Hochschule Geisenheim University

Investigations on the use of the VBUNG® technology for the production of wine without additives

Introduction

Wine production is a technological process that is strictly regulated by law. The Regulation EU 2019/934 specifies all oenological techniques for wine production. This includes traditional oenological practices, as well as “new processes”. The oenological treatments can be divided into physical processes, additives and processing aids. Increasing public awareness of the link between food and health and the negative impact of traditional food production methods on environmental resources has led consumers to be more selective and pay more attention to the ingredients and constituents used in the foods and beverages they eat and drink in their daily lives (Asioli et al. 2017). Consumer demand for natural foods has increased significantly in recent years. The term "natural" has become one of the most important claims for these types of foods, which are launched to meet new consumer demands and market niches (Roman et al. 2017; Hemmerling et al. 2016). However, there is no universally accepted definition or legal regulation regarding the naturalness of food or wine, leaving it up to the discretion of producers to determine how natural foods are produced. In the wine industry, the production of "natural wines" is generally aimed at reducing or eliminating additives and processing aids. In particular, the use of sulfur dioxide (SO_2) is critically questioned, but only a few production practices are known to produce wines without SO_2 use. The Institute of Oenology at Geisenheim University has been researching the topic of winemaking without the use of sulfur dioxide and winemaking without additives and processing aids in general for several years. In 2021, a preliminary test was carried out at the Institute of Oenology of Geisenheim University to investigate whether the use of barrique barrels equipped with the VBUNG® technology enables the production of wines without any additives or processing aids. This report describes findings from these experiments. Since these were preliminary tests, the experiments were not performed in multiple repetition, so that a statistical evaluation of the results is not possible.

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Material and Methods

The experiments were carried out with white wine from the Müller Thurgau grape variety. The health of the grapes was good with a botrytis infestation of 3%. The grapes were harvested by hand on 28.09.2021 in the Geisenheimer Fuchsberg site (Eibinger Weg, test area E6) and transported to the winery in standardized vats with a capacity for 450 kg of grapes. The grapes were vinified in eight different ways (Figure 1).

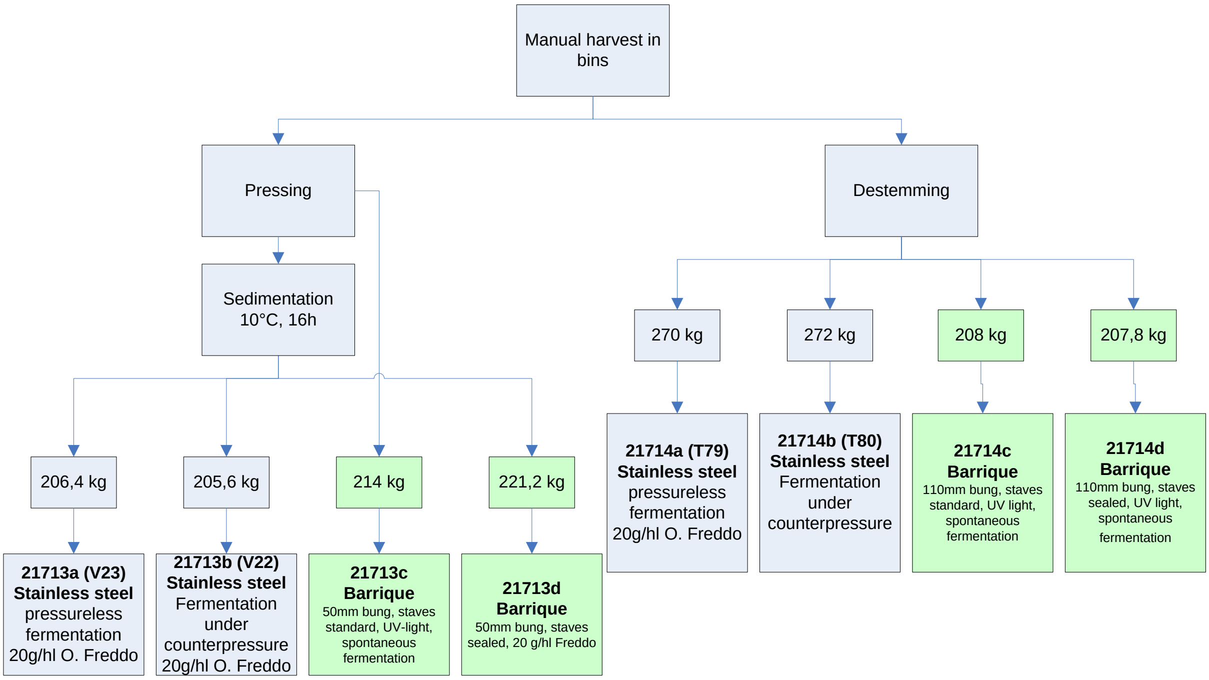

Figure 1 Schematic representation of the eight experimental variants.

Figure 2 Photo of the 8 variants during alcoholic fermentation: in the background are the stainless steel tanks and in the foreground the barrique barrels with VBUNG® technology.

Half of the grapes were pressed directly in a semi-open tank press (Flath, FWP, built in 2016) with a basket capacity of 1,800 l, the press was loaded by gravity. Then, the must was filled directly into new barriques (199 l must/barrique) without the need being pre-clarified and without the addition of SO_2 (variant 21713c and 21713d). The subsequent spontaneous fermentation in barriques (Slavonian oak, origin Croatia, medium toast, Tonnellerie Auric) took place under a counter-pressure of 0.8 bar overpressure. During fermentation, the acrylic barrel heads of variants 21713 C, 21714C and 21714D were not covered and exposed to sunlight as the barrels were stored outside. After completion of the

alcoholic fermentation, the wine was stored outdoors in barriques under a CO_2 atmosphere of 0.8 bar overpressure at cool, wintry temperatures.
Another part of the same batch of must was pre-clarified by sedimentation for 16 h at 10°C and fermented in stainless steel tanks with pure cultured yeast (20 g/hl Oenoferm Freddo, Erbslöh). For the variant 21713A a pressureless fermentation was conducted and for variant 21713B and 21713D the must was fermented under a counter-pressure of 0.8 bar overpressure. All fermentations were conducted without temperature control.

The second half of the grapes were destemmed and fermented on the skins. For these wines, the berries were separated from the stalks with a drum destemmer (Amos, built in 1988) and the mash was filled by gravity in new barriques equipped with the VBUNG® technology. The fermentation on the skins took place spontaneously under a counter-pressure of 0.8 bar overpressure (variants 21714C and 21714D). After completion of alcoholic fermentation the wines aged outdoors in the barriques without SO_2 addition and under CO_2 overpressure of 0.8 bar. The variants 21714A and 21714B were fermented in stainless steel tanks, with the first variant (21714A) being added a pure culture yeast (20 g/hl Oenoferm Freddo, Erbslöh) and fermented without counterpressure and the second variant (21714B) was fermented spontaneously under a counterpressure of 0.8 bar.

Description of VBUNG® technology:

The barriques with the VBUNG® technology differ from standard barriques in four main ways:
1. a silicone gasket is inserted between the staves, sealing them against each other and reducing gas exchange between the staves,
2. an acrylic plate is inserted into one head side of the barrel,
3. The bunghole is equipped with a bunging valve that can be precisely adjusted to the desired opening pressure. The bunging valve ensures a constant bung pressure throughout the fermentation process and during storage. If the pressure inside the barrel exceeds the set pressure, the excess CO_2 is blown off.
4. A stainless steel tube reaches from the bunging valve to the bottom of the barrique and allows the barrique to be filled and emptied in the same way as keg tanks. Emptying is done by gas pressure, a pump is not necessary.
The design of the bunghole is available in two variants. For fermentation of must the diameter is 50 mm and for fermentation of mash 110 mm (Figure 3).

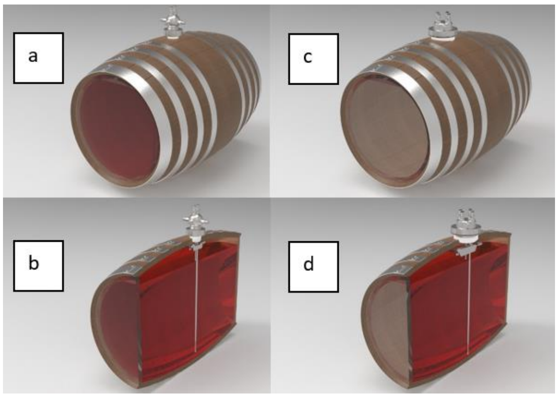

Figure 3 Construction view of barrels a,b for wine 21713c and 21713d and c,d for wine 21714c abd 21714d (source: POPA, 2021)

Must and Wine analysis

The turbidity was determined with a turbidity photometer (Dr Lange, Nephla LPG 239). The yeast-available nitrogen content (N-OPA) was determined enzymatically (Megazyme, Primary amino nitrogen kit). The grape must and wine was analyzed by FTIR analysis (FOSS, WineScan SO2). During alcoholic fermentation, density and temperature were determined daily with a density meter (Metler Toledo, DensitoPro). Yeast propagation was monitored microscopically. Total phenolic content was determined using the Folin-Ciocalteu method (SINGLETON et al., 1999). Flavonoid content was determined by colorimetric determination of catechin content in must and wine using dimethylaminocinnamaldehyde (DAC) solution of the Institute of Oenology, cf. (ZIRONI et al., 1992; SCHNEIDER, 1995; SCHNEIDER and KOST, 2020). The color of the samples was recorded using a spectrophotometer (photoLab, 7600 UV-VIS), measuring absorbance over a wavelength range from 380 nm to 770 nm in 10 nm steps. Values characterizing the color were calculated from the measured values. In addition to the standard color values XYZ, these are the values of the L*a*b* color space, also called CIELab color space.

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Results and Discussion

The must analysis of the eight different variants shows no differences between the must variants (21713) and mash fermentation variants (21714). Only the must turbidity for the variant 21713C was much higher (913 NTU) in comparison to the three other must fermentation variants (21713A, B, D). This can be explained by the fact that no must clarification was performed for this variant. Usually, winemakers target turbidity values of 100 - 200 NTU after clarification for the fermentation of white musts. The analytical values regarding sugar content and composition of organic acids are comparable, which means that the grape and must quality were homogenous among the different variants. The total phenolic contents are slightly increased for the mash fermentation variants in wooden barrels compared to stainless steel tanks. This is probably due to the somewhat more difficult filling of the barrels and the associated increased mechanical stress on the berries.

Parameter	Method	Unit	21713 a Stainless steel	21713 b Stainless steel	21713 c VBUNG®	21713 d VBUNG®	21714 a Stainless steel	21714 b Stainless steel	21714 c VBUNG®	21714 d VBUNG®
Density	FTIR	20/20	1,07607	1,0761	1,07633	1,07608	1,07676	1,07712	1,07577	1,07767
Extract	FTIR	g/L	198	198,1	198,7	198	199,8	200,8	197,2	202,2
Reducing sugars	FTIR	g/L	175,8	176,6	179,5	177	179,3	176,4	176,1	180,8
pH - value	FTIR		3,2	3,2	3,2	3,2	3,2	3,3	3,2	3,3
Total acidity	FTIR	g/L	6,3	6	6	6,1	5,6	5,8	5,4	5,4
Tartaric acid	FTIR	g/L	4,9	4,5	4,5	4,7	4,1	4	3,9	4
Volatile acid	FTIR	g/L	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2
Malic acid	FTIR	g/L	2,9	2,8	2,8	2,9	3	3,2	2,9	2,9
Ethanol	FTIR	g/L	n.n.	n.n.	n.n.	n.n.	n.n.	n.n.	n.n.	n.n.
Gluconic acid	FTIR	g/L	n.n.	n.n.	n.n.	n.n.	n.n.	n.n.	n.n.	n.n.
Glycerol	FTIR	g/L	< 0,1	< 0,1	< 0,1	< 0,1	< 0,5	< 0,5	< 0,5	< 0,5
Sediments after centrifugation	calc.	w/w	0,6	0,64	0,56	0,64	-	-	-	-
Trubidity before centrifugation	photom.	NTU	347	473	913	380	-	-	-	-
Turbidity after centrifugation	photom.	NTU	104	95	85	87	-	-	-	-
Total phenols	FOLIN	mg/L	185	192	190	211	199	239	259	262
N-OPA	enzym.	mg/L	68	71	74	67	85	79	91	89

Table 1 Grape must analysis from 30.09.2021 [calc. = calculated; n.n. = not detectable; photom: = photometrically; FOLIN = Folin-Ciocalteu] Variants: 21713A = pressureless fermentation with cultured yeast strain in stainless steel tank; 21713B = spontenous fermentation in stainless steel tank under counterpressure; 21713C = spontaneous fermentation in barrique VBUNG®; 21713D = spontaneous fermentation in barrique VBUNG®; 21714A = pressureless fermentation with cultured yeast strain in stainless steel tank; 21714B = spontenous fermentation in stainless steel tank under counterpressure; 21714C = spontaneous fermentation in barrique VBUNG®; 21714D = spontaneous fermentation in barrique VBUNG®

Diagrams 2-4 show the fermentation curves of the individual variants. For the must fermentation variants (21713), the musts fermented at slightly higher temperatures of about 3°C in the barrique barrels compared to the two variants in the stainless steel tank, which could be explained by a lower heat radiation through the wood. It resulted in a faster fermentation process for variants 21713C and 21713D. The wines fermented in the barrel completed the alcoholic fermentation three days earlier in comparison to the wines fermented in stainless steel. It is interesting to mention that the must that fermented spontaneously fermented faster than the two variants with the cultured yeast strains. During the microcopic control, it was noticed that the yeasts from the variants exposed to sunlight (21713C, 21714 C+D) during fermentation had a thicker yeast cell wall compared to the yeast cells from variant (21713D) and the stainless steel tank variants.

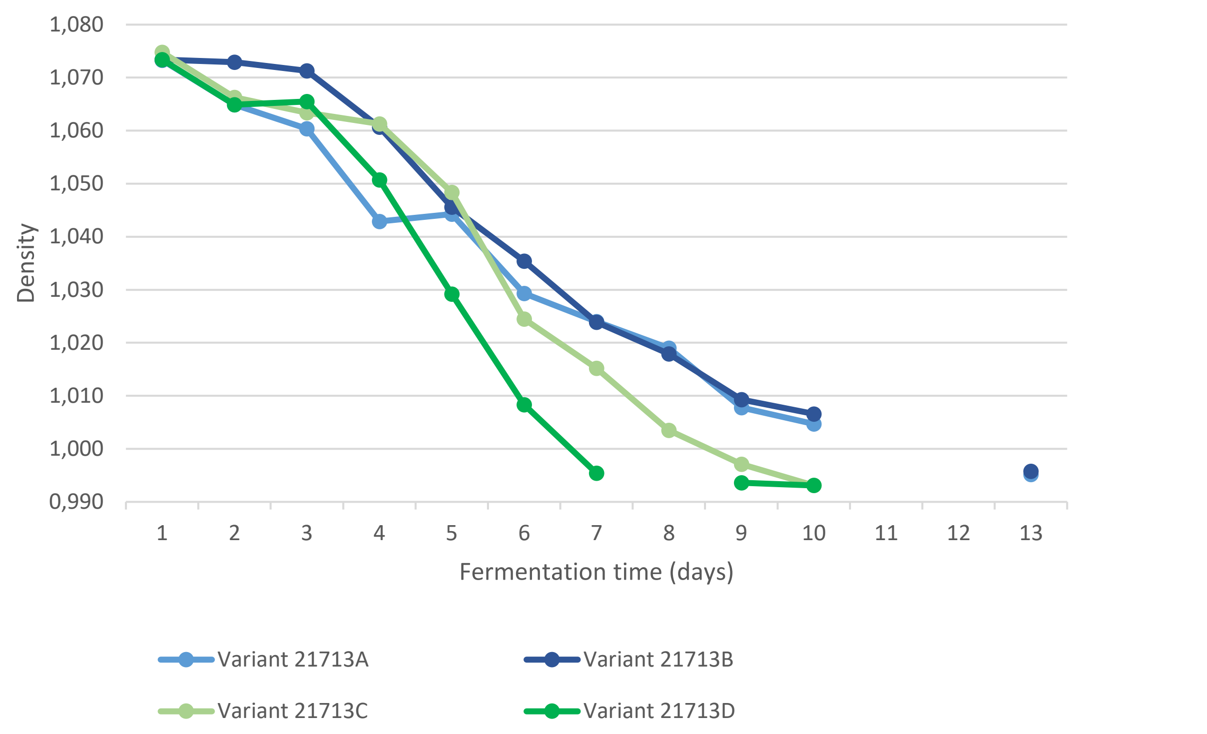

*Figure 4 Density decrease during alcoholic fermentation for **must fermentation** (variants 21713A-D).*

[21713A = pressureless fermentation with cultured yeast strain in stainless steel tank; 21713B = spontenous fermentation in stainless steel tank under counterpressure; 21713C = spontaneous fermentation in barrique VBUNG®; 21713D = spontaneous fermentation in barrique VBUNG®]

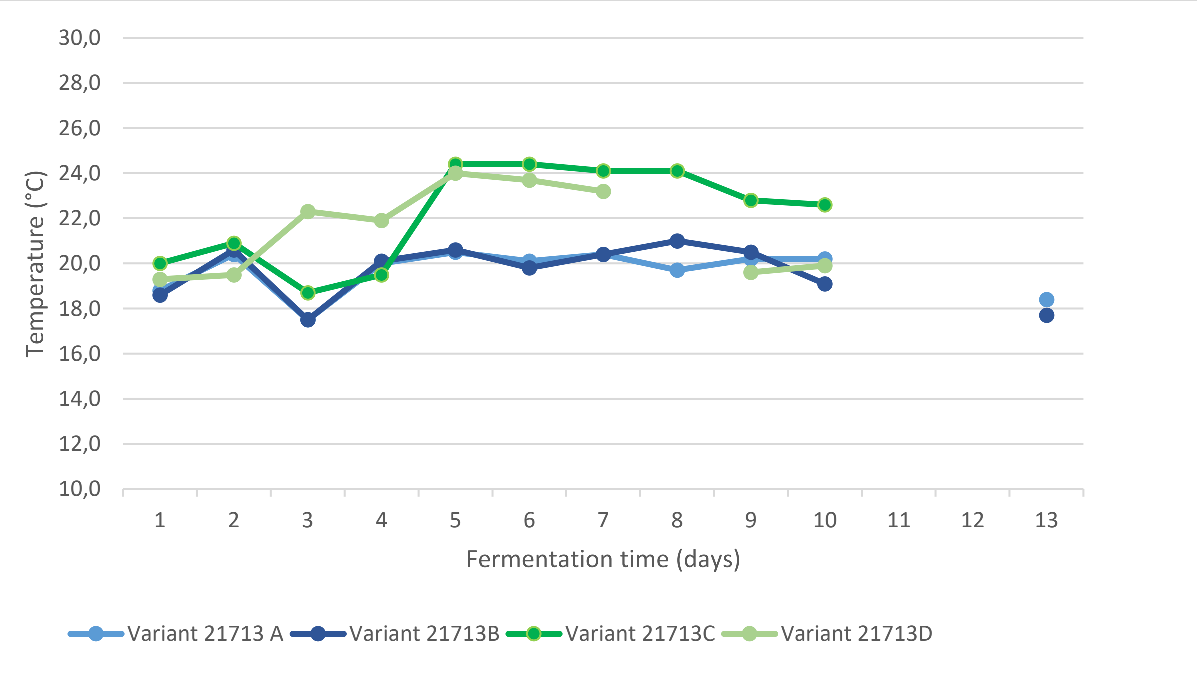

*Figure 5 Temperature profile during alcoholic fermentation for **must fermentation** (variants 21713A-D).*

[21713A = pressureless fermentation with cultured yeast strain in stainless steel tank; 21713B = spontenous fermentation in stainless steel tank under counterpressure; 21713C = spontaneous fermentation in barrique VBUNG®; 21713D = spontaneous fermentation in barrique VBUNG®]

The alcoholic fermentation of the four variants fermented on the skins (21714) was more heterogeneous. The fermentation of the three variants 21714 A,C,D was completed within 10 days. In the case of the 21714B variant, fermentation got stuck, which meant that the sugar did not ferment completely. This variant was not investigated further in the subsequent vinification.

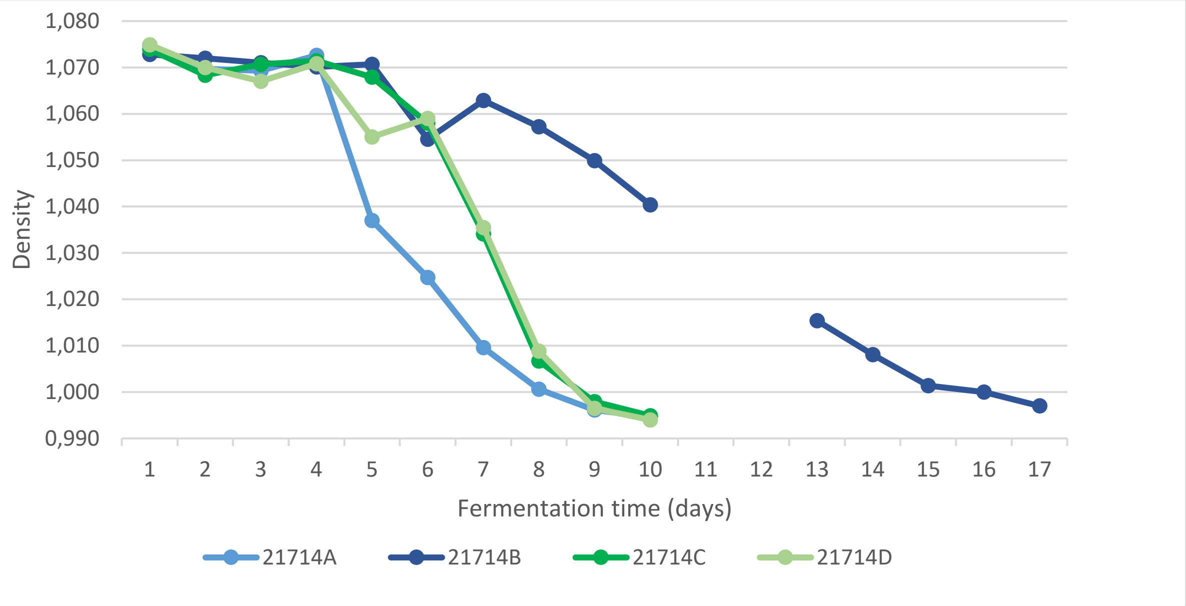

*Figure 6 Density decrease during alcoholic fermentation for **mash fermentation** (variants 21714A-D).*

[21714A = pressureless fermentation with cultured yeast strain in stainless steel tank; 21714B = spontenous fermentation in stainless steel tank under counterpressure; 21714C = spontaneous fermentation in barrique VBUNG®; 21714D = spontaneous fermentation in barrique VBUNG®]

The fermentation temperature of the wines in the barrique barrels was about 5 °C higher than the wine in the stainless steel tanks during the main fermentation phase.

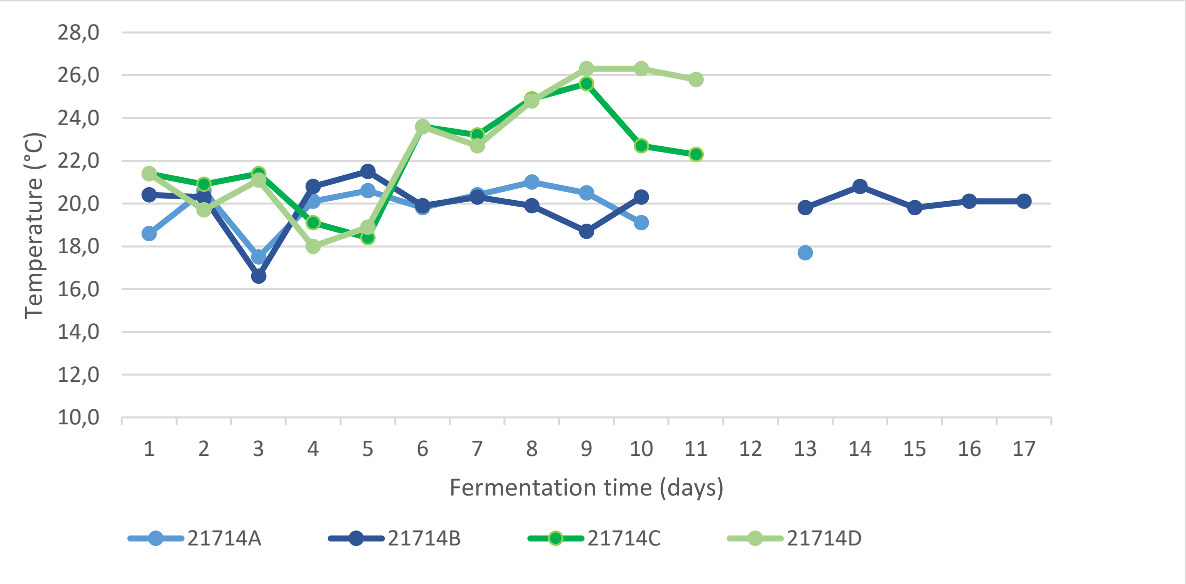

*Figure 7 Temperature profile during alcoholic fermentation for **mash fermentation** (variants 21714A-D).*

[21714A = pressureless fermentation with cultured yeast strain in stainless steel tank; 21714B = spontenous fermentation in stainless steel tank under counterpressure; 21714C = spontaneous fermentation in barrique VBUNG®; 21714D = spontaneous fermentation in barrique VBUNG®]

The young wine analysis (Table 2) shows comparable values for the seven variants. The variants 21714C and 21714D contain 2,8 and 2,4 g/L of residual sugar, respectively. However, a later analysis showed no more residual sugar (results not published). The degradation of malic acid and low levels of lactic acid indicate an ongoing maloclatic fermentation.

Parameter	Method	Unit	21713 A Stainless steel	21713 B Stainless steel	21713 C VBUNG®	21713 D VBUNG®	21714 A Stainless steel	21714 C VBUNG®	21714 D VBUNG®
Density	FTIR	20/20	0,9964	0,9961	0,9952	0,9936	0,9946	0,9959	0,9959
Alcohol	FTIR	g/L	81,3	79,6	82,2	87,7	82,2	77,3	77,5
Extract	FTIR	g/L	25,1	23,8	22,5	20,5	21,5	22,9	23,3
Sugar free extract	FTIR	g/L	24,5	23,3	22	20,5	21,4	20,1	20,9
Fermenting sugar	FTIR	g/L	0,6	0,5	0,5	0	0,1	2,8	2,4
Glucose	FTIR	g/L	0,5	0,4	0,5	0	0,1	0,1	0,1
Fructose	FTIR	g/L	0,1	0	0,1	0	0	2,7	2,3
Total acidity	FTIR	g/L	5,7	5,5	5,4	6,4	6,3	6,5	6,9
Tartaric acid	FTIR	g/L	3,8	3,5	2,9	3,6	3,9	3,6	3,6
Malic acid	FTIR	g/L	1,2	1,4	1,5	1,9	1	2	2
Lactic acid	FTIR	g/L	1,7	1,3	1,2	0,6	1,6	0,6	0,8
Volatile acid	FTIR	g/L	0,5	0,5	0,5	0,5	0,4	0,5	0,4
pH value	FTIR		3,7	3,6	3,7	3,7	3,8	3,8	3,9
Glycerol	FTIR	g/L	6,6	6,2	6,4	6	6,3	5,5	6,2
Free SO2	FTIR	mg/L	1	2	2	3	3	3	3
Total SO2	FTIR	mg/L	16	11	11	13	7	6	7
Acetaldehyde	enzym.	mg/L	10	11,9	4,3	6,9	3,7	4,2	2,6
Total phenols	FOLIN	mg/L	122	113	143	145	912	673	821
Conductivity		µS/cm	1120	1193	1127	1087	1497	1582	1619
Tartrate stability	Δ	µS/cm	75	121	68	52	128	87	140
	after 80°C, 2h	Δ NTU	8,28	10,98	0,49	0,65	15	12,16	5,34

Table 2 Wine analysis from 11.10.2021. [calc. = calculated; n.n. = not detectable; photom: = photometrically; FOLIN = Folin-Ciocalteu] Variants: 21713A = pressureless fermentation with cultured yeast strain in stainless steel tank; 21713B = spontenous fermentation in stainless steel tank under counterpressure; 21713C = spontaneous fermentation in barrique VBUNG®; 21713D = spontaneous fermentation in barrique VBUNG®; 21714A = pressureless fermentation with cultured yeast strain in stainless steel tank; 21714B = spontenous fermentation in stainless steel tank under counterpressure; 21714C = spontaneous fermentation in barrique VBUNG®; 21714D = spontaneous fermentation in barrique VBUNG®

The must variants from the barrique barrel were already protein-stable shortly after the end of fermentation (heat teast Δ NTU < 1) and showed no need for bentonite. Possibly, tannins from the oak reacted with thermolabile proteins to form tannin-protein complexes and flocculated them. This effect was not observed in the mash fermented variants.

During vinification, the wines were regularly sensory tasted by five scientists. A sensory tasting with a larger panel did not take place. A sensory tasting of the young wines showed that the wines from the stainless steel tanks exhibited reductive aromas probably caused by hydrogen sulfide (H_2S) and were rated worse overall than the wines that fermented in the barriques. The primary aroma was masked by the reductive aromas. Surprisingly, the wines from the barriques did not show any reductive aromas. These wines did not show the typical bouquet of young wine, but were rated as ready to drink and the flavor was described as a wine flavor that establishes to a minimum of 3 to 6 months aging for traditional winemaking . These barrel fermented wines were characterized by a pronounced primary aroma. The carbonic acid overpressure of 0.8 bar at 20°C was not sensory perceptible, and the wines did not show an increased amount of carbonic acid in taste. The clarification of the wines of the variants 21713C and 21713D started very quickly after the alcoholic fermentation was completed. These wines were visually almost bright 14 days after the end of fermentation. All the must fermented wines had a comparable color and did not show any oxidation or browning hues in terms of color (Table 3). All variants fermented on the skins were described as slightly bitter and astringent. The wine color was somewhat more intense compared to the must variants, but did not exhibit the typical orange, amber color of mash-fermented white wines (see Table 3).

Variants 21713C and 21713D were tasted regularly over a period of 11 months and the wines were characterized by an intense fresh primary aroma. Oxidative notes and aromas of free acetaldehyde could not be detected.

	21713 a Stainless steel	21713 b Stainless steel	21713 c VBUNG®	21713 d VBUNG®	21714 a Stainless steel	21714 c VBUNG®	21714 d VBUNG®
L*	97,9506607	98,1859761	97,4444176	98,4665081	98,9614039	99,2320893	98,0728719
a*	-0,06172663	-0,10152772	-0,10336324	-0,48404092	-1,18565913	-0,92140261	-1,05938473
b*	6,84752524	6,55346544	7,73226288	7,43231006	8,25437973	9,67720497	10,5183896
420 nm	0,103	0,098	0,122	0,099	0,116	0,132	0,159
520 nm	0,031	0,028	0,038	0,023	0,015	0,016	0,029
620 nm	0,006	0,004	0,01	0,002	-0,002	-0,009	0,003
Color intensity	0,14	0,13	0,17	0,124	0,129	0,139	0,191
Color hue	3,3	3,5	3,2	4,3	7,7	8,3	5,5

Table 3 Wine color according to LAB space (380-770nm)

The mash fermented wines reacted violently with air contact. Already after a few hours air contact, the wines developed an intense brown coloration and the aroma changed to strongly oxidative. This phenomenon is probably explained by the oxidation of flavonoid phenols. The content of flavonoid phenols in the mash-fermented wines was elevated and ranged between 69.5 and 75.8 mg/L. Schneider (2021) reports values of below 20 mg/L catechin/epicatechin from 858 white wines from all over the world. This includes a large-scale test with 664 wines, in which the mean values of flavanols across all grape varieties are below 6 mg/L. Cooling the mash fermented wine to -4°C for 24 h followed by a sterile filtration prevented the brown coloration (results not shown). This heavy oxidation reaction did not occur in the wines fermented as must in barrique (Figure 8Figure 5).

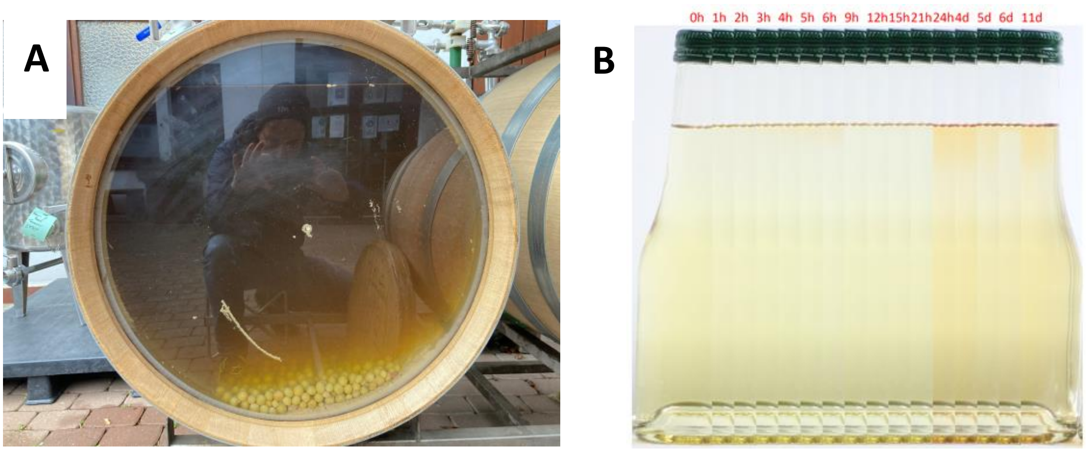

Figure 8 ***A*** *Müller Thurgau 2021 in VBUNG® Barrel (Variant 21713D)* ***B*** *Color change of sterile filtered wine (Variant 21713D) [h= hours; d=days; 21713D = spontaneous fermentation in barrique VBUNG®]*

Conclusion

The first tests on the use of VBUNG® technology in barrels showed that this technology allows the production of wines without additives and processing aids, which are sensorially comparable to conventionally produced wines. The early drinking maturity of the wines produced in wooden barrels with VBUNG® was remarkable in contrast to the variants fermented in stainless steel tanks, but also in contrast to conventionally produced wines, which often require 3-6 months of wine maturity until the fermentation aroma is integrated to such an extent that it no longer dominates the wine aroma.

After pressing the grapes and transferring the must to the barrels, no further technology is required for vinification. Pumping of the wine is not necessary, because the wine transfer is done by gas pressure. Regular topping up of the barrels is not necessary, as the bung is gas tight sealed. The headspace in the barrel consists of either carbon dioxide or nitrogen gas and the absence of oxygen means that no microbial or chemical oxidation reactions harmful to the wine take place. The wines can be tapped directly from the barrel by gas pressure, but filtration and bottling with gas pressure are also possible.

Even after eleven months of aging in partial filled barrels, these white wines showed no oxidation aromas, despite the absence of SO_2. Bottled wines also showed no unusual flavors over a period of six months and were rated as positive. The wines should be bottled under low-oxygen filling conditions to prevent the onset of undesirable oxidation processes. Longer wine aging periods have not yet been observed.

Follow-up trials will investigate further aspects of the VBUNG®technology, with a focus on the vinification of different grape varieties and replications will show whether the results from the first trial are confirmed. A bibliography can be requested from the author.

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