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Evolution of quality parameters during red wine dealcoholization by osmotic distillation

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ABSTRACT

Osmotic distillation technique was used for the total dealcoholization of a red wine (Aglianico grape variety) up to 0.19 vol.%. The dealcoholization process was performed in subsequent cycles which gave rise wine samples at different alcoholic degrees. The effect of processing on the main chemical and physical properties of Aglianico wine was evaluated. Among wine samples, no significant differences ($p < 0.05$) of oenological parameters such as pH, total acidity were found. Similarly, the total phenolic, flavonoids and tartaric esters content and the composition of organic acids did not show significant differences ($p < 0.05$) during the process. On the contrary, colour intensity and tonality of wine samples changed significantly when the alcohol reduction was over the 6.5 vol.%. Finally, the total dealcoholized wine showed properties similar to Aglianico wine except for the volatile compounds, which decreased over 98%. Hence, flavour enrichment may be required to produce a pleasurable and delicious non alcoholic beverage from wine.

1. Introduction

Techniques for producing low and reduced alcoholic strength beverages have been developed over the last years in order to satisfy consumer demand for healthier products.

Decreasing alcohol consumption is a worldwide trend in order to achieve healthier life styles, and it could be advisable for wine producers when external factors, such as global warming and winemaking practices, cause an increasing alcohol content in wines. Accordingly, consumers can complain about these beverages that are getting too heavy and strong to drink together with harmful effects of alcohol on health. Besides, in some countries, winemakers have to pay taxes when alcohol content in wine is over 14.5 vol.% (Massot, Mietton-Peuchot, Peuchot, & Milisic, 2008).

Technologies for reducing alcohol in wines can be classified according to the stage of wine production in which they are typically applied; that is pre-, concurrent or post-alcoholic fermentation (Schmidtke, Blackman, & Agboola, 2012). Several methods to reduce the concentration of fermentable sugars in juice are: early grape harvest, juice dilution, or arrested fermentation that involve some defects in wine such as the need of pasteurization treatment and thus the potential loss of volatile compounds. Recent methods of pre-fermentation strategies are focused on technologies that, using enzymes (glucose oxidase), minimize loss or alteration of desirable organoleptic qualities and off-flavour development. Another practice is the use of selected or novel yeast strains alternative to *Saccharomyces cerevisiae* in order to lower ethanol production during fermentation of wine grapes. One of the drawbacks with novel or wild yeast species is the potential off-flavour development and the loss or alteration of desirable sensorial parameters (Heard, 1999).

Distillation under vacuum, extraction using supercritical carbon dioxide (Pickering, 2000), spinning cone column (Belisario-Sanchez, Taboada-Rodriguez, Marin-Iniesta, & Lopez-Gomez, 2009), membrane processes such as reverse osmosis (Labanda, Vichi, Llorens, & Lopez-Tamames, 2009), pervaporation (Takács, Vataia, & Korány, 2007) and osmotic distillation (Bocca, Piubelli, Stassi, Carbognin, & Ferrarini, 2010; Diban, Athes, Bes, & Souchon, 2008; Hogan, Canning, Peterson, Johnson, & Michaels, 1998; Liguori, Attanasio, Albanese, & Di Matteo, 2010; Liguori, Russo, Albanese, & Di Matteo, 2012; Lisanti, Gambuti, Genovese, Piombino, & Moio, 2012; Varavuth, Jiraratananon, & Atchariyawut, 2009) are used as post-vinification treatments.

Among membrane processes, osmotic distillation (OD) is proposed as an emerging and promising technique to reduce the ethanol content in beverages. Because of operating conditions (room temperature and atmospheric pressure), OD avoids thermal damage to aroma volatile compounds and assures low energy consumption (Varavuth et al., 2009). Osmotic distillation is a membrane separation process which involves the transport of

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volatile components from an aqueous solution (feed) into another liquid solution (stripping agent) capable of absorbing these components. The driving force of the process is the vapor pressure difference of volatile components across the membrane, which is usually microporous and hydrophobic. The mass transfer involves the ethanol evaporation from the feed stream at the membrane surface, the diffusion through the membrane pores and, the condensation into the stripping agent on the opposite side of the membrane (Gostoli, 1999). The main advantages of OD are the following: (i) ethanol has higher volatility and diffusivity than the main components of the wine, (ii) the vapor pressure of volatile components is low and, so is their flux through the membrane and (iii) their solubility in hydroalcoholic solutions is substantially higher than in pure water. As a consequence, the mass transfer rate of these components from wine to stripping agent is low. Furthermore, because the vapor pressure of water in wine is nearly identical to that of pure water, there is virtually no transfer of water from stripping stream into the wine (Hogan et al., 1998). In fact a water flux from stripping stream into the wine was measured when pure water was used as stripping agent; on the contrary, an opposite water flux (from feed to the stripper) occurred using as stripping agent salt solutions at concentration >7 wt.% NaCl (Michaels, 1993) and equal to 40 wt.% $CaCl_2$ (Varavuth et al., 2009).

Osmotic distillation used for wine dealcoholization was investigated in literature: Diban et al. (2008) studied the effect of partial dealcoholization on ethanol and aroma compounds in wine. Varavuth et al. (2009) investigated the best stripping agent for ethanol removal, the analysis of mass transfer coefficients and the loss of aroma compounds during the process. Few papers were focused on the changes of chemical and physical properties of wine during the dealcoholization process (Liguori et al., 2012; Lisanti et al., 2012). These authors studied the evolution of wine properties as consequence of partial dealcoholization which, according to Commission Regulation (EC) No.606/2009, consists of a reduction of the actual alcoholic strength not more than 2 vol.% and an alcoholic strength of the final product not less than 8.5 vol.% (Commission Regulation EC, 2009). The literature lacks of papers investigating the total dealcoholization (final alcohol content lower than 0.5 vol.%) of wine. This latter could be used for the development of a healthy beverage that contains the wholesome properties of wine against atherosclerosis and heart disease, without the negative effect of alcohol (Shrikhande, 2000).

Hence, the objective of this work was to evaluate the effect of total dealcoholization by means of OD on the main properties of a red wine. It is well known (Ronald, 2008; Singleton, 1992) that the quality of red wine was affected by several chemico-physical parameters such as alcohol content, pH, total acidity, total phenolic content, colour, flavonoids and tartaric esters content, organic acids composition and volatile compounds, thus the changes in the mentioned parameters were investigated during the dealcoholization process.

2. Materials and methods

2.1. Materials

Red wine from cv. *Aglianico* grape variety grown in Campania region (year 2009) was used in dealcoholization process.

The hollow fiber membrane module, 1×5.5 minimodule (Liqui-Cel) was used. Its characteristics were: polypropylene membrane, 1800 cm^2 surface area, 42 μm thickness and 14 cm length, 40% porosity, 0.03 μm membrane pore diameter. It consisted of 2300 fibers with dimensions: 11.5 cm length, 220 μm inner diameter and 300 μm outer diameter.

All reagents used for chemical analysis were analytical grade by Sigma Aldrich.

2.2. Experimental setup and dealcoholization conditions

A lab scale plant equipped with membrane module was set up (Fig. 1): feed and stripping streams were fed into the module in counter-current and circulated through tube and shell side, respectively. Wine and hydroalcoholic solution (ranging from 0.7 to 13.0 vol.%) were used as feed stream while water as stripping agent. The temperature of inlet streams was set at 20 °C by a thermostatic water bath while that of outlet streams was monitored by K-type thermocouples. Feed pressure was measured by a manometer, whereas flow rates by flow meters. Dealcoholization tests were carried out at feed and stripping flow rates of 70 and 140 ml/min, respectively. These conditions were chosen according to previous study (Liguori et al., 2012), where the effect of operating conditions on OD was investigated. The feed (0.5 L) and stripping agent (1 L), with an initial volume ratio between stripping and feed streams equal to 2, were recycled during the trials. The process was performed in cycles: at the end of each cycle the

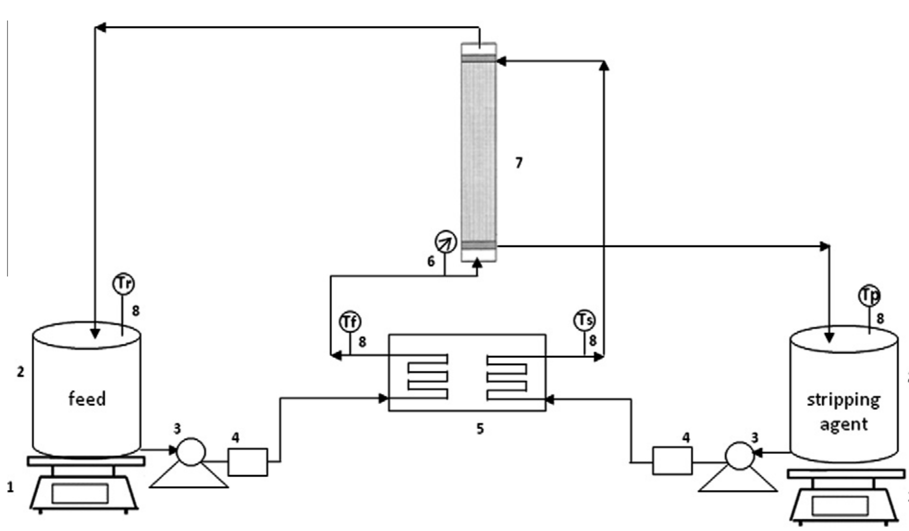

Fig. 1. Experimental setup of dealcoholization plant: (1) stirrer, (2) feed and stripping tanks, (3) pumps, (4) flow meter, (5) thermostatic bath, (6) pressure gauge, (7) membrane module, (8) thermocouples in feed (T_f), stripping (T_s), retentate (T_r) and permeate streams (T_p).