Strategies for the sensorial optimization of alcohol-free wines

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Abstract. De-alcoholized wines are currently experiencing an increasing demand, but are also being discussed very controversially at this time. The de-alcoholization process is usually carried out by distillation processes under vacuum. The treatment is accompanied by a series of changes in terms of analytical and sensory parameters of the wines. Ethanol has a very complex and far ranging influence on the wine sensory character. Even more, the de-alcoholization process goes along with certain losses of aroma components. Several strategies were assessed to buffer and balance the effect of de-alcoholizing wines below 0.5% v/v. Compared to the addition of tannins and mannoproteins, sweetening showed clearer results on the panelist's preference. The assessment of a commercial resin treatment to recover aroma from de-alcoholization process showed promising results.

1 Introduction

The interest and demand for alcohol free wine (<0.5% v/v) is globally rising withinrecent years. The production of de-alcoholized wine is, nevertheless not a very new issue. There is e.g. a production of de-alcoholized wine for more than 100 years in Germany.

The de-alcoholization process can be carried out by several physical processes based either on membrane technology or on distillation processes [19, 22]. In terms of membrane processes, the de-alcoholization can be carried out by osmotic distillation, pervaporation, dialysis orreverse osmosis in combination with another separation process like osmotic distillation or thermal distillation. In comparison to the initial wine, de-alcoholized wines are usually coined by clear changed sensory characteristics due to the absence of ethanol.

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

The influence of ethanol on the sensory properties of wine is very complex and partly controversial. Alcohol affects gustatory, olfactory and trigeminal stimulating properties [11, 26, 28].

The direct sensory influence of ethanol is sweetness and the higher the content in wine, the more the sweetness perception of wine is increased [14, 18, 24, 29]. The perception of acidity in wine is reduced with increasing alcohol content [6]. Consequently, wines with reduced alcohol content appear more acidic [16, 22]. Alcohol creates, up to a certain degree, a warm sensation in the wine, which can lead up to burning sensation [8, 10]. Alcohol enhances the sensory descriptor of body and fullness in wine [1, 10, 28]. The extent of that effect depends on the individual wines' matrix. Following literaturesources point out that body and fullness in wine are only slightly altered by alcohol [18, 20, 21]. Especially the attribute of body and fullness is mainly seen positive by wine consumers and leads to elevated liking and willing ness to pay [25].However, with increasing ethanol content, the bitterness of wine increases [2, 15, 17, 18]. The perception of astringency in wine, decreases with increasing alcohol content [7]. Furthermore, ethanol can reduce the perception of "fruitiness" in wine by masking the perception of esters [5, 9].

Due to the wide range of changes in the sensory perception of wine, targeted enological strategies could help to balance the alcohol-free products after the de-alcoholization process and overcome negative quality perceptions.

The de-alcoholization of wine is mainly based on distillation that is usually performed under vacuum. Due to that, the ethanol separation can take place under moderate temperatures of 30-40°C. In addition to that, the de-alcoholization is usually performed by continuous counter-flow distillation (vacuum rectification or Spinning Cone Column process). This allows very short processing times of 1-2 min [22]. Even though the different technologies aim to gently remove the ethanol from wine, the process goes along with certain aroma losses [3, 4, 13, 23].

2 Material and methods

As basis for the trials on sensory optimization a Rheingau Riesling from vintage 2019 of the Hochschule Geisenheim University's winerywas de-alcoholized at a commercial service provider in Rüdesheim am Rhein. The de-alcoholization was done by vacuum rectification as explained in [23].

The de-alcoholizedwine was then transported back after the treatment to Geisenheim University for bottling on the same day. The wine was adjusted in free sulphur to 35mg/l and bottled then by filtering the wine through sheets before (Seitz EK1, Pall Filtersystems GmbH, Bad Kreuznach, Germany).

Prior to the tasting sessions the de-alcoholized wine was spiked with different enological products to replace and buffer the absence of ethanol. In pre-trials on basis of the alcohol-free wine, two different enological tannins were selected for showing best results. A grape tannin (Tannivin Grape, Erbslöh, Geisenheim, Germany) was added in a concentration of 5 g/hl.An oak tannin (Tannivin Superbe, Erbslöh, Geisenheim, Germany) was added in a range of 2.5 g/hl. Another sample was spiked with 30 g/hl of mannoprotein (Manno Complexe, Erbslöh, Geisenheim, Germany). A further sample was combining a dosage of mannoprotein and grape tannin in the same concentrations mentioned before. In order to buffer the elevated acidity perception of the de-alcoholized samples, a set of samples was treated by chemical de-acidification by potassium hydrogen carbonate to reduce the total acidity by 1g/l.In order to assess the potential of residual sugar on improving the perception of de-alcoholized wine, adjustments were done to different sweetness levels by adding 10, 20, 30 and 40 g/l of sucrose. The de-alcoholized wine also got a sugar addition of 30 g/l with different sweetening methods (Sucrose, Fructose, Glucose and unfermented must) to determine the preferred sweetening method. The must used for sweetening was a 2020 Riesling with a sugar content of 198 g/l. This must was stored until use under sterile conditions in a pressure tank with of 15 g/l of CO_2. Before using it for sweetening it was properly degassed.

Sensory evaluation took place during 3 different tasting sessions by an experienced panel group consisting of 22-28 students and staff member of Hochschule Geisenheim University.

In a first session several ranking tests were performed according to the individual taster's preference.

For the tasting sessions, the panelists were trained on the attributes mentioned in Table 1.

Table 1. Attributes and reference standards.

Attribute	Training standard
Apple	Apple skin in wine
Citrus	Citrus peel in wine
Peach	Peach aroma (Wild/Heidelberg/Germany)
Body/Fullness	6 g/l Glycerin added to wine
Acid	Wine de-acidified by 1.5 g/l with calcium carbonate
Bitterness	1 g/l caffeine added to wine
Sweetness	5 g/l sucrose in wine
Cooked vegetables	French bean in wine

The different tasting sessions took place in a well-lit and neutral room for sensory evaluation with 30 individual tasting booths according to ISO 3501. The wine samples were coded with a randomized three-digit code and cooled at 14°C. The tasters recorded their results by electronic questionnaires on PC through the Fizz (Biosystems, Couteron, France) computer program (version 2.51). The statistical data analysis was performed afterwards with this system as well.

Wine analysis was performed by NMR technology as described in [27].

In addition to the sensory tests with oenological preparations, a new commercial application for the recovery of aromas from spirit fractions, based on adsorbers, was investigated. A distillate fraction from a de-alcoholized muscat wine (Muscat à petits grains blancs) was treated by a resin bed (Flavologic, Vaterstetten, Germany) to recover aroma from the de-alcoholization process. This fraction was then added to the de-alcoholized fraction to equalize the aroma losses during the distillation under vacuum. Aroma analysis was performed on the different fractions during the process, as cited in [12]. Due to the strongly varying alcohol contents of the fractions, these different samples were adjusted to 12% v/v with ethanol for analysis purposes.

3 Results and Discussion

The wine analysis shown in chart 2 indicates that there is a certain concentration effect on non-volatile wine components due to the de-alcoholization process. This effect in addition to the changed sensory perception due to the absence of ethanol indicates that the initial wine must meet certain specific analytical requirements so that, for example, the acid perception of the final wines is not too pronounced after de-alcoholization.

Figure 1 shows that the addition of two selected enological tannins, as well as the addition of themannoprotein product did not affect the preference towards the de-alcoholized (control) wine without any addition. Even the de-alcoholized wine spiked with 10 g/l of glycerin did not have a significant impact on the panelist's preference.The rating of personal preference was very unevenly distributed across the different samples.

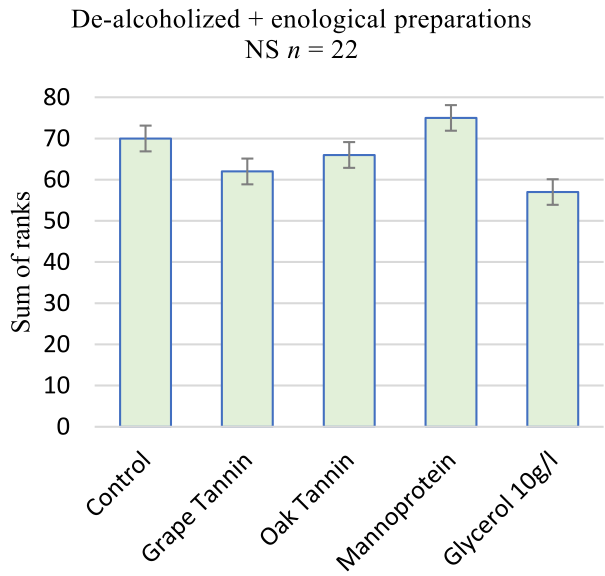

Figure 1. Ranking according to preference of several enological preparations added to the de-alcoholized wine (control).

Figure 2 shows similar results. The combination of chemical de-acidification, tannins, mannoprotein or glycerin did not lead to a significant preferred variant.

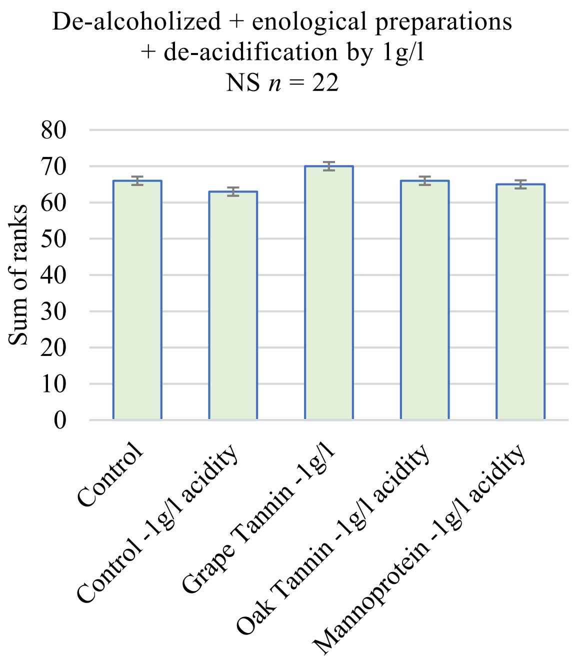

Figure 2. Ranking according to preference of several enological preparations added to the de-alcoholized wine combined with de-acidification by 1 g/l.

Sweetening the de-alcoholized wine showed clear differences in terms of the panelist's preferences. An addition of 20 g/l and more (30 g/l and 40 g/l) significantly increased the common preference.

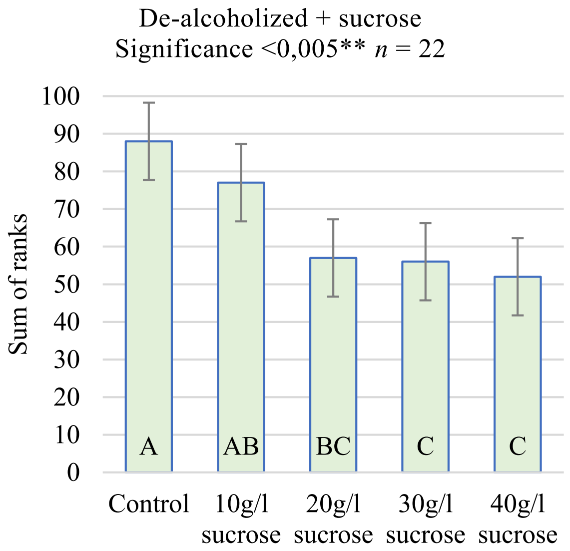

Figure 3. Ranking according to preference of different amounts of sucrose added to the de-alcoholized wine.

The comparison of different methods to sweeten the de-alcoholized wine by 30 g/l showed a significant preference of the samples spiked with sucrose and fructose towards the samples were glucose or must was added. The sample sweetened by unfermented must was described by several panelists as less "wine like" and more "must aroma coined". Due to the dilution with 17% must in contrast to sweetening with pure sugar, a deviation of the product matrix seems plausible. The primary aromas of the must can dominate the remaining aromas in the dealcoholised wine.

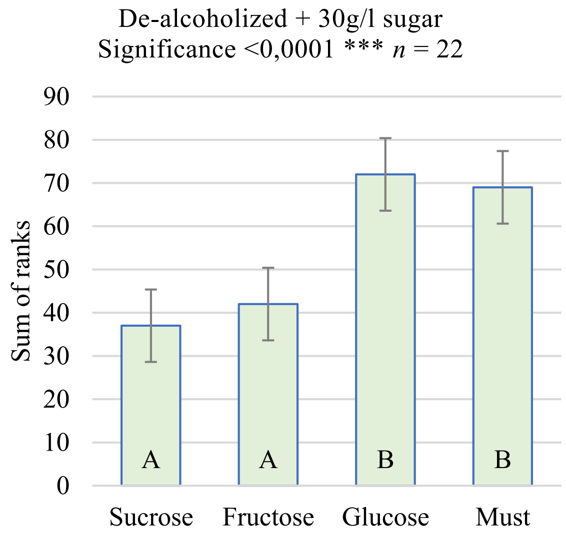

Figure 4. Ranking according to preference of different sugar sources added to the de-alcoholized wine.

Descriptive analysis of the dry Riesling showed that the perception of fruit characteristics as apple, citrus, and peach were not affected significantly by the de-alcoholization. Even though there is a reduction in volatiles during de-alcoholization the panelists did not perceive a significant difference towards the untreated initial wine with 11.5% v/v. This is similar to the resultson Riesling partly de-alcoholized by 4% v/v [22]. A clear significant difference was seen in terms of the attribute body/fullness. The de-alcoholized samples were significantly rated having less body than the initial wine. The addition of tannins and mannoprotein could slightly increase this attribute but not in a significant way. All de-alcoholized samples significantly showed higher ratings in terms of acidity. This goes back to the concentration effect of de-alcoholization and is furthermore enhanced by the increased acidity perception due to the low alcohol content (<0.5% v/v). In terms of bitterness a clear significant difference between the initial wine and the de-acloholized samples could be shown. As indicated in [2, 15, 17, 18] ethanol seems to be mainly in charge of bitterness perception of wine. The initial try Riesling with 11.5% v/v showed a significantly higher rating in terms of sweetness compared to the de-alcoholized samples. This can be proven by the sweet perception of ethanol [14, 18, 24, 29]. The sensory perception in terms of notes of cooked fruits was not significantly affected by the de-alcoholization or addition of the different enological preparations.

The descriptive analysis of the Riesling sweetened by 30 g/l showed similar results in terms of cooked vegetables and the fruit characteristics of apple, citrus and peach. The sweetening with pure sucrose did not alter that aroma perception. Body and Fullness perception was again significantly higher for the sample with 11.5% v/v compared to the different de-alcoholized variants. Other than in the case of the dry wine, the sweetened Riesling did not show a significant difference in terms of acidity.

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Eventhough the perception of acidity was still higher for the de-alcoholized samples. Bitterness significantly scored higher in the initial wine compared to the de-alcoholized samples. The sweetness perception was significantly higher for the initial wine. The de-alcoholization led to a significantly lower sweetness perception.

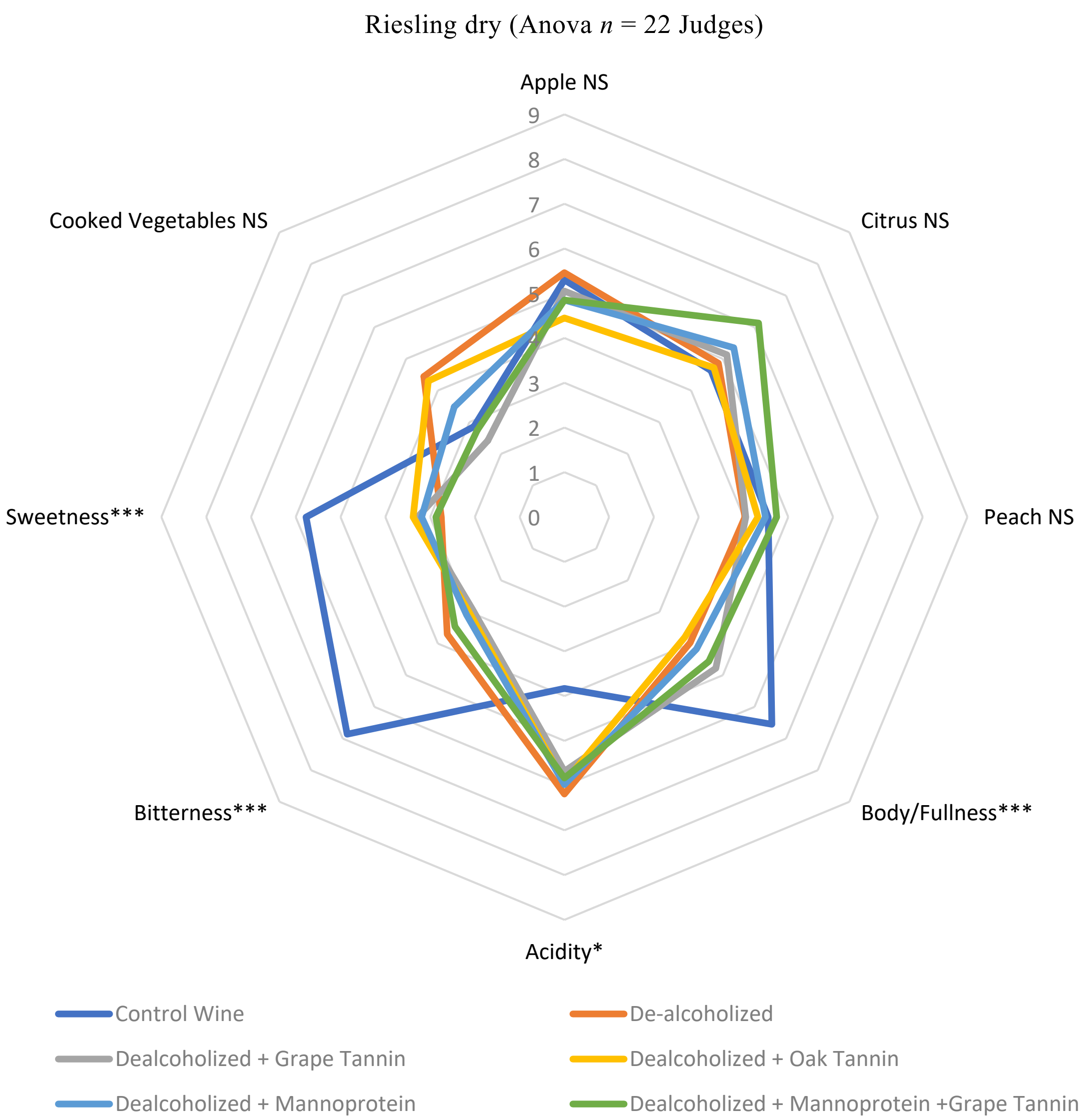
In general, the de-alcoholization had a much stronger effect on the sensory characteristic of the wine, than the addition of enological preparations mentioned.

Figure 6 shows different fractions during the aroma recovery process and its content in relation to the initial concentration of the wine before de-alcoholization. It can be seen that the de-alcoholization process for all wines is accompanied by a significant reduction in the aroma components mentioned. Due to the adsorber technology a certain amount of aroma can be recovered from the distillate fraction and blended back to the de-alcoholized wine. The degree of aroma recovery nevertheless, differs between the different aroma components shown.

Table 2. Ethanol content, residual sugar, glycerol, malic, and tartaric acid (± standard error).

	Ethanol g/l	Ethanol % v/v	Residual sugar g/l	Glycerol g/l	Malic Acid g/l	Tartaric acid g/l
Initial wine	91.05 ± 2.30a[1]	11.53 ± 0.29a	6.30 ± 0.25a	5.67 ± 0.40a	1.92 ± 0.15a	6.24 ± 0.58a
De-alcoholized	1.66 ± 0.04b	0.21 ± 0.05b	7.47 ± 0.30b	6.26 ± 0.37b	2.50 ± 0.08b	7.07 ± 0.19a

[1]Letters within a column indicate significant differences at $p < 0.05$.



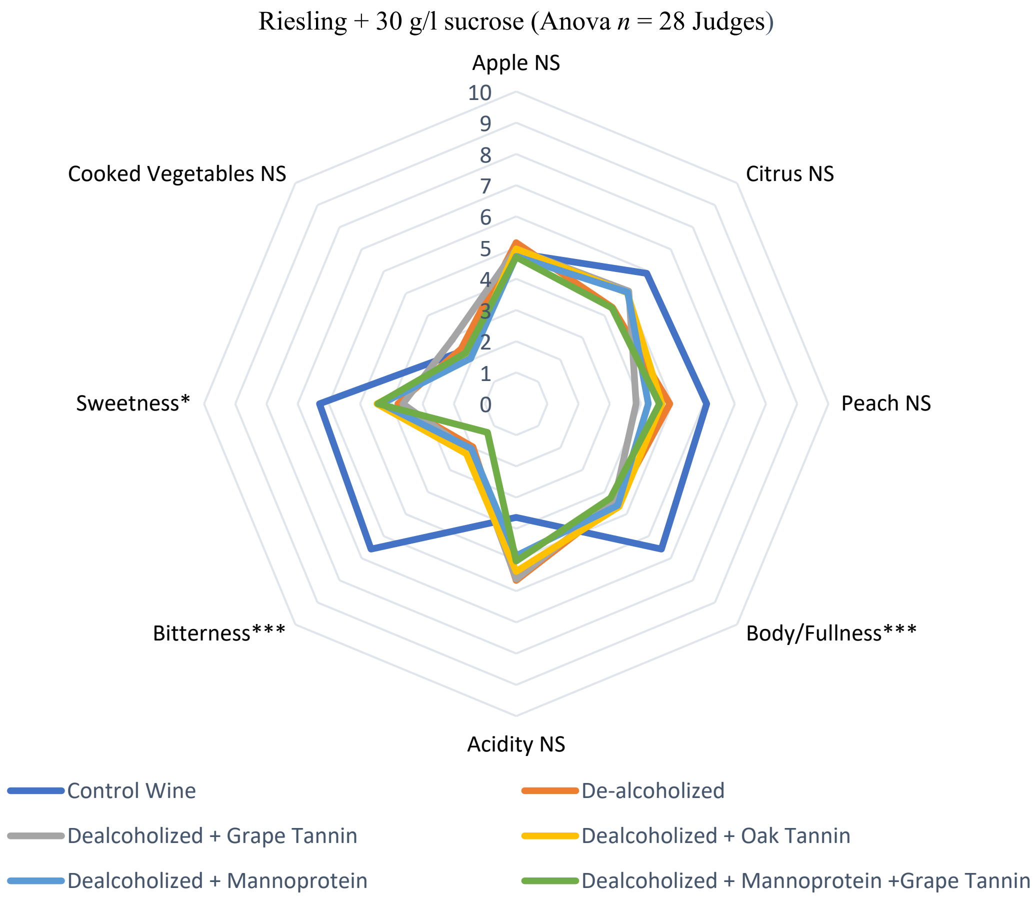
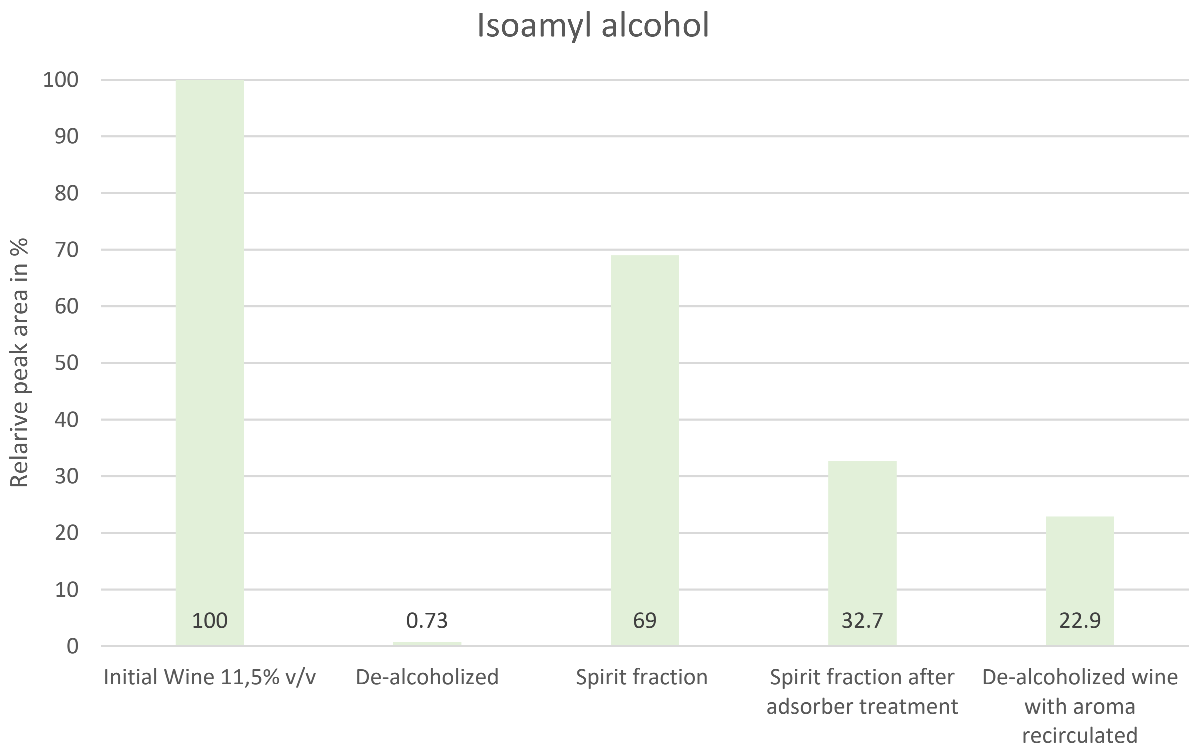


Figure 5. Smell and in-mouth attribute mean scores from descriptive analysis of the original wine in contrast to the de-alcoholized wine added with different enological products. Levels of significance: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$).



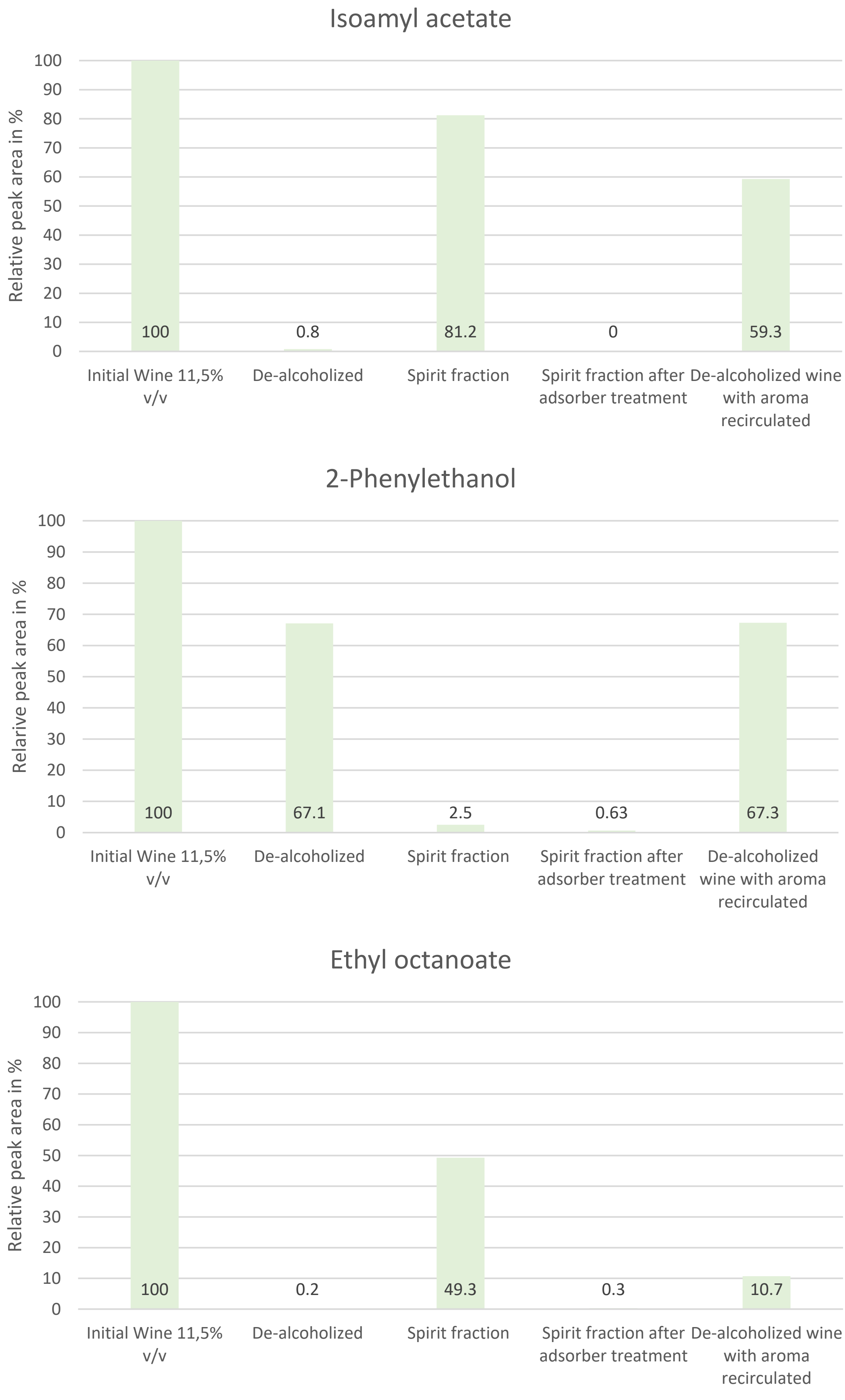


Figure 6. Relative peak area in % of several aroma compounds during the aroma recovery process.

4 Conclusion

The de-alcoholization goes along with significant changes in the analytical composition of the wine. The concentration of non-volatile components increases due to the removal of ethanol and other volatile components in the distillate fraction. The removal of ethanol causes clear changes in the sensory perception. The present results show a clearer effect on the mouth-feel than on the perception of fruit components. Sweetening of the de-alcoholized wines appears to be useful to a greater extent than with the usual wine.

Flavour recovery using commercial adsorber technology shows some potential to recover certain aroma components from de-alcoholization by vacuum rectification.

Further studies should reveal the exact sensory impact and the specific capacity with regard to other wine aromas. However, the studies should be extended to other grape varieties and wine styles to gain a better understanding of the specific effects of de-alcoholization on the respective wines.

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