Analytical examination of dealcoholized wines

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Abstract. The demand for dealcoholized wine has been steadily increasing in recent years. Moreover, the attention for such products is probably increasing even more. More producers are seeking to participate in the marked to dealcoholized wine. Due to that increasing demand and market awareness the different legal authorities are also discussing the regulation and harmonizing of rules, for those products. However, there is a lack of precise data on how to analytically describe these products on the market. To this end, the present study examined 200 commercial dealcoholized wines and their carbonated variants on the basis of key enological analytical parameters (acidity, density, extract, glycerin, exact alcohol content, etc.). This work aims to help understand the specific characteristics of dealcoholized wines that are currently found on the major wine markets.

1 Introduction

The awareness and interest for dealcoholized wine (<0,5% v/v) is rising globally within recent years. The process of dealcoholizing wine is, nevertheless not a very new topic. There is e.g. a production of dealcoholized wine for more than 110 years in Germany. But also, in other countries, dealcoholized wine was produced for long time as a niche product. Due to the increasing demand and interest, more and more companies are starting to produce and market such products. Therefore, the need for specific advice on the optimization and tuning of such alcohol-free wines is increasing. The process of dealcoholization can be carried out by several physical processes based either on membrane processes or on distillation technology [27,31].

Dealcoholization by membrane processes can be carried out by osmotic distillation, pervaporation, dialysis or reverse osmosis in combination with another separation process such as osmotic distillation or by thermal distillation.

The dealcoholization of wine is so far mainly based on continuous distillation that is usually performed under vacuum. Due to that, the process can take place under moderate temperatures, usually between 30 and 40°C. The dealcoholization via continuous counter-flow distillation (vacuum rectification or Spinning Cone Column process) allows very short processing times of 1-2 min [31]. Even though the different technologies aim to gently remove the ethanol from wine, the process goes along with certain aroma losses [6,7,18] Here modern aroma recovery systems can help to reduce the aroma losses during processing [3]. While reducing the alcohol to a content lower than 0,5% v/v, there is a concentration effect of approximately 1,1% per 8 g/L that is removed. The dealcoholization of wine goes along with 15-20% compared to the initial volume before processing [32].

Besides aroma losses, the dealcoholization means a significant change in sensory characteristics due to the absence of ethanol [10].

Ethanol is number-wise, the most important volatile component found in wine.

The effect of ethanol on the sensory characteristics of wine is far ranging, complex and partly controversial. Ethanol, or generally speaking alcohol affects gustatory, olfactory and trigeminal stimulating properties [15,39,40]

Ethanol has a direct effect on the perceived sweetness in wine. An increase in the alcohol content causes a higher sweetness perception of the corresponding wine [19,24,27,41]. Due to reducing the alcohol content, the perceived sweetness is reduced as well [10]. Acidity perception in wine is reduced with increasing alcohol level [10]. Due to that, wines with reduced alcohol content are perceived being more acidic [21,31]. Alcohol creates, up to a certain level, a heat feeling in the wine, which can lead up to burning sensation [12,14]. Alcohol enhances the sensory parameter "body and fullness" in wine [1,14,40]. The intensity of that effect depends on the individual wines' matrix. The following literature sources point out that body and fullness in wine are only slightly altered by the alcohol content [24,28,30].

An elevated body and fullness in wine is mainly seen positive by consumers and leads to elevated preference and willingness to pay [35]. On the other hand, elevated ethanol content positively correlates with bitterness in wine [2,11,20,23,24]. The perception of astringency in wine, decreases with increasing alcohol content [11]. Furthermore, ethanol negatively correlates with the perception of "fruitiness" in wine. This goes back to the masking of several esters [9,13].

Senseful enological interventions can help to buffer and balance the severe changes in the sensory perception of wine after dealcoholization and thus improving the quality and acceptance of these products.

2 Material and methods

200 commercial dealcoholized wines were collected at an international wine competition by Meininger Verlag in Neustadt/Germany in July 2022. Sampling was performed immediately after opening the commercial wines into sterile 50ml containers. These were immediately transported refrigerated to the Department of Beverage Research of Geisenheim University. In order to avoid microbiological contamination of this very fragile products, all the samples were then analyzed within the following 2 days.

At this time dealcoholized wine was still handled as a part of German food law. The nutrient labeling and indication of ingredients on the back label were mandatory for all samples. One fifty seven out of that amount were dealcoholized wines and 43 were carbonated /sparkling products with a CO2 content of more than 3g/l up to sparkling wine like ranges of more than 10g/L (at 20 °C).

The 200 products claimed different countries as their origin: Germany (*n*=124), France (*n*=32), Spain (*n*=19), Italy (*n*=6), Australia (*n*=3) and Austria (*n*=3). 13 Samples nevertheless, did not indicate their origin. The majority of the analyzed wines were white (*n*=112). Red (*n*=38) and rosé wines (*n*=55) counted for less than the half of the samples.

The information on the labels of each bottle were also collected. Therefore, each bottle got photographed in a professional photo-chamber (Orbitvu, Alpha Shot xl, Berlin, Germany).

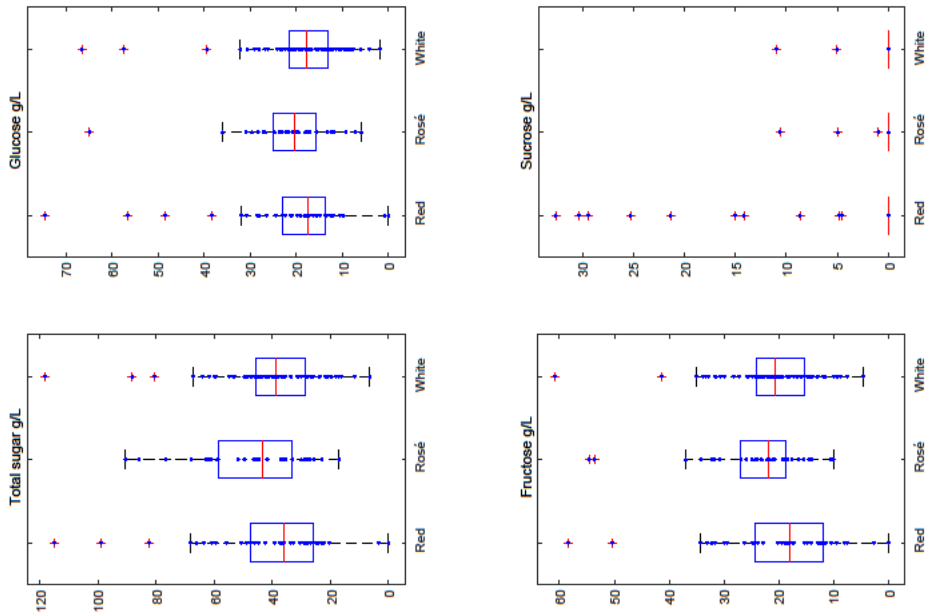
Chart 1. Analytical parameters and method of analysis.

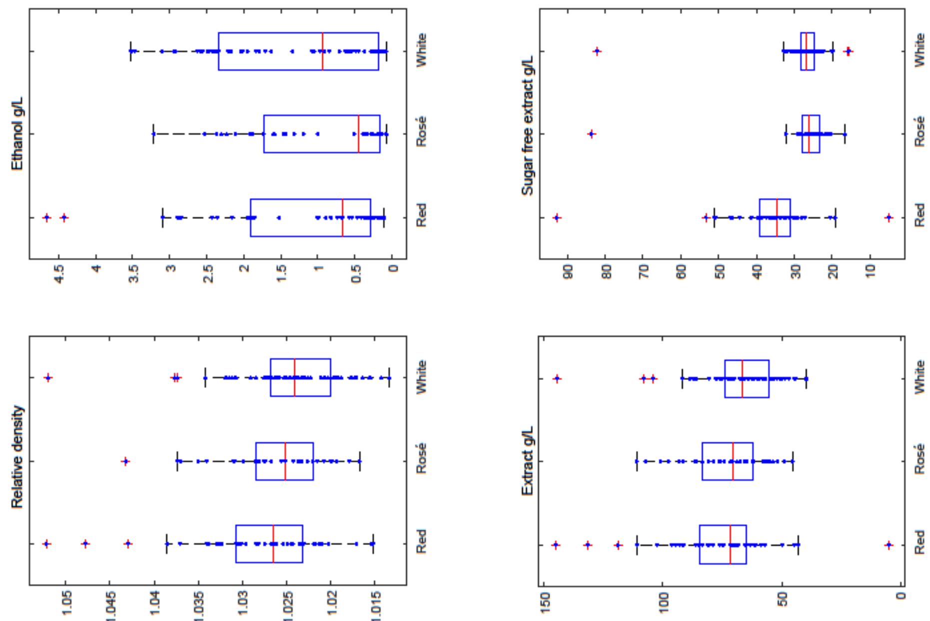
Parameter	Method
Density	Oscillating tube density meter
Ethanol	Enzymatic analysis
Extract	FTIR
Sugar free extract	FTIR
Total sugar	FTIR
Glucose	FTIR
Fructose	FTIR
Sucrose	FTIR
Total acidity	FTIR
pH	FTIR
Tartaric acid	FTIR
Malic acid	FTIR
Lactic acid	FTIR
Volatile acidity	FTIR
Citric acid	FTIR
Glycerin	Enzymatic analysis

The density measurement of the samples took place my oscillating u-tube density meter according to OIV standards (OIV-MA-BS-06). The enzymatic analysis indicated in chart 1 were conducted as described by Weber et al. 2004 [38] via the automated analysis system Winechem 600 (KPM Analytics/Westborough/United States) with corresponding test kits from R-Biopharm (Darmstadt/Germany). The other parameters were measured by Fourier Transform Infrared (FTIR) by Winescan ™ SO2 Foss instrument equipped with Foss Integrator software (Foss, Hillerød, Denmark).

3 Results and Discussion

The dealcoholization of wine goes along with certain concentration effect for the non-volatile components. The analysis could show that certain parameters were typical for certain types of dealcoholized samples.


Glucose g/L
Sucrose g/L
Total sugar g/L
Fructose g/L
Red
Rosé
White


Ethanol g/L
Sugar free extract g/L
Relative density
Extract g/L
Red
Rosé
White

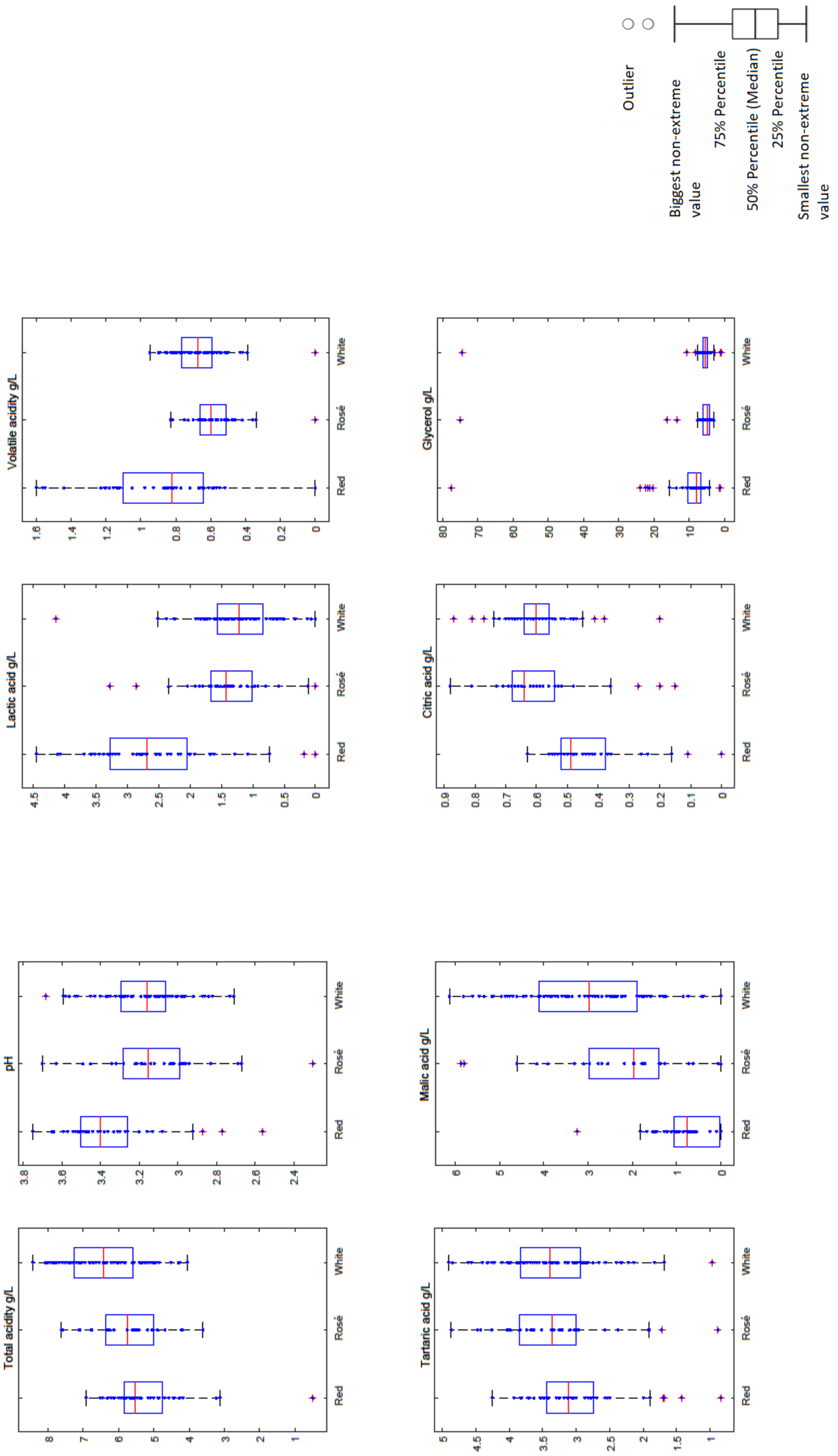
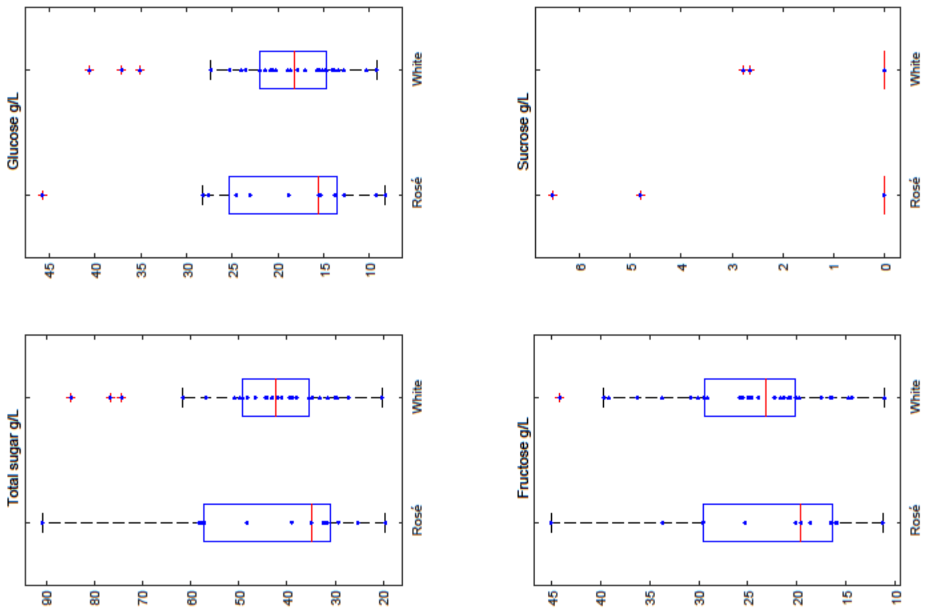
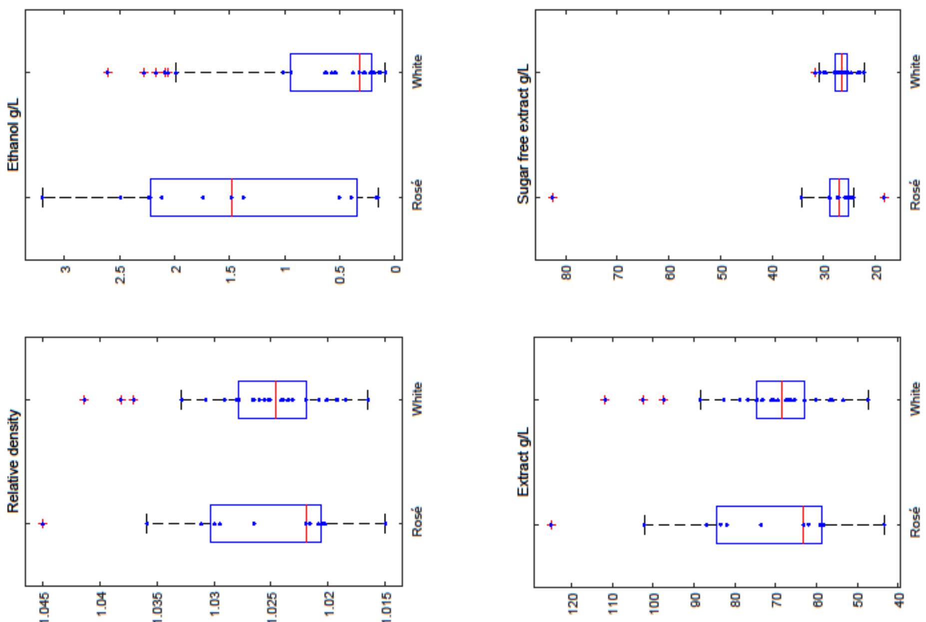


Figure 1. Analytical parameters of dealcoholized still wine (<2 g/L CO_2) according to wine color (*n*=157).


Glucose g/L
Sucrose g/L
Total sugar g/L
Fructose g/L
Rosé
White


Ethanol g/L
Sugar free extract g/L
Relative density
Extract g/L
Rosé
White

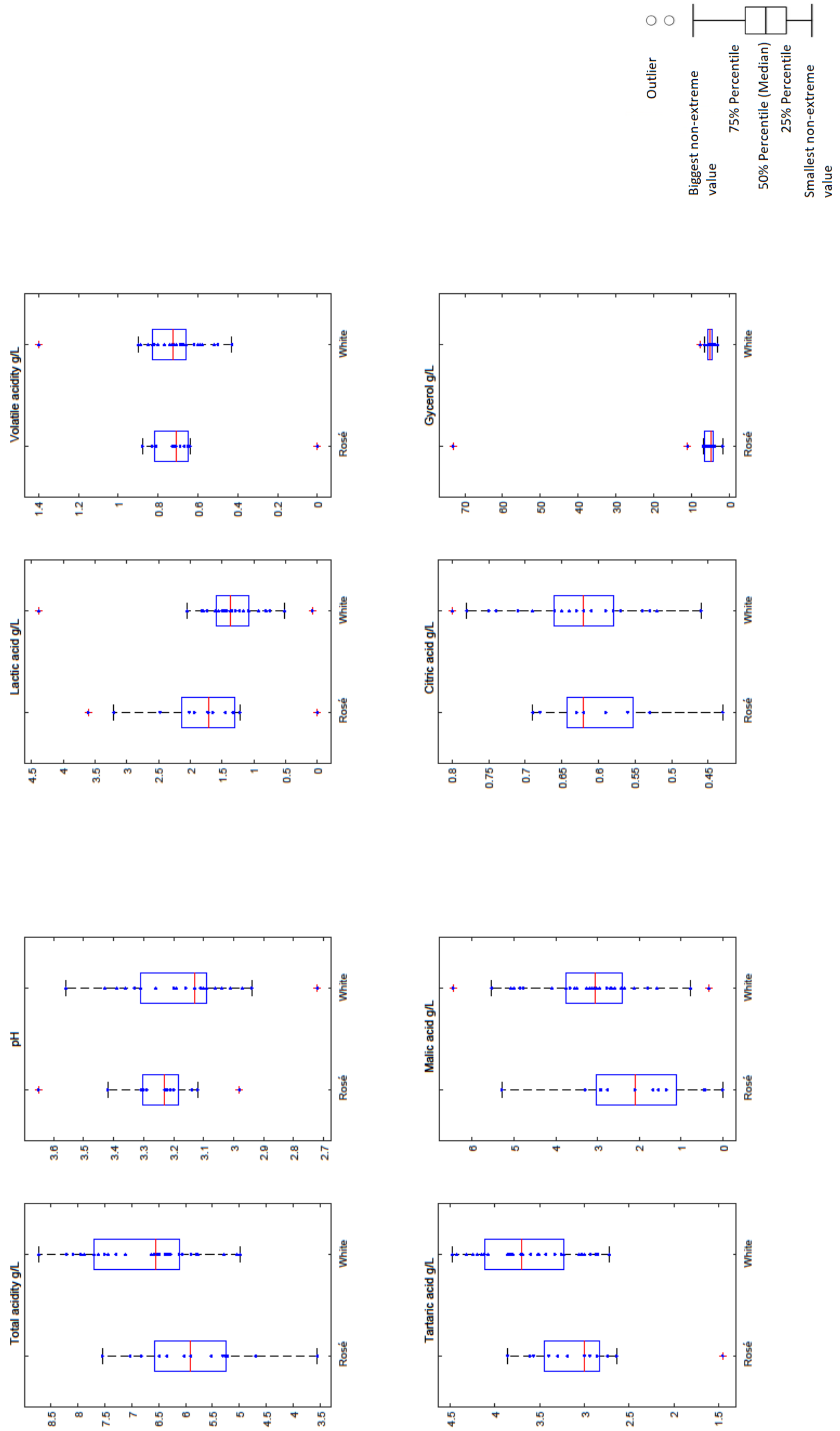


Figure 2. Analytical parameters of dealcoholized wines carbonated (sparkling) to more than 3,5 g/L of CO_2 according to wine color (*n*=43).

The analysis of the dealcoholized still wines showed in general that the relative density was clearly above 1,000. This is to be explained by the increase in density due to their removal of alcohol and the concentration effect of the wine [26,31] Furthermore, the elevated residual sugar levels proof the density values in the range shown in Fig. 1.

The measured alcohol levels were, with two exceptions, all below the legal value of 0,5% v/v. The two samples above this legal value, had with 4,66 g/L and 4,42 g/L a bit more alcohol than legal. This point out, that accurate alcohol analysis at such low levels requires a sound and very precise method, to avoid unintentionally exceeding of the legal limits.

The extract values presented in Fig. 1 show, similar to wine with normal alcohol values, higher numbers for red and rosé wines than for white wines. Nevertheless, there are some samples with values clearly above 100 g/L. The values for the sugar free extract were, due to the generally high sugar levels, clearly reduced. Sugar free extract is generally seen as an analytical parameter for wine authenticity. Wines with values of 18 g/L and less are often seen as poor in quality. The extremely low values of 5 g/L found in two red dealcoholized wines, could indicate a dilution with water. On the other hand, there were also samples with values in terms of sugar free extract of 82 and 92 g/L. These extremes clearly differ from the range in different wine styles for sugar free extract presented by Patz et al. 2004 [25].

The total sugar contents shown in Fig. 1 indicate a generally higher value for dealcoholized wines compared to wines with a common alcohol content. The majority of samples for red, rosé and white wines shows levels of more than 25 g/L. These generally elevated numbers indicate the sensory effect of dealcoholization and the reduction in sweetness going along. By reducing approximately 100g/L of alcohol a certain amount of sugar is needed to overcome the changed sensory profile in terms of sweetness perception. Furthermore, sweetening can help to substitute the lack alcohol in terms of perceived body and fullness in wine [33].

Glucose and fructose were found at nearly similar values in the different wine colors shown in Fig. 1. This indicated that the high residual sugar is not based on stopped fermentation of the initial wine before dealcoholization. As this would have shown higher fructose values than glucose values in the samples.

It is common to sweeten the dealcoholized wines after the treatment and short time before bottling, to avoid unnecessary microbiological spoilage, as dealcoholized wine is very susceptible to reinfection by yeast or bacteria [22].

The choice of the source for the residual sugar can furthermore play and fundamental role in creating a certain style and in terms of consumer preference [33]. While adjusting the residual sugar level in such products, rectified grape must concentrate and sucrose showing less dilution effects, than sweetening with unfermented grape must. Sucrose was found in red, rosé and white wines in values up to 32,6 g/L.

In addition to that, that sucrose turned out as preferred sweetening method in sensory studies in terms of with dealcoholized white wines [33]. Besides that, is also a very convenient and economically favorable solution to adjust the residual sugar in such products.

The total acidity in wine in ranges widely depending on the variety, the origin and the wine style. Figure 1 shows that the acidity content in the dealcoholized white wines was generally higher than the content of dealcoholized red and rosé wines.

As the dealcoholization process generally goes along with a concentration of non-volatile components, such as acids, it is obvious that the general differences between red and white wines in terms of acidity does not change. As the dealcoholization of wine increases the sensory perception of acidity/sourness [21,31] it is necessary to select and adjust wines for dealcoholization with regard on that parameter as well. So, the acidity value of the initial wine before dealcoholization should have generally lower acidity values than the corresponding wine style with normal alcohol content.

The pH was generally higher for the red dealcoholized still wines compared to the rosé and white wines. The wide majority was in the wine common range between 2,8-4,2 [29]. Nevertheless, in case of red wines some samples showed untypically low values with 2,3 and 2,7. This could be the result of ion-exchange treatment to increase the acidity.

The values for tartaric acid shown in Fig. 1 were generally lower in terms of the red wines compared to the rosé and white wines. The malic acid contents were clearly lower for red wines than the rosé and white wines. So, it is indicated that the majority of the red variants went through partial or complete malolactic fermentation. This is in line with the values of lactic acid for those samples. The red wines show clearly higher values of mainly between 2 and 3,3 g/L.

The volatile acidity values shown in Fig. 1 indicate generally higher values for the red wines than for the rosé and white wines. This is in line with general observations of these wine styles at normal alcohol ranges. The dealcoholization is not going along with a loss of volatile acidity [31], but the dealcoholized wine is very susceptible to microbiological spoilage, than can lead to an undesired increase of volatile acidity. The sensory threshold in terms of volatile acidity is dependent on variety and wine style [8,29]. Further research should show the specific sensory effect of volatile acidity on different dealcoholized wines and how it can influence the sensory perception.

Citric acid in wine usually ranges between 0,5 and 1 g/L Red wine samples shown in Fig. 1 were generally lower for the red than for the rosé and white wine samples.

Glycerin is found in wine usually in ranges between 5 and 20 g/L [29]. The investigated red wine samples were in general higher terms of glycerin content, than the rosé and white wines. Some extreme deviation was detected within the set of samples. Values of more than 70 g/L clearly indicate that an addition must have taken place.

Figure 2 shows the results of the products which were spiked with CO_2 by more than 3g/L ("sparkling"). The density measurements shown in Fig. 2 are similar to the results of the dealcoholized samples presented in Fig. 1. Due to the reduction of alcohol and the elevated levels of residual sugar, the values are generally above 1,000. The alcohol content measured on the corresponding sparkling samples are clearly below the legal threshold for dealcoholized products. The majority of samples was furthermore clearly below 1,5 g/L. Some samples were even below 0,4 g/L which is necessary for the declaration as Halal or similar labels, that should proof minimum alcohol levels. The levels for extract and sugar free extract were in general comparable to those shown in Fig. 1. The extreme value of sugar free extract above 80 g/L found in a rosé sample is to be explained by a corresponding glycerin level of 77,6 g/L which indicates a targeted addition. The total sugar levels in Fig. 2 differ from rosé (*n*=13) to white samples (*n*=30). More than half of the rosé samples had values lower than 33g/L. This could be related to the target labeling according to sparkling wine classification as dry (32 g/L). The white samples presented in Fig. 2 are similar to those in Fig. 1. The majority of samples showed values above 40 g/L of residual sugar. Carbon dioxide in elevated values can reduce the sweetness sensation of a beverage [5,34]. This could help to explain the elevated sugar in the dealcoholized products with CO_2 levels of 3g/L and more. Besides sugar CO_2 appears very suitable to re-balance the wines after dealcoholization. Sucrose was just found in four out of 43 sparkling samples. In those four cases, sucrose was found in addition to fructose and glucose to sweeten the products.

The acidity values of the majority of dealcoholized white and rosé "sparkling" products shown in Fig. 2, are slightly higher than those of the corresponding groups shown in Fig. 1. As the addition of CO_2 is causing elevated acidity perception [16] as well as the dealcoholization, those "sparkling" products are showing slightly higher values mainly between 4,9-7,2 g/L.

The pH measurements shown in Fig. 2 are comparable to those presented in Fig. 1. As the dealcoholization of wine is not causing significant changes in the pH [17], values outside the common range between 2,8 and 4,2 should not be expected.

The numbers for tartaric and malic acid shown in Fig. 2 are within the usual range of wine. The lactic acid values for the white and rosé "sparkling" products indicated that the majority of those wines went through malolactic fermentation.

The citric acid values shown in Fig. 2 are in a similar range as found in Fig. 1. There was no sample that exceeded the legal threshold of 1 g/L.

The glycerin contents for the white and red dealcoholized samples shown in Fig. 2 are mainly in the typical range for glycerin. The exceptionally high value above 70 g/L found in a "sparkling" rosé sample, could indicate an addition with the aim of improving mouthfeel and body sensation. In a former study the author could show that an addition of 10 g/L of glycerin did not alter significantly the mouthfeel of a dealcoholized white wine [33].

The investigation of the information on the label of the commercial dealcoholized wine provided important further information about additives used and the labeling for the consumer.

All investigated sampled (*n*=200) showed the declaration of the ingredients on back label, as this was the legal issue at the time the samples were collected (in 2022). All samples indicated dealcoholized wine as an ingredient on the back label. Furthermore, all investigated samples mentioned SO_2 as ingredient. Even though the anti-microbiological effect of common SO_2 dosages is not sufficient to guarantee the microbiological stability of such products [32], the producers seem to use the other effects of SO_2 for their dealcoholized wines. Ascorbic acid was found on 34 of the 200 products.

Sorbic acid, used as preservative against yeast, was found in 34 out of 200 samples.

Dimethyl dicarbonate (DMDC), a conservation product that was at the time of the sampling not legally restricted to be labeled, was nevertheless mentioned on 3 of the investigated samples.

The declaration of alcohol was found on the label either as "<0,5% v./v." (*n*=35) or as 0,0 (*n*=35). The majority of samples were not indicating the alcohol level and just indicating the dealcoholized status (*n*=130).

34 of the samples were labelled as organic and 66 as vegan. Two samples mentioned "Halal" on the label. Market research indicates that many of the consumers of dealcoholized wine have a health oriented life-style. This could be the reason why the producers of such products seem to label such information. Further consumer studies should help to better understand the specific consumer expectations towards such products.

The majority of samples (*n*=142) were indicating CO_2 as ingredient on the label. Even red dealcoholized were found that indicated CO_2 addition Besides the 43 "sparkling" products with more than 3g/L added, many wines got smaller additions of CO_2. Due to its sensory characteristics in terms of mouthfeel [4], CO2 appears a suitable strategy to buffer the missing alcohol in dealcoholized wine.

All investigated products had residual sugar levels of more than 10 g/L. In terms of sugar sources, sucrose (*n*=97) was the most often used form for sweetening followed by grape must (*n*=77) and rectified grape must concentrate (*n*=51). Some samples used several sugar sources to adjust sweetness. In general, the 200 samples showed elevated sugar levels (average above all products 43 g/L), none of the samples indicated the sugar level on the label, as it is usually found for wine or sparkling wines.

Five samples listed gum Arabic on the label. This product is used in terms of colloidal stabilization of white and rosé wines and to avoid pigment precipitation in red wines [36,37]. The impact on taste characteristics is, nevertheless not absolutely clear, especially when it comes to dealcoholized wines.

4 Conclusion

Dealcoholized wine is intensively discussed in many fields worldwide. The current study could help to understand better these products. The analytical parameters shown deliver an oversight of that products and how producers try to buffer the fundamental changes that are going along by the dealcoholization procedure. The investigated samples show generally elevated sugar levels that are going back to a sweetening procedure after dealcoholization. Sucrose was the most commonly used sweetening method here. Furthermore, the majority of samples indicated CO_2 additions.

Sweetening combined with CO_2 addition can be considered as essential oenological strategies for sensory tuning of the studied dealcoholized wines.

Further examination of the ingredient statements of the dealcoholized wines showed no clear trends toward other oenological preparations.

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