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Reduced product loss associated with inline bentonite treatment of white wine by simultaneous centrifugation with yeast lees

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ABSTRACT

Removal of residual grape protein from white wine is a routine winemaking practice for prevention of protein heat instability that can otherwise result in haze formation and consumer product rejection. Protein removal is typically achieved by batch treatment with bentonite, however considerable costs ($0.5–1.0 billion per annum worldwide) are experienced through product loss within the bentonite sediment. Continuous inline bentonite dosing followed by centrifugation is an alternative contacting approach, however previous attempts have resulted in significant carryover of bentonite into the clarified stream. This issue is addressed in the present work, whereby an 84% reduction in carryover was achieved by undertaking bentonite inline dosing in conjunction the simultaneous centrifugal removal of yeast lees following primary alcoholic fermentation. Economic modelling suggests the cost of wine losses associated with bentonite treatment may be decreased by up to 82.5% using this protocol, representing significant opportunity to reduce processing costs of industrial-scale wine production.

1. Introduction

Clarification and stabilisation operations are undertaken throughout the winemaking process to achieve process efficiency and satisfy consumer demand for quality, fault-free wine. Clarification operations such as centrifugation, floatation, sedimentation and filtration occur at various stages of winemaking to remove suspended solids and improve turbidity and clarity (Boulton et al., 1996). Stabilisation operations on the other hand reduce the risk of undesirable physical or sensorial changes occurring during storage. Cold stabilisation treatments for example, such as cold storage, electrodialysis or chemical treatment are used to prevent tartrate crystals from precipitating in the packaged product (Waterhouse et al., 2016). Batch addition of bentonite clay is another distinct but routine unit operation that is widely employed throughout the wine sector, in this case for the removal of heat unstable white wine proteins (van Sluyter et al., 2015). If these proteins are not removed prior to packaging, temperature-induced protein denaturation can lead to subsequent haze formation in the final product.

Bentonite has been used by winemakers for oenological control of protein instability at industrial scale since the 1930s (Saywell, 1934), with protein adsorption occurring primarily by cation exchange (Waters et al., 2005). However, whilst the process is effective for protein removal (Hsu and Heatherbell, 1987; Blade and Boulton 1988; Muhlack et al., 2016), treatment can adversely affect wine quality (Lambri et al., 2010), especially at high bentonite doses. Furthermore, because of bentonite's considerable swelling and poor settling characteristics, significant wine volume is trapped within (or occluded by) the bentonite sediment (Tattersall et al., 2001). Methods to extract wine that is trapped by bentonite sediment (known as lees) are oxidative and do not achieve complete recovery, resulting in a cost to industry of the order of US$0.5–1 billion per year (van Sluyter et al., 2015; Høj et al., 2000). Hence there is a significant interest in improving the performance of this process.

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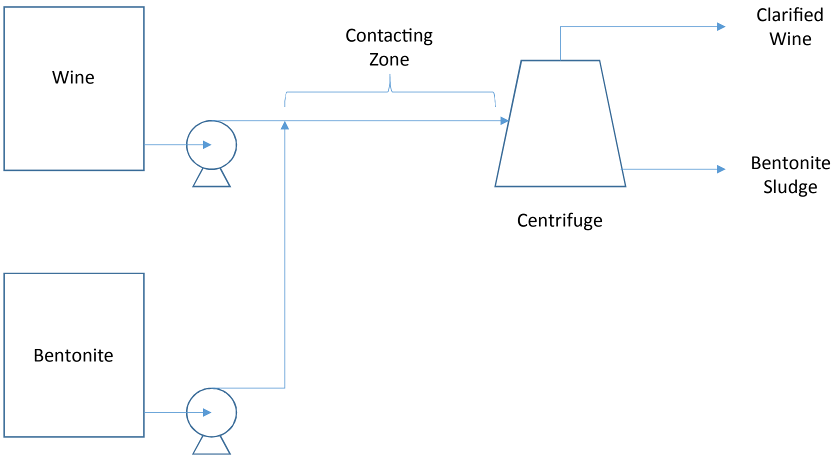

Fig. 1 – Simplified schematic of continuous in-line dosing of bentonite into wine.

Previous studies have investigated mechanisms of haze formation (Dufrechou et al., 2010; Marangon et al., 2011; Gazzola et al., 2012; van Sluyter et al., 2015), as well as factors which impact on the protein adsorption capacity of bentonite (Hsu and Heatherbell, 1987; Blade and Boulton, 1988; Achaerandio et al., 2001; Lambri et al., 2010; Muhlack et al., 2016). Targeting improvement to the efficiency of bentonite-liquid contacting and solids removal is a further strategy to limit wine losses. This approach was historically noted by several authors (Rector, 1983; Zoecklin, 1988) with more recent quantitative work by Muhlack et al. (2006) and Nordestgaard et al. (2007) which utilised continuous addition of bentonite slurry to fully developed turbulent flow of wine in a pipe, rather than the batch contacting methods and natural gravity settling that are more traditionally used by wine producers. In these more recent studies, a contacting zone was provided to allow adsorption of protein to occur, after which bentonite was separated from wine by continuous disc stack centrifugation, as depicted in Fig. 1. Whilst inline dosing of bentonite was found to be effective for protein removal and indistinguishable from traditional batch treatment in terms of its sensory impact (Muhlack et al., 2006), incomplete separation of bentonite from the liquid during centrifugation produced substantial carryover (up to 30%) of the added bentonite into the clarified stream. For industrial-scale production this is undesirable, as carryover bentonite will still eventually settle in a storage vessel and once again lead to volume and quality losses from wine trapped within the resulting lees.

Separation performance of a continuous centrifuge may be improved however by modulation of flowrate and particle size (Clarkson et al., 1998; Maybury et al., 1998). Increasing bentonite particle size was investigated by Nordestgaard et al. (2007) with some success in carryover reduction. An alternative but related strategy is to conduct bentonite addition and removal in conjunction with an existing centrifuge step, where bentonite can aggregate with other solids present leading to more easily separated larger particles. This alternative approach however, has not yet been investigated and therefore the aim of this study was to establish the extent to which carryover could be reduced by combining bentonite treatment with an existing centrifugation process: the centrifugation of white wine following completion of primary yeast fermentation, a common practice in large commercial wineries. To provide insight into the effectiveness of this strategy for commercial use, the experiment was conducted at Berri Estates Winery using technology common to large scale wine production. The Berri Estates Winery is located at Berri in the Riverland district of South Australia, and is the second largest winery in Australia with an annual grape processing capacity of 220,000 metric tonnes (WineTitles, 2017). Testing was conducted using a commercial Chardonnay wine and sodium exchanged bentonite at various flowrates typical of industrial practice. Centrifuge separation performance was evaluated by spin test and nephelometry to establish carryover and compared with conventional batch treatment practices using the same wine and bentonite. Economic modelling was then undertaken to inform industry practice regarding optimal treatment conditions to reduce volume losses and associated processing costs arising from bentonite treatment using both inline dosing and conventional batch treatment methodologies.

2. Theory

Solids carryover for a continuous centrifuge is a function of separation performance, and may be described by a Grade Efficiency Model (Clarkson et al., 1998; Maybury et al., 1998):

$$T(d) = 1 - exp\left(-(kd/d_c)^n\right) \quad (1)$$

where $T(d)$ is the faction of particles of size d that are recovered by the centrifuge, d_c is known as the critical particle diameter and k and n are regression parameters describing the grade efficiency curve. The fraction of particles not recovered by the centrifuge is known as the carryover and is given by:

$$C = 1 - T(d) \quad (2)$$

The critical particle diameter from Eq. (1) is a threshold particle size separation limit and is given by:

$$d_c = \left(\frac{18Q\mu}{\Delta\rho A_e g}\right)^{0.5} \quad (3)$$

where Q is the volumetric flowrate, $\Delta\rho$ is the density difference between solid and liquid phases, μ is the dynamic viscosity, g is acceleration due to gravity and A_e is the equivalent settling area which is a function of the disc stack centrifuge geometry. Theoretically all particles larger than d_c will be recovered by the centrifuge (Maybury et al., 1998)

3. Materials and methods

3.1. *Wine*

A large-scale (278 kL) commercial batch of Chardonnay wine was used for this experiment, produced from vineyards in the Riverland district of South Australia. This wine had been stored on yeast lees prior to treatment in a single stainless steel winery tank. Throughout the experiment, the internal racking arm of the tank was positioned to draw supernatant from above the settled yeast lees.