Analytica Chimica Acta 660 (2010) 164–170

Contents lists available at ScienceDirect

Analytica Chimica Acta

journal homepage: www.elsevier.com/locate/aca

Foaming properties of various Champagne wines depending on several parameters: Grape variety, aging, protein and CO_2 content

Clara Cilindre[a,b,*], Gérard Liger-Belair[a], Sandra Villaume[a], Philippe Jeandet[a], Richard Marchal[a]

[a] Laboratoire d'Oenologie et Chimie Appliquée, Université de Reims, URVVC-SE UPRES EA 2069, BP 1039, 51687 Reims Cedex 2, France
[b] Laboratoire Stress, Défenses et Reproduction des Plantes, Université de Reims, URVVC-SE UPRES EA 2069, BP 1039, 51687 Reims Cedex 2, France

ARTICLE INFO

Article history:
Received 7 August 2009
Received in revised form 7 October 2009
Accepted 10 October 2009
Available online 4 November 2009

Keywords:
Champagne
Foaming properties
CO_2
Effervescence
Protein
Yeast
Aging
Champagne tasting

ABSTRACT

A comparison of the foaming parameters of various Champagne wines was undergone with two well distinct methods: (i) a classical gas-sparging method providing standardized but artificial effervescence conditions (the so-called Mosalux), and (ii) a computer assisted viewing equipment (CAVE), much closer to the real champagne tasting conditions. The latter one is the only apparatus which enables a thorough descriptive analysis of foam behavior, during the pouring process of a sparkling wine, and from the end of its pouring. Various Champagne wines elaborated from two grape varieties (Chardonnay and Pinot Meunier) and having experienced different aging-periods (15 months and 5 years) were analyzed and compared to a model sparkling wine, elaborated from a model base wine (devoid of grape colloids). The CO_2 and protein content was also investigated to discuss the foaming behavior of these wines. A significant loss of the CO_2 content during aging was observed and might be the reason for the worse foaming properties of the old champagnes, as determined with CAVE. It is worth noting that contradictory foaming parameters were obtained through the Mosalux method, which is indeed more intrusive than the CAVE, and finally far from the real champagne tasting conditions, since it requires filtration and champagne degassing prior experiment.

1. Introduction

Champagne and sparkling wines differ from still wines by the formation of foam during the pouring of the liquid in the glass, followed by bubbles nucleating on the glass wall – the so-called effervescence process which leads to the formation of a foam ring at the periphery of the glass, also known as collar. Those three criteria – foam, effervescence and collar – are highly requested by the consumer during a sparkling wine tasting considering both the visual appearance, taste and olfactory. Analysis of sparkling wines' foaming parameters is usually achieved by sensory analysis. However, some specific instruments have been developed since the early 1990s to characterize the foaming properties of Champagne and sparkling wines [1–4] as well as their natural bubbling process (the so-called effervescence) [5,6].

The Mosalux, developed in 1990 by Maujean et al. [1], is a gas-sparging method that enables the measurement of the foaming properties of a still wine (base wine or degassed sparkling wine) in standardized effervescence conditions. This method, adapted from those used by brewers [7,8], consists in producing foam with a carrier-gas, generally carbon dioxide (CO_2). Other related methods employ other carrier-gas such as air [4] or nitrogen (N_2) [9]. Numerous studies have employed the Mosalux and related gas-sparging methods to assess the influence of various parameters (grape variety, winemaking conditions...) on foam behavior. Actually, the first investigations on Champagne wines foaming properties have established a positive correlation between the protein content of wines and the foamability and/or foam stability [1,10]. However, it is worth noting that this correlation was not systematically observed [11–13]. These discrepancies could be due to environmental conditions and grape variety which can affect the protein content of grapes [14,15]. On the other hand, the wine proteins may be modified throughout the winemaking [16] such as clarification with bentonite which has a negative influence on the foam of base wine and/or the protein content of wines [17,18].

In Champagne winemaking, the "*méthode traditionnelle*" consists of two major steps performed by yeast, to transform sugars into alcohol and CO_2: (i) a first alcoholic fermentation (from grape must to base wine) and (ii) a second alcoholic fermentation in bottle or "*prise de mousse*" (from base wine to champagne). The second fermentation and the aging on yeast lees (which may last from 9 months up to several years) both induce various quantitative and qualitative changes in the wine through the action of

* Corresponding author at: Laboratoire d'Oenologie et Chimie Appliquée & Laboratoire Stress, Défenses et Reproduction des Plantes, Université de Reims, URVVC-SE UPRES EA 2069, BP 1039, 51687 Reims Cedex 2, France. Tel.: +33 326 91 33 40; fax: +33 326 91 33 40.
E-mail address: clara.cilindre@univ-reims.fr (C. Cilindre).

0003-2670/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.aca.2009.10.021

yeast, as listed hereafter: (1) development of aromas during aging on lees [19], (2) release of nitrogen compounds during autolysis [20], (3) release of macromolecules in wine [21], (4) secretion of lipids [22]. The yeast mannoproteins released during the fermentation and the process of autolysis, have been widely studied in recent years. They were found to improve the stability of wine against protein haze [23], and to increase the foaming properties of sparkling wines [24]. Indeed, some strains of yeast have the capacity to improve the foaming properties of sparkling wine [25]. Moreover, since Maujean et al. [1] have established a positive correlation between wine foamability before and after the "*prise de mousse*" ($r^2 = 0.8862$), the Mosalux is often used to predict the foaming properties of a sparkling wine from those measured on the corresponding base wine [10–13,18]. However, it is worth noting that the natural CO_2-dissolved molecules content (responsible for the "natural" effervescence process which leads to the formation of foam in glasses poured with Champagne and sparkling wines) is not taken into account with a classical Mosalux experiment. Actually, Champagne and sparkling wines have to be degassed prior to a Mosalux experiment. Such conditions being finally quite far from the usual tasting conditions of Champagne and sparkling wines, the development of a computer assisted viewing equipment (CAVE) was initiated to assess, in real tasting conditions, the foaming properties of a sparkling wine [2,26]. This apparatus was originally developed in the 1990s in order to quantify the evolution of the collar over time, with three cameras producing multi-angle points-of-view. In 2001, Marchal et al. [11] employed a more sophisticated system, with a pouring robot allowing strictly repeatable pouring, in order to study the impact of various levels of *Botrytis cinerea* infection. Different parameters are retrieved to characterize foam behavior in the glass, as for example the velocities of foam and liquid during pouring, as well as the collar height after pouring. This is the only apparatus that enables a descriptive analysis of foam behavior during sparkling wine pouring and after the end of pouring. But, to date and to the best of our knowledge, very few studies have employed this system to describe the foaming properties of sparkling wines. Moreover, with the CAVE system, service conditions (wine temperature and glass shape) can also be controlled and standardized, which constitutes a huge advantage, since both the wine temperature and glass shape were recently found to strongly influence the kinetics of CO_2 fluxes outgassing from champagne in tasting conditions [27,28].

The present work proposes a comparison between the foaming properties obtained from the Mosalux and CAVE methods to assess the influence of the "*prise de mousse*" and aging. Three types of base wine and champagnes were analyzed: one part composed primarily of Chardonnay, a second one composed of Pinot Meunier, and a third batch of model base wine and its corresponding champagne. We compared the foaming properties of these "old" champagnes (5 years of aging) with those of a "younger" Champagne of Chardonnay variety (15 months of aging). The model wine did not contain any protein of grape origin or derived from the first alcoholic fermentation. The model Champagne wine will assess the possible impact of compounds released by yeasts on the foaming properties of champagne. Furthermore, the protein and CO_2 content was also investigated to discuss the foaming behavior of these various wines.

2. Experimental

2.1. Reagents

Deionized water (resistivity 18.2 MΩ cm^{-1}) was obtained from a Milli-Q Water System™ (Millipore, Guyancourt, France). All reagents and solvents were of analytical-reagent grade.

2.2. Wine samples

Two monovarietal base wines of Chardonnay (OCH_{BW}) and Pinot Meunier (OPM_{BW}) were elaborated respectively at the Nogent l'Abbesse and the Troissy cooperatives. A third wine (OM_{BW}), a synthetic wine devoid of grape and yeast colloids, was prepared containing 12% (v/v) ethanol and 3 g L^{-1} of tartaric acid. The pH of the synthetic wine was adjusted to 3.2. One-half of those three base wines was champagnized, the other half was kept in a cellar at 12 °C. The second fermentation (i.e., the "*prise de mousse*") was carried out with immobilized yeasts, reaching a final concentration of approximately 1.2×10^7 cells mL^{-1} and 24 g L^{-1} of sucrose, at 12 °C. After an aging-period of 5 years (60 months), riddling and disgorging were done. No shipping dosage was added. These base wines and champagnes were respectively named: "old" base wines (OCH_{BW}, OPM_{BW}, OM_{BW}) and "old" champagnes (OCH_C, OPM_C, OM_C). Experiments done on these champagnes were compared to those on a "younger" commercial champagne (YCH_C) elaborated with the Chardonnay grape variety at the Nogent l'Abbesse cooperative. The aging-period of the younger champagne was 15 months.

2.3. Protein concentration

The wine protein content was determined according to the Bradford method [29], with some modifications to avoid interferences due to ethanol and phenolic compounds [30]. Briefly, the wine was ultrafiltrated with Microcon YM-10 (Millipore, Bedford, USA) and the ultrafiltrate was recovered. The protein assay was done as follows: 200 μL of Bradford dye reagent (Bio-Rad) was added to 400 μL of sample (wine or ultrafiltrate) plus 400 μL of ultrapure water. Absorbance of the mixture was determined at 595 nm. Ultrafiltrate value (containing interferences) was subtracted from that of the sample to determine the wine protein content. Results were expressed in mg L^{-1} and bovine serum albumin (BSA) was used as a standard. Each value was the average of three independent measurements. The standard coefficient of correlation was $r^2 = 0.992$.

2.4. Concentration of dissolved CO_2 in Champagne samples

Concentration of CO_2 molecules dissolved in champagne samples (before pouring), was determined using carbonic anhydrase (labeled C2522 Carbonic Anhydrase Isozyme II from bovine erythrocytes, and provided from Sigma–Aldrich, US). This is the official method recommended by the OIV (namely the International Office of Vine and Wine) for measuring the CO_2 content in Champagne and sparkling wines. This method is thoroughly detailed in two recent papers [28,31].

2.5. Mosalux procedure

Foam measurements using the Mosalux apparatus were performed as described by Maujean et al. [1]. Mosalux gives the foaming parameters of a still wine, a sparkling wine previously degassed, or any non-effervescent solution. The base wines were filtered (0.45 μm) before foam analysis and the champagne wines were also degassed prior to filtration. Then, 100 mL of the sample was introduced in a glass cylinder (4 cm in diameter and 40 cm long) with a glass frit (pore size 16–40 μm) at the bottom. The carbon dioxide was injected through the glass frit at a constant rate flow (7 L h^{-1}) and a constant pressure (1 bar). Foam height was then measured during gas injection and followed for 8 min. Two parameters were obtained with this method: foamability which corresponds to the maximum height reached by the foam column and foam stability which represents the height at which the foam stabilizes during carbon dioxide injection. Experiments were