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Protein extracts from white wine lees: toward new fining agents for red wines

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This study demonstrates the potential of white wine lees, rich in proteins and polysaccharides, as sustainable fining agents for red wines. Protein extracts obtained by subcritical water extraction (SWE) showed performance comparable to that of commercial gelatin in reducing turbidity, tannin content, and astringency, while preserving the wine's color. These results are promising for the valorization of white wine lees as an innovative and sustainable alternative to animal-derived fining agents and are part of a circular economy approach.

The Challenge of Oenological Fining: Toward Alternative and Sustainable Agents

Fining is an essential oenological practice aimed at improving the clarity, phenolic stability, and sensory properties of wines[1,2]. Historically, these agents have relied primarily on animal-derived proteins such as gelatin, casein, or ovalbumin, which are highly effective but associated with regulatory, allergenic, and societal concerns[3].

In response to shifting consumer preferences toward natural, vegan, and allergen-free products, numerous studies have explored plant-based or microbial alternatives, particularly those derived from peas, lupins, potatoes, or grape seeds, demonstrating binding performance comparable to that of animal proteins[2,4,5]. More recently, yeast protein extracts have also demonstrated strong potential for wine clarification and phenolic modulation[6].

The use of wine lees as a source of new fining agents represents a promising alternative. Rich in proteins and polysaccharides, and still largely untapped, they can be transformed into functional extracts through subcritical water extraction. This study is the first to examine the potential of protein extracts from white wine lees as alternative fining agents, combining the circular economy with oenological performance.

Methodology

Fining tests were conducted by comparing white wine lees (prior to extraction), a lees extract obtained via subcritical water extraction (SWE), and a commercial fining agent based on pork gelatin.

The white wine lees (Sauvignon Blanc, AOC Pessac-Léognan, 2023 vintage) were collected after fermentation, centrifuged, washed three times to remove tartaric acid, and then freeze-dried. The protein extract was prepared by SWE (optimized conditions) at 155 °C and 30 bar pressure for 5 minutes, with a solid-to-liquid ratio of 5 %. This process was evaluated using life cycle assessment (LCA) and proved to be particularly advantageous from an environmental standpoint (equipment materials, solvent recycling, energy consumption) compared to extractions using conventional solvents (ethanol, methanol, etc.)[7].

The samples (residue, extract, and commercial fining agent) were characterized to determine the concentration of proteins (Bradford and Kjeldahl methods), total polysaccharides (phenol–sulfuric acid method), and the molecular weight profile of proteins/peptides (SDS-PAGE and SEC with UV detection at 214 nm).

Fining trials were conducted on a Cabernet Sauvignon red wine (Bordeaux, 2024) using different treatment conditions (n = 3): an unfined control wine, gelatin at 8 g·hL^{-1} (the average dose recommended by the supplier), lees and lees extract at 20 g·hL^{-1} (average dose comparable to that of commercial yeast extracts). The fining duration was set at 7 days (recommended contact time in the cellar) at a temperature of 10 °C. The clarified wines were then analyzed to determine oenological parameters (FTIR), turbidity (NTU), color (color intensity, hue, CIELAB/ΔE), the concentration of monomeric anthocyanins (SO_2 decolorization method) and total tannins (Bate-Smith method), as well as astringency via the gelatin index.

Chemical analyses of lees extracts and commercial fining agent

Analysis of protein and polysaccharide content shows (Table 1) that gelatin has high protein levels (881.7 mg·g^{-1}). White wine lees and their extracts, on the other hand, are characterized by a lower protein content (≈ 360–375 mg·g^{-1}), combined with a high proportion of polysaccharides (543–663 mg·g^{-1}), reflecting their yeast origin. SDS-PAGE analysis (Figure 1) reveals distinct protein profiles between commercial agents and matrices derived from lees. Gelatin consists mainly of low-molecular-weight peptides (<30 kDa). In contrast, the lees have a more complex profile with an accumulation of compounds larger than 75 kDa, likely due to the formation of protein–polyphenol complexes and the presence of yeast aggregates. The lees extract exhibits high intensity in the lower part of the gel, indicating a predominance of very low molecular weight peptides (<1.4 kDa), suggesting partial protein hydrolysis induced by subcritical

TABLE 1. Protein and polysaccharide contents of fining agents (mean ± standard deviation, n = 3). Significant differences are indicated by letters (Tukey's test, α = 0.05).

	Proteins (mg·g^{-1})	Polysaccharides (mg·g^{-1})
Gelatin (G)	881,7 ± 0,4 a	0,00 ± 0,0 d
Lees (L)	375,5 ± 1,1 c	543,0 ± 6,6 b
Lees extract (E)	361,7 ± 4,1 d	663,0 ± 5,9 a
p-value	< 0,0001	< 0,0001

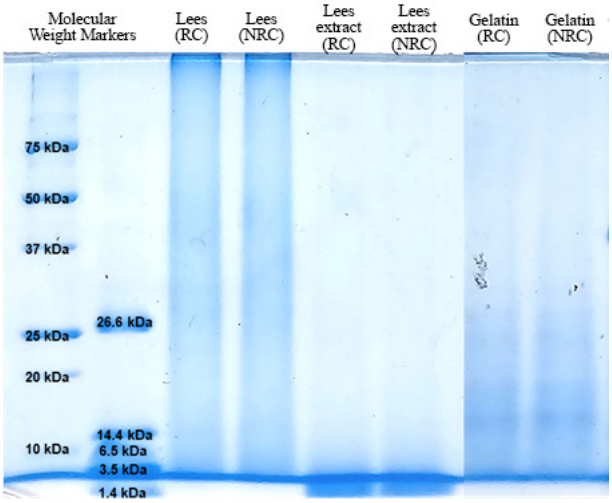


FIGURE 1. SDS-PAGE profiles of fining agents (lees, lees extract and gelatin) under non-reducing (NR) and reducing (R) conditions. Molecular weight markers for proteins and polypeptides, in kDa, are shown on the left.

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TABLE 2. Analytical characteristics of the raw wine (initial wine), the control wine (wine in experimental conditions without fining agents), and the wines treated with fining agents (8 g·hL^{-1} gelatin, white wine lees, and 20 g·hL^{-1} subcritical water protein extract). Results are expressed as mean ± standard deviation (n = 3). Significant differences are indicated by letters (Tukey's test, α = 0.05).

	Turbidity (NTU)	Anthocyanins (mg/L)	Tannins (g/L)	Color intensity	Color	L*	a*	b*	ΔE	Gelatin index
Raw wine	39.8 ± 0.2 a	207.4 ± 3.0 a	3.9 ± 0.0 a	14.2 ± 0.2 a	0.8 ± 0.0 a	64.1 ± 0.2 c	34.5 ± 0.3 b	4.2 ± 0.6 b		64.1 ± 1.9 a
Control	18.4 ± 0.6 b	206.5 ± 2.3 a	3.9 ± 0.1 a	14.4 ± 0.1 a	0.8 ± 0.0 a	63.6 ± 0.3 d	35.2 ± 0.3 a	5.0 ± 0.1 a	1.2 ± 0.3 a	64.1 ± 0.8 a
Gelatin	3.08 ± 0.2 f	195.7 ± 1.0 c	3.1 ± 0.06 d	13.6 ± 0.1 c	0.8 ± 0.0 a	65.3 ± 0.2 a	34.2 ± 0.3 b	5.0 ± 0.2 a	1.3 ± 0.3 a	54.2 ± 1.2 c
Lies	15.0 ± 0.6 c	203.6 ± 2.8 ab	3.65 ± 0.0 b	14.4 ± 0.0 a	0.8 ± 0.0 a	64.0 ± 0.1 cd	34.5 ± 0.1 b	5.3 ± 0.1 a	1.2 ± 0.1 a	62.1 ± 1.1 a
Wine lees extract	6.6 ± 0.1 e	197.8 ± 3.2 bc	3.2 ± 0.0 d	14.0 ± 0.0 b	0.8 ± 0.0 a	64.7 ± 0.1 b	34.1 ± 0.1 b	5.1 ± 0.0 a	1.2 ± 0.1 a	54.6 ± 0.6 c
p-value	< 0.0001	0.001	< 0.0001	< 0.0001	0.026	< 0.0001	0.001	0.002	0.94	< 0.0001

water extraction. Analysis by size-exclusion chromatography (data not shown) confirmed that the lees extract consists mainly of soluble peptides, with a broad distribution typical of a protein hydrolysate. In contrast, the lees are predominantly insoluble, likely due to the presence of cellular aggregates resulting from yeast lysis. Commercial gelatin exhibits a profile characteristic of a collagen hydrolysate, whereas the lees extract shows a peptide distribution with a median molecular weight of approximately 2,000 g·mol^{-1} but a slightly lower proportion of high-molecular-weight peptides.

Fining performance in wine

The white wine lees protein extract obtained by subcritical water extraction (SWE) exhibits high fining performance, comparable to that of commercial gelatin and superior to that of the lees prior to extraction (Table 2). It enables a significant reduction in wine turbidity (– 64.4 %), close to that observed with gelatin (–83.3 %), while the lees show more moderate efficacy (Table 2).

The lees extract also induces a marked decrease in total tannins (–18.4 %), similar to that obtained with gelatin (–20.9 %), which leads to a significant reduction in astringency (–14.8 %) confirmed by the gelatin index (Table 2). These effects are attributed to its composition, rich in low-molecular-weight peptides that promote interactions with polyphenols, as well as to the presence of polysaccharide fragments derived from yeast cell walls.

Colorimetric changes (Table 2) remain limited for all treatments, with slight decreases in color intensity and the a* parameter, but overall color differences (ΔE < 3) imperceptible to the human eye. The moderate decrease in monomeric anthocyanins (–4.2 % for the extract) is consistent with the partial adsorption of pigments during fining. Thus, the combination of low-molecular-weight peptides and polysaccharide fragments confers on the lees extract a high reactivity toward phenolic compounds, explaining its fining efficacy.

Overall, these results demonstrate that subcritical water extraction yields a functional peptide hydrolysate capable of effectively modulating turbidity, tannin content, and astringency while preserving the wine's color characteristics, positioning this extract as a new sustainable alternative to conventional fining agents.

Conclusions

Protein extracts from white wine lees obtained using subcritical water exhibit fining efficacy comparable to that of gelatin, while offering a sustainable alternative of viti-vinicultural origin. This approach enables the valorization of a major by-product of the wine industry from the perspective of the circular economy and oenological innovation. ■

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