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Original

New perspectives in safety and quality enhancement of wine through selection of yeasts based on the parietal adsorption activity / Caridi, A.. - In: INTERNATIONAL JOURNAL OF FOOD MICROBIOLOGY. - ISSN 0168-1605. - 120:1-2(2007), pp. 167-172. [10.1016/j.ijfoodmicro.2007.08.032]

Availability:

This version is available at: <https://hdl.handle.net/20.500.12318/3800> since: 2020-12-24T17:21:26Z

Published

DOI: <http://doi.org/10.1016/j.ijfoodmicro.2007.08.032>

The final published version is available online at: <https://www.sciencedirect>.

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New perspectives in safety and quality enhancement of wine through selection of yeasts based on the parietal adsorption activity

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Abstract

The present article aims to review research papers that focus on the parietal adsorption activity of wine yeast and on its contribution to the enhancement of wine safety and quality.

There is a great diversity among yeasts for their parietal adsorption activity: the outermost layer of the cell wall has a chemical composition that notably varies from yeast to yeast. Parietal mannoproteins can contain phosphate, pyruvate, or glucuronic acid, which impart negative charges, modifying the electrostatic and ionic interactions with wine components.

The following could give a good reason to propose a specific selection of wine yeasts based on their parietal adsorption activity to improve wine safety and quality: (a) ochratoxin A content of wines is greatly reduced by expressly selected yeasts, sequestering the toxin during winemaking; (b) yeast influences concentration and composition of phenolic compounds in wine, above all by adsorbing them on cell wall; (c) among grape pigments, anthocyanins, in particular, may be adsorbed by yeast cell wall; and (d) yeast can also interact with wine colour producing anthocyanin- β -D-glucosidase, pyruvic acid, and acetaldehyde or releasing mannoproteins and different polysaccharides.

Genomic strategies could also be used to obtain a further enhancement of the adsorption/non-adsorption activity of wine yeasts.

Based on winemaking requirements and on parietal adsorption activity, a specific selection of yeasts might be performed: (a) to protect wine colour during red winemaking, (b) to remove residual wine colour during white winemaking, (c) to selectively remove ochratoxin A, and (d) to protect phenolic compounds responsible for antioxidant activity.

Keywords: Cell wall; Mannoproteins; Ochratoxin A; Phenolic compounds; Selection; Wine yeast

1. Introduction

The use of selected yeasts to control winemaking has made manifold contributions to wine quality, such as: (a) faster start to fermentation process, consequential exclusion of defects due to delayed start, and prevention of sluggish and stuck fermentations (Bardi et al., 1999; Torija et al., 2003); (b) greater yield of ethanol (D'Amore and Stewart, 1987; Bauer and Pretorius, 2000); (c) lower production of volatile acidity (Giudici and Zambonelli, 1992); (d) full exhaustion of fermentable sugars, consequential limitation of bacterial growth, and increase of wine stability even in the presence of sugar-induced osmotic stress (Attfield, 1997; Caridi et al., 1999; Caridi, 2002; Erasmus et al., 2003; Malacrinò et al., 2005); (e) better control of fixed acidity through malic acid production or consumption (Fatichenti et al., 1984; Giudici et al., 1995; Zambonelli et al., 1997; Redzepovic et al., 2003); (f) optimal production of secondary metabolites (Soles et al., 1982; Prior et al., 2000); (g) better control of malolactic bacteria through growth inhibition or stimulation (Caridi and Corte, 1997; Alexandre et al., 2004); and (h) better control of subtlety and individuality of wine flavour (Lambrechts and Pretorius, 2000; Fleet, 2003).

Furthermore, the selection of yeasts to control winemaking has contributed to wine safety in different ways, including: (a) stabilization of wines with low levels of SO₂ (Caridi et al., 1998), (b) detoxification of wines from heavy metals (Olasupo et al., 1993; Johnston et al., 2000; Dunn et al., 2005) originating from vineyard treatments, and (c) production of wines with low amounts of ethyl carbamate (Ough et al., 1991) and biogenic amines (Torrea and Ancin, 2002; Husnik et al., 2006).

For oenological strains, the parietal adsorption activity is a new selection feature that is attractive because it can enhance wine safety and quality (Caridi et al., 2004a). The present article aims to review research papers that focus on the parietal adsorption activity of wine yeast and on its contribution to the enhancement of wine safety and quality, apart from winemaking technologies or other environmental factors that may give similar results.

2. Parietal mannoproteins

The parietal adsorption activity is notably different from yeast to yeast, according to structural characteristics and chemical composition of the outermost layer of cell wall. This layer is essentially made up of partially water-soluble glycoproteins, called mannoproteins, which represent 25–50% of the entire cell wall. Parietal mannoproteins are connected with an inner matrix of amorphous β -1,3 glucan and are partly released in wine.

As for other adsorption processes (Huwig et al., 2001), the physical structure of mannoproteins – total charge, charge

distribution, and accessible surface area – is the most important feature determining adsorption differences among strains. Yeast mannoproteins contain both N-linked and O-linked oligosaccharides (Gemmell and Trimble, 1999). O-linked oligosaccharides rarely include charged groups; on the contrary, N-linked oligosaccharides may exhibit negative charges, due to the presence of phosphate (Vernhet et al., 1996) or, in a few instances, glucuronic acid (Fukazawa et al., 1995) and pyruvate (Gemmell and Trimble, 1996). Mannoproteins from *Schizosaccharomyces pombe* generally contain β 1,3-linked pyruvylated galactose residues (Gemmell and Trimble, 1999), whereas mannoproteins from *Saccharomyces cerevisiae* (Odani et al., 1997) and *Pichia pastoris* (Miura et al., 2004) mainly contain mannosylphosphate (mannose phosphate diesters). The percentage of acidic oligosaccharides, containing mannosylphosphate, varies from strain to strain in *Saccharomyces*, *Kloeckera brevis* and *Candida albicans*, whereas the oligosaccharides of *S. pombe* and *Kluyveromyces lactis* do not contain mannosylphosphate (Jigami and Odani, 1999). The presence of negative charges on the acidic oligosaccharides modifies the electrostatic and ionic interactions with wine components.

It is reasonable to hypothesize that also wine yeasts may exhibit a different ratio of neutral/acidic oligosaccharides in mannoproteins. The oenological effects of the expected structural diversity could give a good reason to propose a specific selection of wine yeasts, even though the extent of mannosylphosphorylation also depends on culture conditions such as media and cultivation period (Jigami and Odani, 1999).

Parietal mannoproteins perform various oenological functions (Caridi, 2006); regarding their adsorption activity, mannoproteins can adsorb ochratoxin A from grape must and wine, and can interact with grape pigments and other phenolic compounds.

3. Adsorption of ochratoxin A

Ochratoxin A is a strong nephrotoxic, carcinogenic, immunotoxic and teratogenic mycotoxin that can contaminate various foods and beverages, including wines (Galvano et al., 2005; Varga and Kozakiewicz, 2006).

Various procedures have been developed to remove mycotoxins using yeasts (Stanley et al., 1993; Bauer, 1994; Scott et al., 1995; Devegowda et al., 1996, 1998; Baptista et al., 2004; Bejaoui et al., 2004; Caridi et al., 2004b, 2005a,b, 2006a), yeast cell walls (Huwig et al., 2001; Santin et al., 2003; Yiannikouris et al., 2003; Ringot et al., 2005), or yeast cell wall extracts (Devegowda et al., 1996; Zaghini et al., 1998; Howes and Newman, 2000; Raju and Devegowda, 2000; Baptista et al., 2004; Ringot et al., 2005). Yeast mannoproteins play an important role in the ochratoxin A removal process, due to mycotoxin-binding capacity demonstrated for modified mannanoligosaccharide derived from the cell wall of *S. cerevisiae* (Devegowda et al., 1996). Indeed, ochratoxin A removal depends on yeast macromolecules, such as mannoproteins (Bauer, 1994), and corresponds to a spontaneous (Ringot et al., 2005) adsorption mechanism (Bejaoui et al., 2004) where mannoproteins act like a sponge, removing ochratoxin A. The toxin content of wines is greatly reduced by expressly selected yeasts. Remarkable differences among wine yeasts – both *Saccharomyces* (Caridi et al., 2006b) and non-*Saccharomyces* (Cecchini et al., 2006) – have been reported in the ochratoxin A sequestering activity during winemaking. This may depend on the different mannosylphosphate content in the mannoproteins of wine yeasts, but also on dissimilar fermentation and cell sedimentation dynamics, cell dimension, and flocculence.

4. Interaction with phenolic compounds

To enhance wine suppleness and the release of mannoproteins while reducing the perceived astringency of tannins, in some winemaking procedures wine is aged on lees with the addition of β -1,3 glucanase (Feuillat, 2003). Yeast mannoproteins inhibit tannin aggregation, preventing their tendency to form hazes and precipitates during wine aging (Riou et al., 2002).

Phenolic compounds interact with the mannoproteins produced by yeasts; the amount of mannoproteins released during winemaking depends on yeast strain and grape must (Escot et al., 2001).

Mannoproteins can diminish the total polyphenol index of wine by weak and reversible interactions, mainly between anthocyanins and cell walls (Chatonnet et al., 1992; Vasserot et al., 1997).

Many studies have been carried out to demonstrate the effects of yeast selection on the phenolic compounds of wines (Escot et al., 2001; Riou et al., 2002; Sacchi et al., 2005; Sidari et al., 2007). It has been shown that wine yeast influences concentration and composition of phenolic compounds in wine (Stockley and Høj, 2005), since yeasts usually decrease the phenolic compounds (Castino, 1982), above all by adsorbing them on cell wall.

Remarkable correlations between the yeast strain used for winemaking and phenolic compounds in wine have been reported, demonstrating that strain behaviour can somewhat modify chromatic properties, phenolic profile and antioxidant power of wine (Caridi et al., 2004a). It is interesting to note that the interaction between grape cultivar and yeast is close and important, because grape variety, due to its phenolic composition, modulates yeast strain adsorption activity (Sidari et al., 2007).

5. Interaction with grape pigments

At present, the capacity of yeast to retain pigments on parietal mannoproteins is used in dye biosorption (Dönmez, 2002; Aksu and Dönmez, 2003; Forgacs et al., 2004) and in colour correction of white wines (Bonilla et al., 2001;

Razmkhab et al., 2002).

The parietal adsorption of colour during winemaking (Bourzeix and Heredia, 1976; Vasserot et al., 1997; Salmon et al., 2002; Merida et al., 2005) has important consequences for wine quality, because of the amount of pigment removed (Mazauric and Salmon, 2005; Medina et al., 2005). Yeast can also interact with wine colour in two additional ways: (1) producing anthocyanin- β -D-glucosidase (Delcroix et al., 1994; Sponholz, 1997; Manzanares et al., 2000), pyruvic acid (Fulcrand et al., 1998; Morata et al., 2003b, 2006), and acetaldehyde (Dallas et al., 1996; Liu and Pilone, 2000; Morata et al., 2003b; Lopez-Toledano et al., 2004; Morata et al., 2006); and (2) releasing mannoproteins and different polysaccharides (Saucier et al., 1995; Ferrari et al., 1997; Escot et al., 2001; Feuillat et al., 2001; Feuillat, 2003). There is a great diversity from yeast to yeast in the adsorption of wine colour (Castino, 1982; Cuinier, 1988; Delteil, 1995; Conterno et al., 1997; Cuinier, 1997; Ferrari et al., 1997; Girard et al., 2001; Boisson et al., 2002; Eglinton and Henschke, 2003; Malacrinò et al., 2005). Accordingly, anthocyanin adsorption has recently been proposed as a criterion for selection of yeasts able to increase or decrease the colour of wine (Medina et al., 2005; Morata et al., 2005).

Acyated anthocyanin derivatives are, among grape pigments, the most strongly adsorbed by yeasts (Morata et al., 2003a). However, these red-bluish pigments are very important in red wines, since, although present in minor amounts, they are stable and adsorb at higher wavelengths (Monagas et al., 2003).

Currently, bluish hues are highly valued in the production of red wines of superior quality (Morata et al., 2005).

Therefore, it seems undesirable that these grape pigments be highly adsorbed by yeast cell walls during winemaking. This suggests that it may be possible to enhance red wine quality by performing a selection of yeasts showing a low adsorption profile regarding red-bluish pigments.

6. Genomic strategies

Recent developments in expression profile and proteomic techniques have shown that the main oenological traits are complex and influenced by several genes, each of them identified as essential. Wine strain improvement strategies are numerous and often complementary to each other; the choice among them is based on three factors: the genetic nature of traits (monogenic or polygenic), the knowledge of the genes involved (rational or blind approaches), the purpose of the genetic manipulation (Giudici et al., 2005).

The inheritable nature of the adsorption of wine colour was recently analysed on a population of 88 descendants derived from three wine strains of *S. cerevisiae*. Investigation of the progeny demonstrated that the adsorption of wine colour is a polygenic inheritable quantitative traits loci, partially and interdependently correlated to colour and phenolic content of wines (Caridi et al., 2007). These findings constitute an initial step for establishing genomic strategies to obtain a further enhancement of the adsorption/non-adsorption activity of wine yeasts.

7. Conclusion

Overall, it appears that the selection of wine yeasts based on their parietal adsorption activity can enhance wine quality and safety. Based on winemaking requirements and on parietal adsorption activity, a specific selection of wine yeasts might be performed: (a) to protect wine colour during red winemaking, (b) to remove residual wine colour during white winemaking, (c) to selectively remove ochratoxin A, and (d) to protect phenolic compounds responsible for antioxidant activity.

Further research needs to be carried out to study the specific adsorption activity of neutral and acidic yeast mannoproteins on the different compounds present in wine. It would be also interesting to investigate the competition for binding sites on parietal mannoproteins among ochratoxin A, grape pigments and other phenolic compounds.

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