Available online at www.sciencedirect.com
ScienceDirect
Food Chemistry 103 (2007) 404–412
Food Chemistry
www.elsevier.com/locate/foodchem

Aging characteristics of different beer types

Bart Vanderhaegen *, Filip Delvaux, Luk Daenen, Hubert Verachtert, Freddy R. Delvaux

Centre for Malting and Brewing Science, Katholieke Universiteit Leuven, Kasteelpark Arenberg 22, B-3001 Heverlee, Belgium

Received 14 February 2006; received in revised form 20 April 2006; accepted 17 July 2006

Abstract

Eight commercial beers (3 lager beers, 2 dark ales and 3 high-alcoholic ales) were aged for one year under normal storage conditions, and the changes with time of flavour profile and the concentration of 15 volatile compounds were monitored. The compounds were chosen as markers to evaluate the importance of different reactions in the aging process of each beer type. The development of typical aging flavours during beer storage could be linked to the Maillard reaction, the formation of linear aldehydes, ester formation, ester degradation, acetal formation, etherification and the degradation of hop bitter compounds. A difference in the nature of aging flavours between lager and specialty beers was found and seemed to be mainly the result of an increased Maillard reaction in specialty beers. Based on the results, some practical strategies are proposed to improve the flavour stability, depending on the beer type.

Keywords: Beer; Aging; Flavour stability; Staling; Brewing

1. Introduction

The flavour of bottled beer changes with time of storage. Beer aging is considered to be a major quality problem since the aging flavours are mostly experienced as unpleasant. Furthermore, the type of flavour evolution during storage is uncontrollable, making it difficult for brewers to assure a constant product quality or to meet some consumers' expectations regarding flavour (Stephenson & Bamforth, 2002). Therefore, much research on beer has been devoted to the chemistry of the aging phenomenon (Bamforth, 1999; Hashimoto & Kuroiwa, 1975; Kaneda, Kobayashi, Takashio, Tamaki, & Shinotsuka, 1999). Most of these studies are focussed on lager beers, since they represent the largest part of the beer market. Consequently, the aging processes in specialty beers are less understood and methods to improve their flavour stability are scarce.

In the past, specialty beers were produced by small breweries and restricted to local markets. However, due to market globalization, production volumes and export of the specialty beers are rapidly increasing. This has resulted in longer transportation times and variable storage conditions, which demand more attention to the production of beers with improved flavour stability. A first step in optimizing the brewing process, with respect to flavour stability, consists in characterizing the sensory and chemical aging properties of beer. Due to differences in production processes, it can be expected that the aging characteristics differ between beer types.

A comparison of the flavour stability of different beers is usually based on the determination of one of the following parameters: the endogenous reducing power, measured by one of the many procedures available (Araki et al., 1999; Chapon, Louis, & Chapon, 1981; Kaneda, Kobayashi, Furusho, Sahara, & Koshino, 1995), the concentration change during storage of a particular beer constituent, such as trans-2-nonenal (Larsen, Aastrup, Nielsen, & Lillelund, 2001), furfural (Brenner & Khan, 1976), 5-hydroxymethylfurfural (Shimizu et al., 2001), ethyl pyruvate (Shimizu, Nara, & Takashio, 2005), or storage-induced sensory changes (Mikyska, Hrabak, Haskova, & Srogl, 2002). However, each of the first methods evaluates only the

---

* Corresponding author. Tel.: +32 16321948; fax: +32 16321576.
E-mail address: bart.vanderhaegen@biw.kuleuven.be (B. Vanderhaegen).

0308-8146/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2006.07.062

resistance of beer to just one type of staling process and gives only a partial insight into the total chemical changes causing the perceived stale flavour. On the other hand, sensory tests give an overall view of flavour stability, but generally little information about specific chemical reactions involved.

In this study, we analyzed the aging characteristics of eight different beers by determination of both the sensory profile and the evolution of chemical staling markers, during a storage period of one year at 20 °C. A correlation is sought and discussed between beer properties and the aging behaviour.

2. Materials and methods

2.1. Chemicals

The following substances, with corresponding purities were supplied by Sigma Aldrich Chemie GmbH (Munich, Germany): ethyl acetate (99.9%), *iso*-amyl acetate (99.7%), ethyl hexanoate (99+%), ethyl lactate (98%), ethyl 3-methylbutyrate (99.7%), ethyl 2-methylbutyrate (99%), acetaldehyde (99,5%), *n*-hexanal (98%), 3-methylbutanal (98%), diacetyl (99.5%), 4-methylpentan-2-one (99%) and 2-furfural (99%). 2-Furfuryl ethyl ether, with a purity of 95%, was purchased from Narchem Corporation (Chicago, IL, USA).

2.2. Beer aging conditions

Eight fresh commercial beers, obtained from different Belgian breweries, were used to examine the effect of natural aging. All beers were bottled with total oxygen levels below 0.2 mg/l. Beers were stored for one year at 20 °C in the dark.

2.3. Beer analysis

Beer colour was measured at 430 nm according to the method of Seaton and Cantrell (1993).

Bitterness of beer was measured according to Analytica EBC method 9.8 (European Brewery Convention, 1998).

2.4. Analysis of staling markers in beer

Prior to analysis, 200 μl of internal standard solution (250 mg/l of 2-heptanol) and 200 μl of a 10% antifoam solution (Sigma Aldrich Chemie GmbH, Munich, Germany) were added to 50 ml of degassed beer. Beer was degassed by Kieselguhr filtration. Five millilitres of beer were transferred by a Tekmar-Dohrman Aquatek 70 autosampler (Emerson, Mason, USA) into the Tekmar-Dohrman 3000 purge and trap concentrator (Emerson, Mason, USA) unit with a Vocarb 3000 trap (Supelco, Bellefonte, PA, USA). The following conditions were used: helium was the carrier gas, 10 min purge at 140 °C, 8 min dry purge at 140 °C, 6 min desorption at 250 °C and 10 min bake at 260 °C. The temperatures are those of the adsorbing trap while the beer sample temperature was kept at 20 °C during purging. Before entering the GC, volatiles were concentrated using a cold trap with a MFA 815 control unit (ThermoFinnigan, San Jose, CA, USA) under the following conditions: initial temperature, −70 °C, final temperature; 200 °C. GC was performed using a Fisons GC 8000 gas chromatograph equipped with a Chrompack CP-WAX-52-CB column (length 50 m, internal diameter 0.32 mm, film thickness 1.2 μm; Varian, Palo Alto, CA, USA). The temperature programme was: 3 min at 50 °C / 4 °C min^{-1} and 3 min at 240 °C. Total ion mass chromatograms were obtained in the Fisons MD 800 quadripole mass spectrometer (ionization energy: 70 eV; source temperature: 250 °C) and analyzed using the Masslab software programme for identification and quantification of volatiles.

2.5. Quantification of volatile compounds

Quantification was performed for compounds of which a standard reference compound was commercially available. Peak areas were normalized using 2-heptanol as an internal standard. Calibration factors were determined using the standard addition method and creating linear regression models. Target ions were used in the identification and quantification of each component. For each compound, a coefficient of variance (CV) was calculated from the areas obtained from 8 consecutive injections of the same beer sample.

2.6. Sensory analysis

Sensory tests on aged beers were carried out with a trained panel of 10 members. Four beers were randomly presented in one session to the panellists. Besides an evaluation of the general aging character, the stale flavour was also evaluated for six aspects by giving a score from 0 to 8. Typical aged beer flavours (Sherry / Madeira, cardboard, solvent, old hops, red fruit and caramel), characterised in a previous study (Vanderhaegen et al., 2003), were used for the evaluation. A score of 0 meant the particular flavour aspect was not present, a score of 8 meant that the particular flavour aspect was extremely strong.

3. Results and discussion

3.1. General

The aging characteristics of 8 commercial Belgian beers; 3 pilsner beers (L-A, L-B and L-C) and 5 specialty beers (S-A, S-B, S-C, S-D and S-E) were compared. These beers differed by their alcohol percentage, pH, colour and bitterness (see Table 1). From the colour values, it is clear that S-A and S-C are dark beers. On the other hand, S-B, S-C, S-D and S-E are high alcoholic beers. Furthermore, S-D is characterized by a high bitterness and L-B by a relatively high pH.