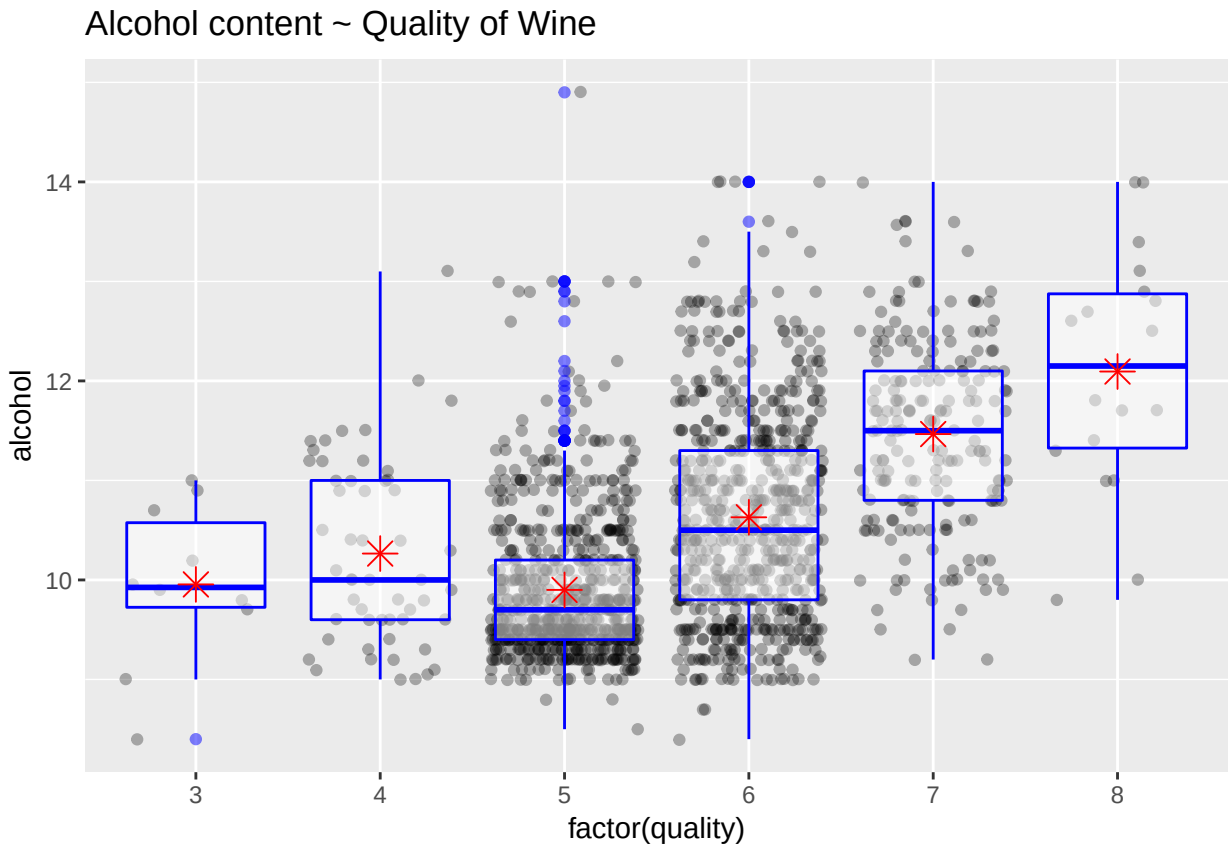
Correlation of parameters



First we check all the variables for correlation. We see which variables are strongly corelated with each other. This function is found from this website https://briatte.github.io/ggcorr/

Inspecting this, we can see alcohol level strongly correlated with quality, citric acid and sulphates also have slight positive correlation, volatile acidity on the other hand has negative correlation. The other variables do not have significant correlations. So if I want to make a model, I will most probably use these 3 variables, alcohol level, volatile acidity and sulphates.

```
ggplot(aes(factor(quality),
           alcohol),
       data = red) +
  geom_jitter( alpha = .3)  +
  geom_boxplot( alpha = .5,color = 'blue')+
  stat_summary(fun.y = "mean",
               geom = "point",
               color = "red",
               shape = 8,
               size = 4) +
   labs(title="Alcohol content ~ Quality of Wine")
```

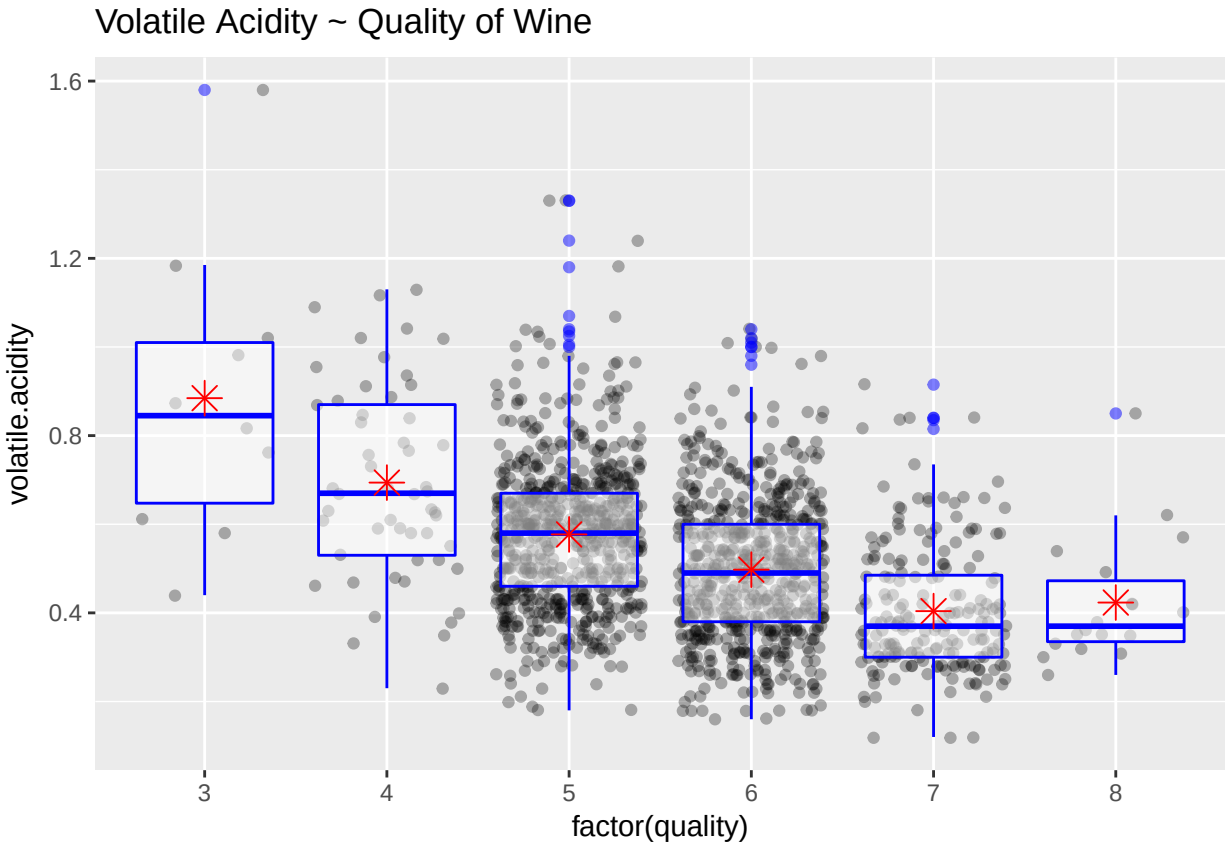


I want to first investigate relation of alcohol content and quality of the wine. I suspect there should be strong correlation.

Checking this graph we see good wines (quality>5) have more alcohol content. Whereas wines that are not so good (quality<6) have varying alcohol content.

We can notice positive correlation between alcohol content and quality.

```
ggplot(aes(factor(quality),
           volatile.acidity),
       data = red) +
  geom_jitter( alpha = .3)  +
  geom_boxplot( alpha = .5,color = 'blue')+
  stat_summary(fun.y = "mean",
               geom = "point",
               color = "red",
               shape = 8,
               size = 4) +
   labs(title="Volatile Acidity ~ Quality of Wine")
```



This shows the relationship between volatile acidity and quality. More volatile acidity causes the wine to taste like vinegar. We can see an opposite correlation between volatile acidity and quality.

Bivariate Analysis

Talk about some of the relationships you observed in this part of the investigation. How did the feature(s) of interest vary with other features in the dataset?

As we have discussed earlier there is a strong corelation between perceived quality of the wine and alcohol content and volatile acidity. Unexpected previously there is no corellation between the sugar content and free sulfur level and quality of the wine, I was expecting a relationship between these values.

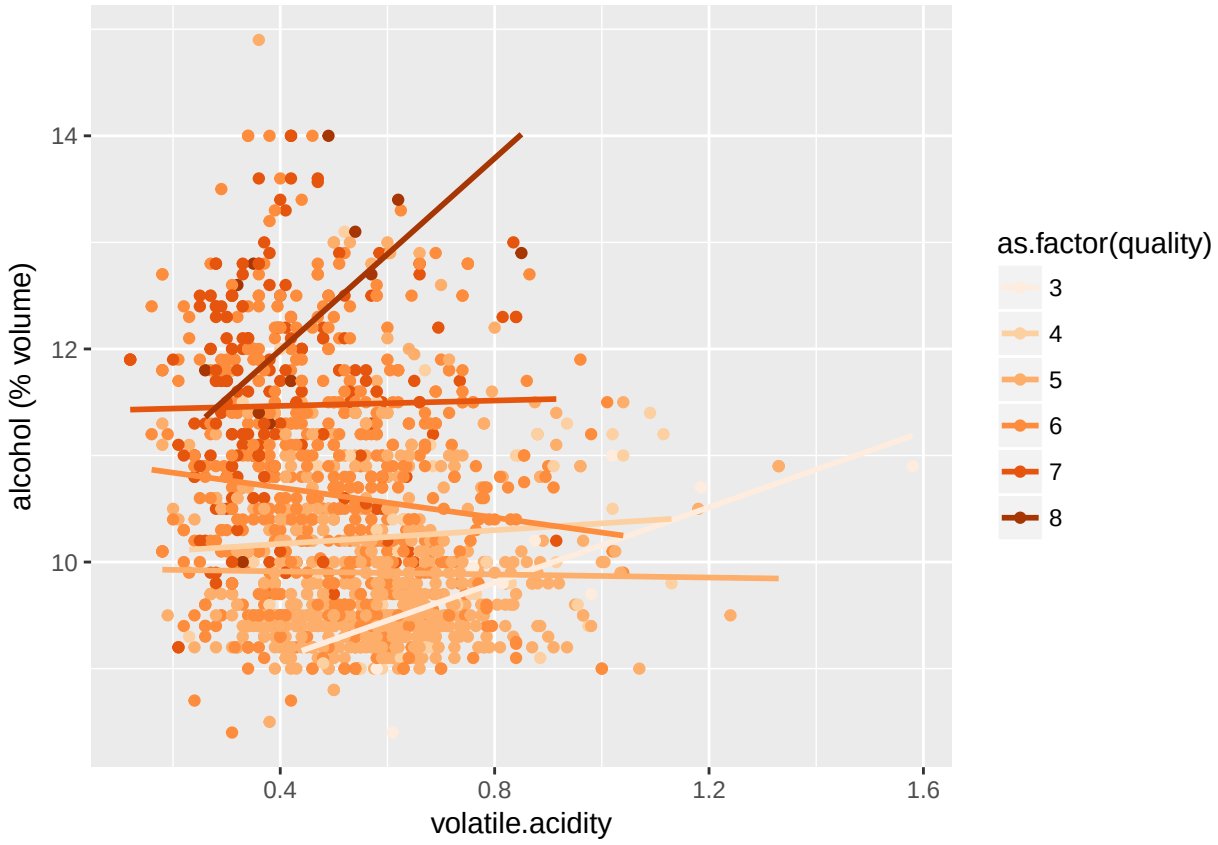
Did you observe any interesting relationships between the other features (not the main feature(s) of interest)?

Here I noted a relationship between volatile acidity, fixed acidity and citric acid level. Citric acid level is positively corelated with fixed acidity and negatively corelated with volatile acidity. So my observation is that wine producers add citric acid to modify their acidity and lowering volatile acidity. But some wine makers cannot do that (as discussed I found out that EU producers cannot use citric acid, it would be good to check this.) Plotting some graphs shows interesting results for wine that doesnot use any citric acid, those are slightly worse in ratings as they contain more volatile acids.

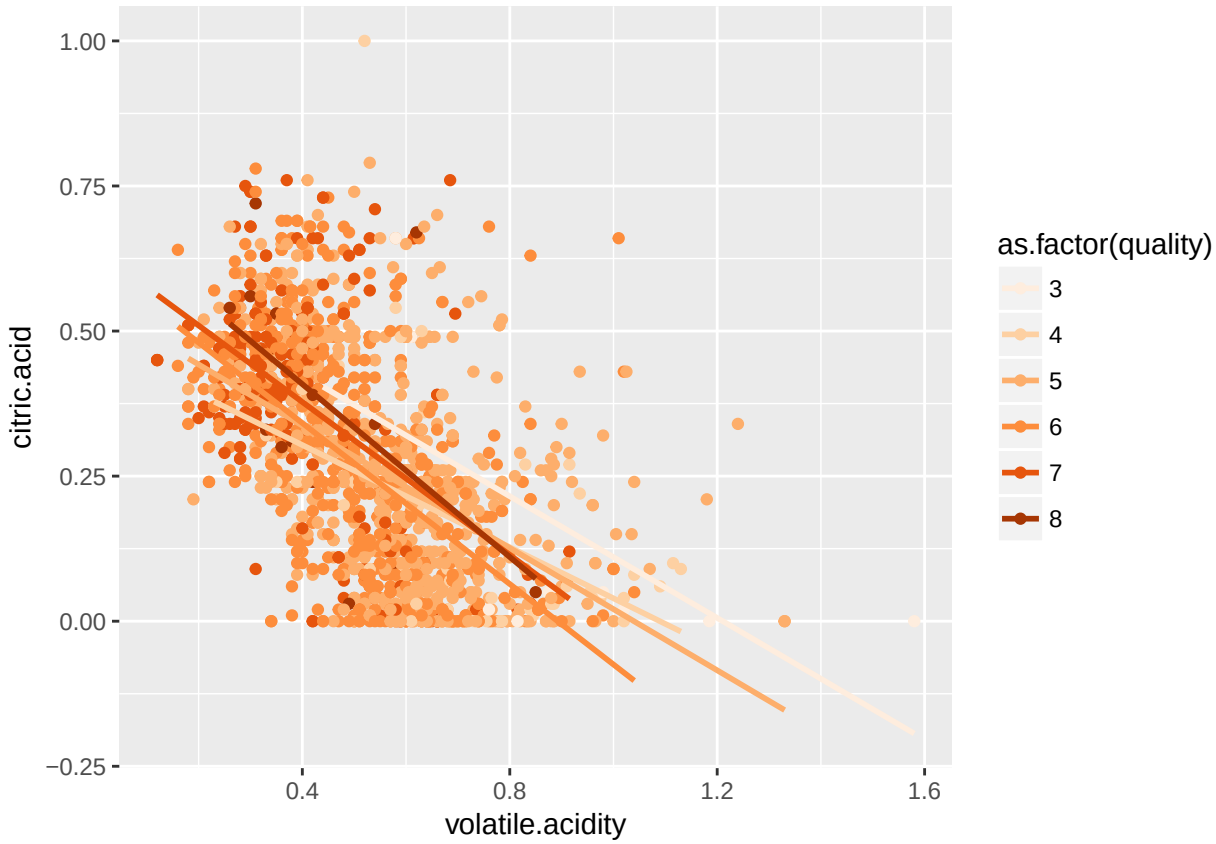
What was the strongest relationship you found?

Strongest relationships are the obvious ones such as pH and acid levels, total sulfur vs free sulfur etc. But there are also some strong relationship that are not that obvious such as alcohol level and volatile acidity levels and quality of wine.

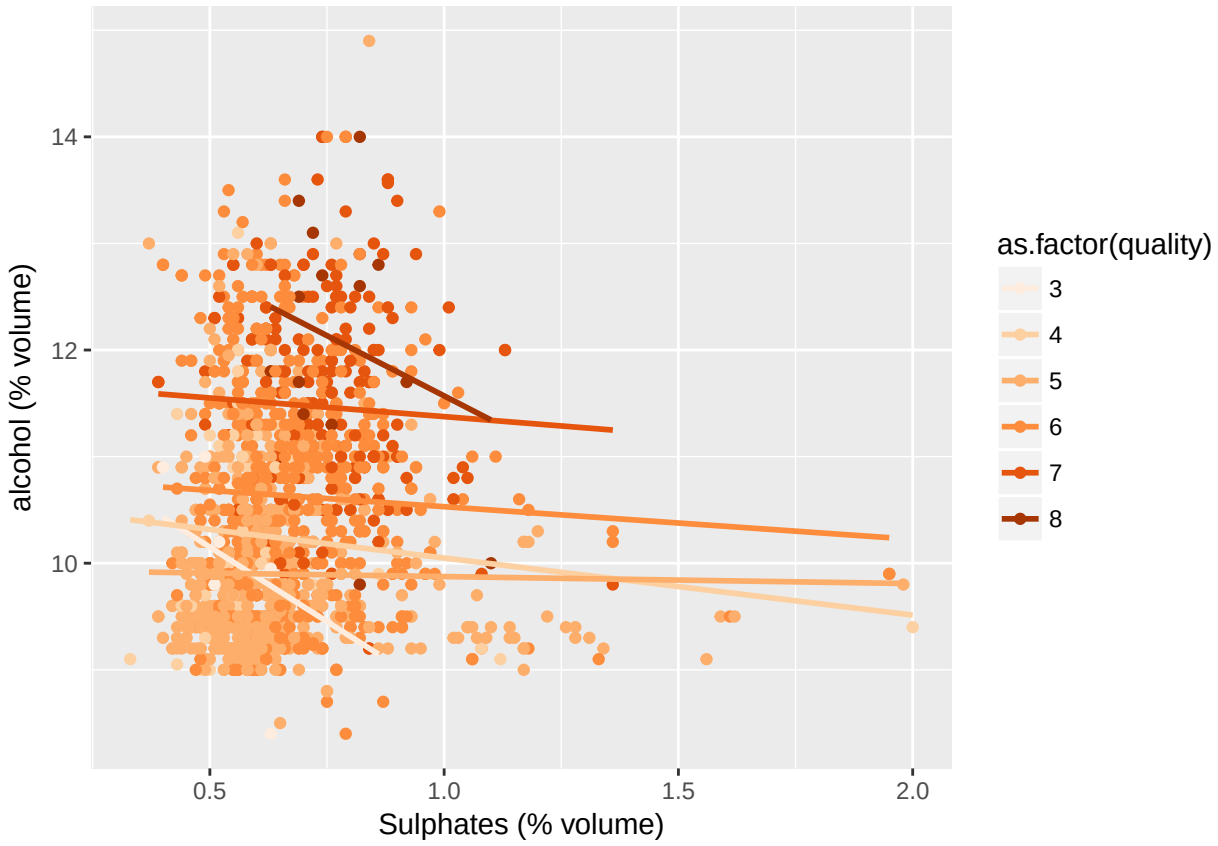
Multivariate Plots Section



I am first inspecting the effect of alcohol and Volatile acidity in quality of wine. These two variables are the ones that have the most correlation value. Alcohol positively correlates with quality of wine whereas, volatile acidity negatively correlates. Plotting the graph we can immediately see the strong relation of alcohol content and quality of the wine as the lines are stacked above each other according to the quality. On the other hand Volatile acidity is more scattered. But it is still possible to see it is negatively correlated with quality of wine, as the lines of better quality wine are located on the left side of the graph. And finally by looking at the graph I though alcohol and volatile acidity levels are positively correlated, but checking the correlations table shows the opposite of this, these two variables are negatively correlated. But at least we can see here for the best quality of wines, there is a strong positive correlation.



Here this time I am looking at the relationship of volatile acidity and citric acid levels with quality of wines. Here immediately we can see a very linear strong negative correlation between citric acid and volatile acidity. And what we can see here again is there are a lot of 0s for citric acid, as it is banned in EU. It is not very clear but we can almost sense the negative correlation of volatile acidity and wine quality as the bands of quality 6, 7, 8 are more to the left of the 3, 4, 5.



The last observation is for alcohol and sulphates. Both have a positive correlation with the quality of a wine. We can see this as the color of dots gets darker as we go towards to the up right corner compared to the bottom left corner.

Multivariate Analysis

Talk about some of the relationships you observed in this part of the investigation. Were there features that strengthened each other in terms of looking at your feature(s) of interest?

These plots strengtened mainly the two topics I have been discussing, quality of wines and effect of alcohol and volatile acidity. And means of acidity (ie. volatile, fixed, citric) and quality. I conclude about the importance of the volatile acidity on the quality. And lastly I have plotted the sulphates and alcohol in a graph to see their effect on the quality.

Were there any interesting or surprising interactions between features?

The interesting conclusion from this study is that, wine is a very complex beverage and there is no easy way to describe what makes a good wine. Playing with the parameters we noted certain correlations but apart from alcohol level and volatile acidity, the affect of others are not so clear.

OPTIONAL: Did you create any models with your dataset? Discuss the strengths and limitations of your model.

So as I discussed earlier I can use these 3 variables, alcohol level, volatile acidity and sulphates. I think these 3 are enough to have a meaningful value to make a linear model. I put the variables in linear model. The results show I have an F value that is greater than 1 so there is a relationship. My r squared value is 0.33 which is not very good but still it show a weak relationship. I wont be spending too much time on this, as this is a topic for later course. And wine quality is a very complicated task to fit into a model.

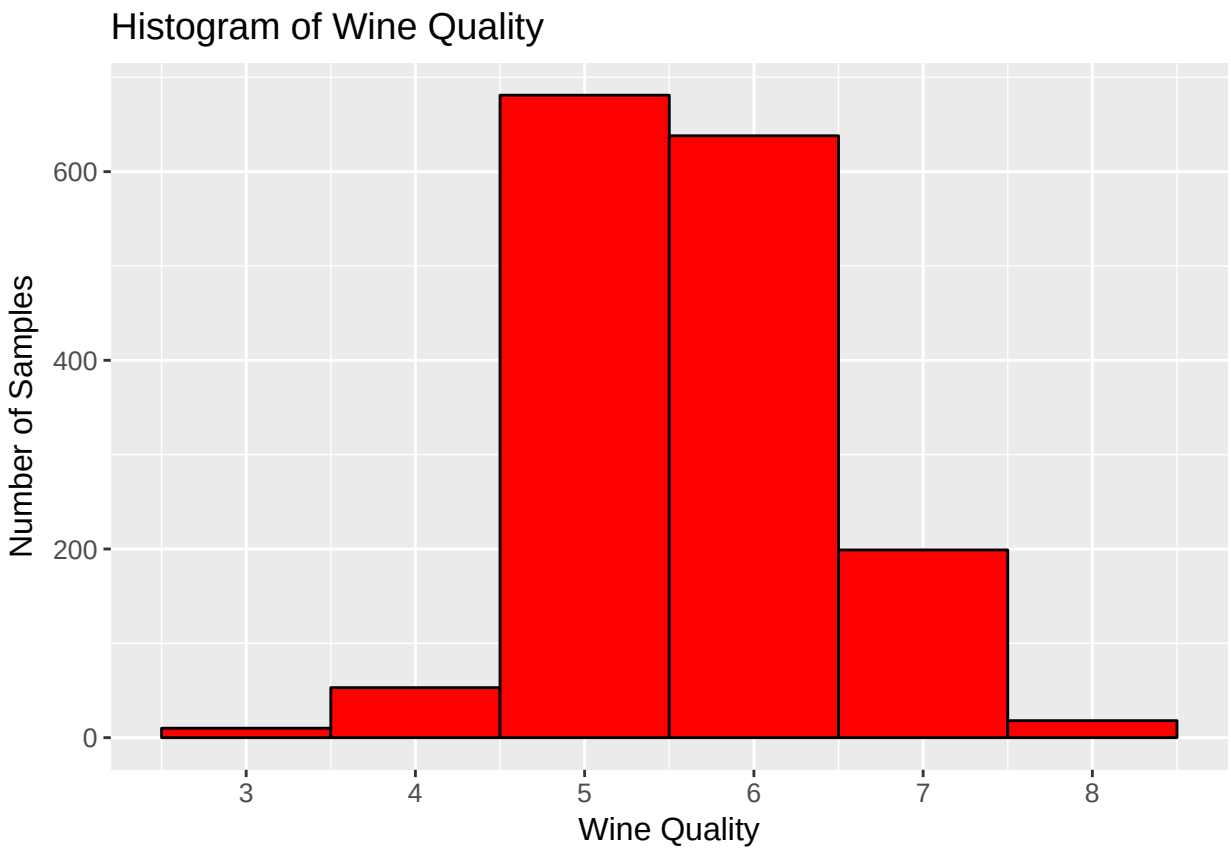
(referrence: https://www.r-bloggers.com/how-to-apply-linear-regression-in-r/)

```
fit <- lm(red$quality ~ red$alcohol
          + red$volatile.acidity + red$sulphates, data=red)
summary(fit)
```

```
##
## Call:
## lm(formula = red$quality ~ red$alcohol + red$volatile.acidity +
##     red$sulphates, data = red)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.7186 -0.3820 -0.0641  0.4746  2.1807
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           2.61083    0.19569  13.342  < 2e-16 ***
## red$alcohol           0.30922    0.01580  19.566  < 2e-16 ***
## red$volatile.acidity -1.22140    0.09701 -12.591  < 2e-16 ***
## red$sulphates         0.67903    0.10080   6.737 2.26e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6587 on 1595 degrees of freedom
## Multiple R-squared:  0.3359, Adjusted R-squared:  0.3346
## F-statistic: 268.9 on 3 and 1595 DF,  p-value: < 2.2e-16
```

Final Plots and Summary

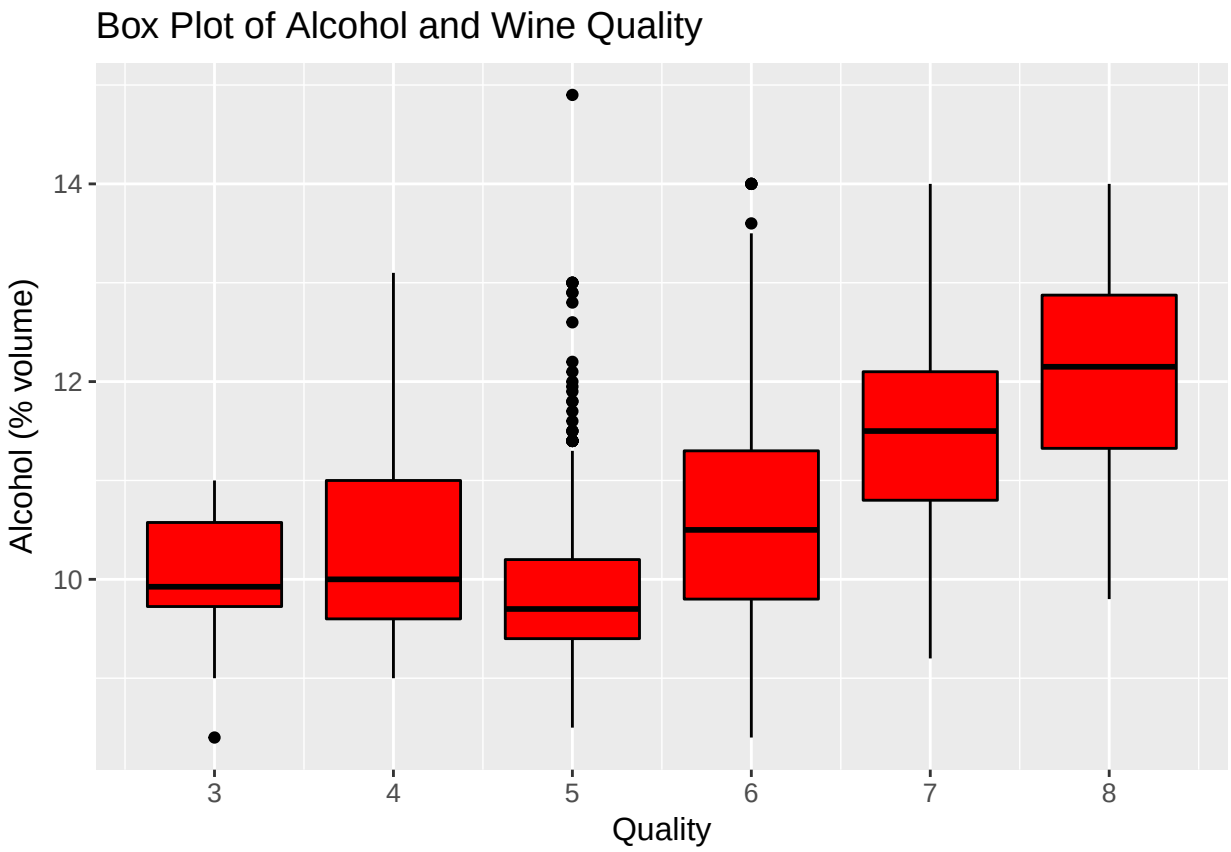
Plot One



Description One

This was the first plot I used in my study, as this is the main aspect that we are studying I put this in the concluding chapter. One can note from this graph majority of the wines are labeled as 5-6 rating whereas low quality or high quality wines are lesser in numbers.

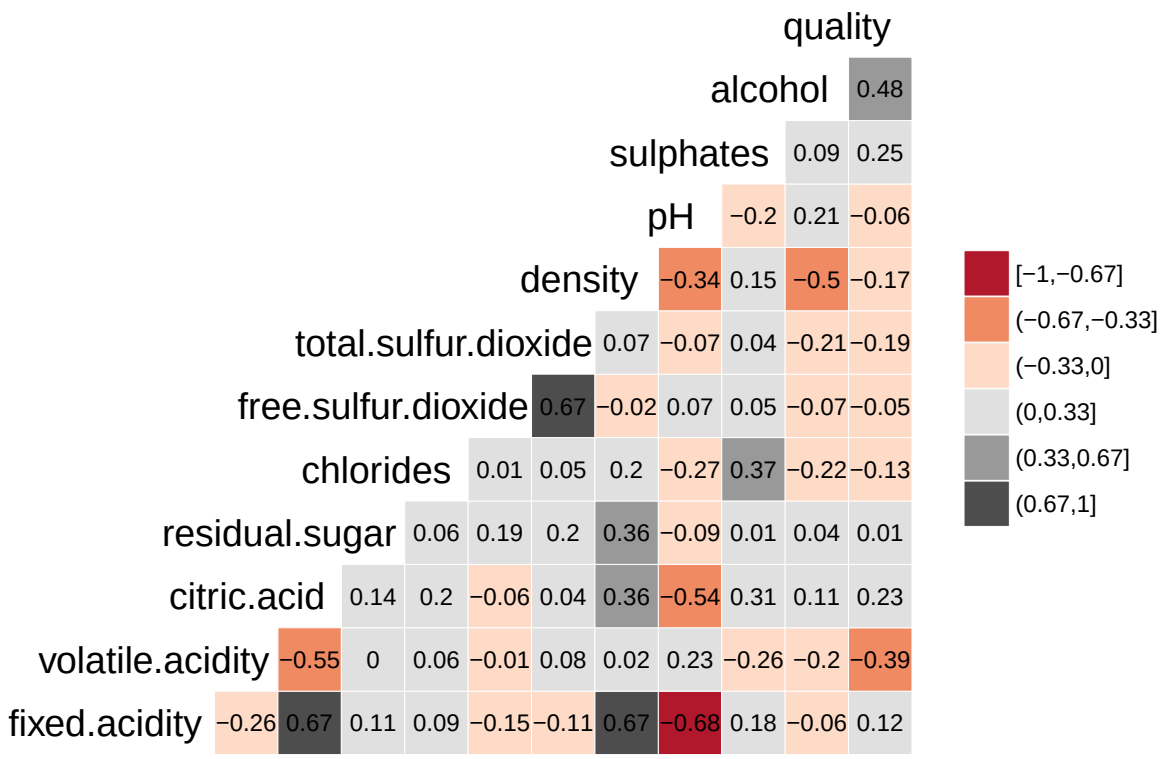
Plot Two



Description Two

Alcohol is strongly correlated with wine quality especially on the better wines (Quality 7-8). This graph is showing this relationship. What I note is the interesting case of wines with rating 5. They are the ones with the lowest mean.

Plot Three



Description Three

Here I put this plot as this summarises all the correlation of different parameters in one plot. There are some interesting things to note. At the start of the study I was certainly expecting some correlation between quality and residual sugar. But this plot and my previous examinations dont show any correlation. Also here it is easy to see the relationship between all the acidity parameters.

Reflection

This was a very interesting study and it gave me a good chance to practice all the functions I learned from R environment. Also I had a chance to learn about red wines which will probably make me appreciate more of the taste of red wine next time. There were some obvious outcomes and not so obvious ones for me as well. The level of alcohol and quality of the wine was surprising for me. I was even expecting the opposite as I think the more alcohol in the wine it would me more “bitter”.

The relationship of volatile acidity and quality of wine is less suprising. As generally people dont like the vinegar taste of the volatile acids.

This study can be extended with the addition of location of the wine, year it has passed and it is fermentation process as the other parameters would probably be more useful. Such as less sulphates can make wines more susceptible to become faulty.

Some hardships I had during this study is about the legends and axis, I sometimes find it difficult to arrange the axis such that the information is readable. But in general I find this study, quite successful, as I was able to identify at least some parameters effecting wine taste, and maybe next time I am enjoying my wine I will appreciate more.

Resources

https://en.wikipedia.org/wiki/Acids_in_wine
https://en.wikipedia.org/wiki/Wine_fault#Acetic_acid
http://www.minitab.com/en-us/Published-Articles/Wine-Tasting-by-Numbers--Using-Binary-Logistic-Regression-to-Reveal-t
https://briatte.github.io/ggcorr/