Pol. J. Food Nutr. Sci., 2015, Vol. 65, No. 2, pp. 137–142
DOI: 10.1515/pjfns-2015-0006
http://journal.pan.olsztyn.pl

Original article
Section: Food Quality and Functionality

Influence of Sweetness and Ethanol Content on Mead Acceptability

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Key words: mead, sweetness, ethanol content, fermentations, sensory analysis

Mead is a traditional alcoholic beverage obtained by fermenting mead wort; however, its production still remains frequently an empirical exercise. Different meads can be produced, depending on fermentation conditions. Nevertheless, to date few studies have been developed on factors that may influence mead quality. The main objective of this work was to study the influence of sweetness and ethanol content on mead acceptability. Different meads were produced with two sweetness levels (sweet and dry meads) and three ethanol contents (18, 20, 22% (v/v)), adjusted by brandy addition. Afterwards, meads acceptability was evaluated by sensory analysis through a consumers' panel (n=108) along with chemical analysis by HPLC-RID of glucose, fructose, ethanol, glycerol and acetic acid.

The sweet (75 $g_{glucose+fructose}$/L) and dry (23 $g_{glucose+fructose}$/L) meads presented glycerol contents equal to 5.10±0.54 and 5.96±0.95 g/L, respectively, that were desirable since glycerol improves mead quality. Low concentrations of acetic acid were determined (0.46±0.08 and 0.57±0.09 g/L), avoiding the vinegar off-character. Concerning sensory analysis, the alcohol content of mead had no effect on the sensory attributes studied, namely, aroma, sweetness, flavour, alcohol feeling and general appreciation. Regarding sweetness, the "sweet meads" were the most appreciated by the consumers (score of 5.4±2.56), whereas the "dry meads" (score of 2.7±2.23) showed low acceptability. In conclusion, this work revealed that sweetness is a sensory key attribute for mead acceptance by the consumers, whereas ethanol content (18 to 22% (v/v)) is not.

INTRODUCTION

Beekeeping is an important income-generating activity in several countries. Portugal is no exception. In rural communities of NE of Portugal, honey production is of great importance; however, sometimes local beekeepers face problems during the sale of their productions due to the low prices practised in international markets. Thus, the development of new honey products can contribute to overcome this problem, to strengthen the local economy and to increase honey production activity competiveness.

Mead is a traditional alcoholic beverage obtained by fermenting mead wort and can represent a good solution to honey over-production and a way of valorising honey of lower quality. Its production has been known since ancient times; however, it still remains frequently an empirical and traditional exercise. Some problems are often encountered during mead production, such as: delayed or arrested fermentations, production of unpleasant *flavors*, poor quality and inconsistency of the final product [Attfield, 1997; Bisson, 1999]. These problems are due to the high sugar and low nutrient contents of honey; its natural antifungal components; and the inability of yeast strains to adapt to these unfavourable growth conditions [Roldán *et al.*, 2011].

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In order to overcome some of these fermentation problems, several research studies have been conducted by our research group focusing on the influence of mead wort composition [Pereira *et al.*, 2009] and the effect of production scale and operational conditions on final product quality [Gomes, 2010; Gomes *et al.*, 2010, 2011].

The role of using different *Saccharomyces* strains [Caridi *et al.*, 1999] and types of honey [Vidrih & Hribar, 2007] on mead production, immobilized ethanol-tolerant yeasts [Navratil *et al.*, 2001], must formulation [Mendes-Ferreira *et al.*, 2010], different heat treatments of honey solutions [Kime *et al.*, 1991a], application of ultra-filtration of honey solution [Kime *et al.*, 1991b], and inoculum size and yeast pitching rate [Pereira *et al.*, 2013], as well as the addition of black rice grains [Katoh *et al.*, 2011] or pollen [Roldán *et al.*, 2011], on mead quality and aroma profile have already been studied by other research groups.

Concerning sensory properties of mead, these are very important for its acceptance by the final consumer. Until now, few studies have been performed on this subject. Only the effects of honey type [Vidrih & Hribar, 2007; Gupta & Sharma, 2009], heat treatment [Kime *et al.*, 1991a], ultrafiltration [Kime *et al.*, 1991b], pollen [Roldán *et al.*, 2011] and black rice grains [Katoh *et al.*, 2011] addition on mead sensory properties have been studied. Nevertheless, sweetness and ethanol content of beverages are fundamental characteristics for their acceptability by the consumer. Smogrovicova *et al.* [2012] verified that different meads have distinct residual sugar contents, reporting that South African meads presented a mean residual sugar content about 70 g/L, whereas higher concentrations were determined in Slovak meads. Nevertheless, in that work no organoleptic studies were performed and so until now nothing is known about the role of sweetness and ethanol content on mead acceptability. As fermentation time influences sugar content and alcohol content, longer times will lead to fewer sugars and higher ethanol concentrations in the final product. Hence, fermentations performed along different time periods will lead to products with different physico-chemical and sensory properties.

In spite of this, the main objective of this work was to study the influence of sweetness and ethanol content on mead acceptability. So, different meads were obtained by allowing the fermentation process to take place along different times. Then, the chemical and sensory characteristics of the meads were evaluated, in order to get knowledge about the role of sweetness and ethanol content on their acceptability.

MATERIALS AND METHODS

Reagents

All chemicals, namely glucose, fructose, saccharose, ethanol, glycerol, acetic acid and tartaric acid, were of analytical grade and purchased from Sigma Chemical Co. (St. Louis, MO, USA). Phosphoric acid was obtained from Fisher Scientific (Porto Salvo, Portugal). Type 2 deionised water was obtained from a TGI pure water system (USA).

Honey and yeast strain

In this study, honey derived from plants of the *Ericaceae* (heather) family (*Erica* spp.) purchased on the Honey House of Trás-os-Montes region (NE of Portugal) was used in all experiments. The yeast strain used was *Saccharomyces cerevisiae,* from Fermol® Reims Champagne (Pascal Biotech®, Brescia, Italy), which is recommended for commercial production of white wines.

Fermentation conditions

The fermentation medium was prepared from honey diluted with water (395 g/L), supplemented with commercial nutrients (90 g/hL) (Enovit®, Brescia, Italy) and 6% (v/v) of SO_2 (8 g/hL). The pH was corrected to 3.5 with tartaric acid, as described by Gupta & Sharma [2009].

The honey mixtures were inoculated with freeze-dried yeast cells (30 g/hL), previously hydrated in water with the addition of saccharose (50 g/L) and incubated at 35ºC for 20 min. The fermentations occurred in cubes of 25 L, using a working volume of 20 L, at 25ºC. All fermentations were performed in triplicate. Density and Beaumé degrees were measured by aerometry at regular intervals.

To produce the "sweet meads", the fermentation process was interrupted at 79 hours when the density was approximately 1060 g/mL by the addition of brandy with 77% (v/v) of alcohol, using the procedure described by Pato [1982]. Mead sweetness was equivalent to 8 ºBeaumé. The mead was divided and the alcohol content was adjusted to 18, 20 and 22% (v/v) with brandy. For production of "dry meads", fermentations continued until reaching a density of about 1020 g/mL. At the end, brandy was added to obtain the alcoholic contents of 18, 20 and 22% (v/v).

Fermentation parameters analysed

Biomass was determined periodically by optical density at 640 nm (Jenway Genova®, Staffordshire, United Kingdom). Glucose, fructose, ethanol, glycerol, and acetic acid were quantified individually, following the methodology described by Pereira *et al.* [2009] and using a Varian HPLC system (Agilent, Santa Clara, USA) equipped with a Rheodyne injector with 20 μL loop, a Supelco Gel C-610H column (300×7.8 mm) at 35ºC and a refractive index detector RI-4 (Varian, Agilent, Santa Clara, USA). Isocratic elution was employed with a mobile phase consisting of 0.1% (v/v) phosphoric acid at a flow rate of 0.5 mL/min. Data were recorded and integrated using the Star Chromatography Workstation software (Varian, Agilent, Santa Clara, USA). Glucose, fructose, ethanol, glycerol and acetic acid were quantified by external standard calibration.

Sensory analysis

The sensory attributes of meads (acceptability) were evaluated by a consumers' panel randomly selected among the academic community of our Institution (IPB). Three testing sessions were organised, each one with 36 persons (total = 108), in a sensory evaluation room equipped with individual cabins. The "sweet meads" and "dry meads", varying in the alcohol content (18, 20 and 22%, v/v) were tasted by all consumers. The samples testing order were randomised in order to remove the effect of sample order presentation from the consumers' evaluation. The consumers evaluated the six meads on a continuous scale from 0 (dislike extremely) to 10 (like extremely) for the following sensory attributes: aroma, flavour, sweetness, alcohol feeling and general appreciation.

Statistical analysis

The data obtained from the consumers' sensory evaluation were analysed by the R® software. The effects of sweetness and alcohol content were evaluated by the following mixed model:

$$Y_{ijk} = \mu + AC_i + S_j + T_k + e_{ijk}$$

where: Y_{ijk} is the sensory appreciation of the k consumer for the mead with i alcoholic content and j sweetness; μ is the overall mean; AC_i is the fixed effect of the alcohol content (i = 1, 2, 3); S_j is the fixed effect of sweetness (j = 1, 2); T_k is the random effect of the consumer (k = 1, 2, …, 108); e_{ijk} is the random error with zero mean and variance 1.

All interaction terms were removed from the full model since they revealed as non-significant ($p > 0.05$) in a preliminary analysis of the data.

RESULTS AND DISCUSSION

Mead fermentations

The rates of yeast growth, sugar consumption, and ethanol, glycerol and acetic acid productions during mead fermentations are represented in Figure 1. In sweet and dry mead fermenta-

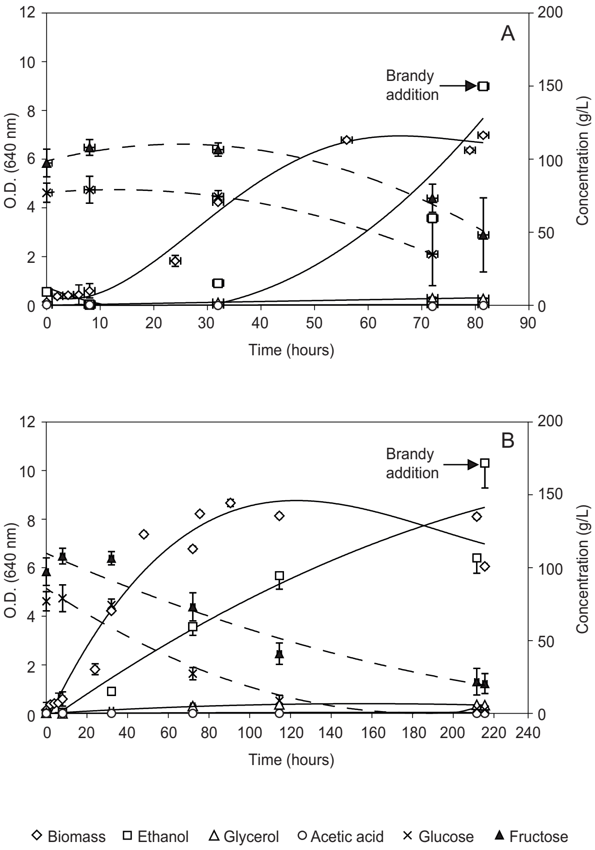

FIGURE 1. Mead fermentations development. Evolution of biomass, ethanol, glycerol, acetic acid and reducing sugars are indicated for sweet (A) and dry (B) meads.

tions (Figures 1A and 1B, respectively), lag phases around 10 hours were observed. The exponential phases followed approximately 45 hours. In sweet mead (Figure 1A), the sugar consumption percentage corresponded to about 80% of the initial level. Glucose and fructose were simultaneously consumed from the beginning to 27±4.2 g/L and 48±9.6 g/L, respectively. As the sweetening power of fructose is higher than glucose (approximately twice), it is expected that these conditions provided very sweet drinks [Lee, 1987]. At the time that the fermentations stopped, the ethanol content was equal to 59.5±0.42 g/L. Glycerol and acetic acid were also produced, reaching concentrations of 5.10±0.54 and 0.46±0.08 g/L, respectively. This low acetic acid content avoided the vinegar off-character [Mendes-Ferreira *et al.*, 2010] that could be developed in the drink.

Figure 1B represents the fermentation development for "dry mead". In this case, ethanol content amounted to 106.8 g/L. This concentration was smaller than that reported by Ukpabi [2006] for cassava honey mead (12.7–15.0%), and Vidrih & Hribar [2007] after fermentation of chestnut, lime and honeydew meads (14.2%). On contrary, our results of "sweet" and "dry" meads were similar to the ethanol contents (4.6 to 11.8%) reported by Gupta & Sharma [2009] for home brewed and commercial meads made from soya honey. Glucose and fructose were metabolised by yeast to values of 2.5±0.9 g/L and 20.4±6.8 g/L, respectively. In this case, it was observed that the glucose consumption rate was higher than that of fructose. The final concentrations of glycerol and acetic acid (5.96±0.95 and 0.57±0.09 g/L, respectively) were similar to those obtained in sweet mead fermentations. The glycerol concentrations reported here were in agreement with those obtained by Pereira *et al.* [2009] of 4.2 to 5.7 g/L, using dark and light honeys enriched with a nitrogen source during mead production.

Regarding glycerol, the production of this component is desirable to obtain good quality meads since its presence, like in wine, improves quality by influencing sweetness, fullness and smoothness. On contrary, the presence of acetic acid is highly undesirable. Our results were identical to those described by Pereira *et al.* [2009] and Mendes-Ferreira *et al.* [2010] who reported meads with a volatile acidity from 0.51 to 0.84 g acetic acid/L. The acetic acid contents reported by Róldan *et al.* [2011], and Sroka & Tuszynski [2007], when studying the influence of pollen addition and the use of buckwheat honey, were of 1.4±0.18 g/L and 0.7 to 1.0 g/L, respectively, values above the sensory threshold for table wines of 0.7 g acetic acid/L.

Ethanol is a primary metabolite that is expected to be produced during the exponential phase; however, in this study, its production was also observed along the stationary phase during both "dry" and "sweet" mead productions. This fact is similar to the reported previously by Pereira *et al.* [2009] and Gomes [2010].

In general terms and regarding both experiments ("dry" and "sweet" meads), the glycerol concentrations obtained were similar and within the values reported in the literature for wines [Scanes *et al.*, 1998]. In relation to the acetic acid, similar results were obtained for both types of mead, being the values smaller than the limit of human perception and within the contents reported for Port wines [Esteves *et al.*, 2004].

TABLE 1. Scores given by the consumers' panel to meads with different alcohol and sweetness contents in relation to aroma, sweetness, flavour, alcohol feeling and general appreciation.

		Aroma	Sweetness	Flavour	Alcohol	General appreciation
Alcohol content (% (v/v))	18	4.4±2.41[a]	3.8±2.57[a]	3.8±2.61[a]	4.0±2.54[a]	4.1±2.83[a]
	20	4.3±2.43[a]	3.9±2.56[a]	4.0±2.63[a]	4.2±2.37[a]	4.1±2.70[a]
	22	4.7±2.39[a]	3.8±2.70[a]	3.9±2.84[a]	4.4±2.61[a]	4.0±2.77[a]
Sweetness	Sweet	4.9±2.46[a]	5.2±2.42[b]	5.1±2.63[b]	5.0±2.36[b]	5.4±2.56[b]
	Dry	4.0±2.27[b]	2.5±2.02[a]	2.7±2.18[a]	3.4±2.39[a]	2.7±2.23[a]

Values within columns with the same letter are not significantly different (p>0.05).

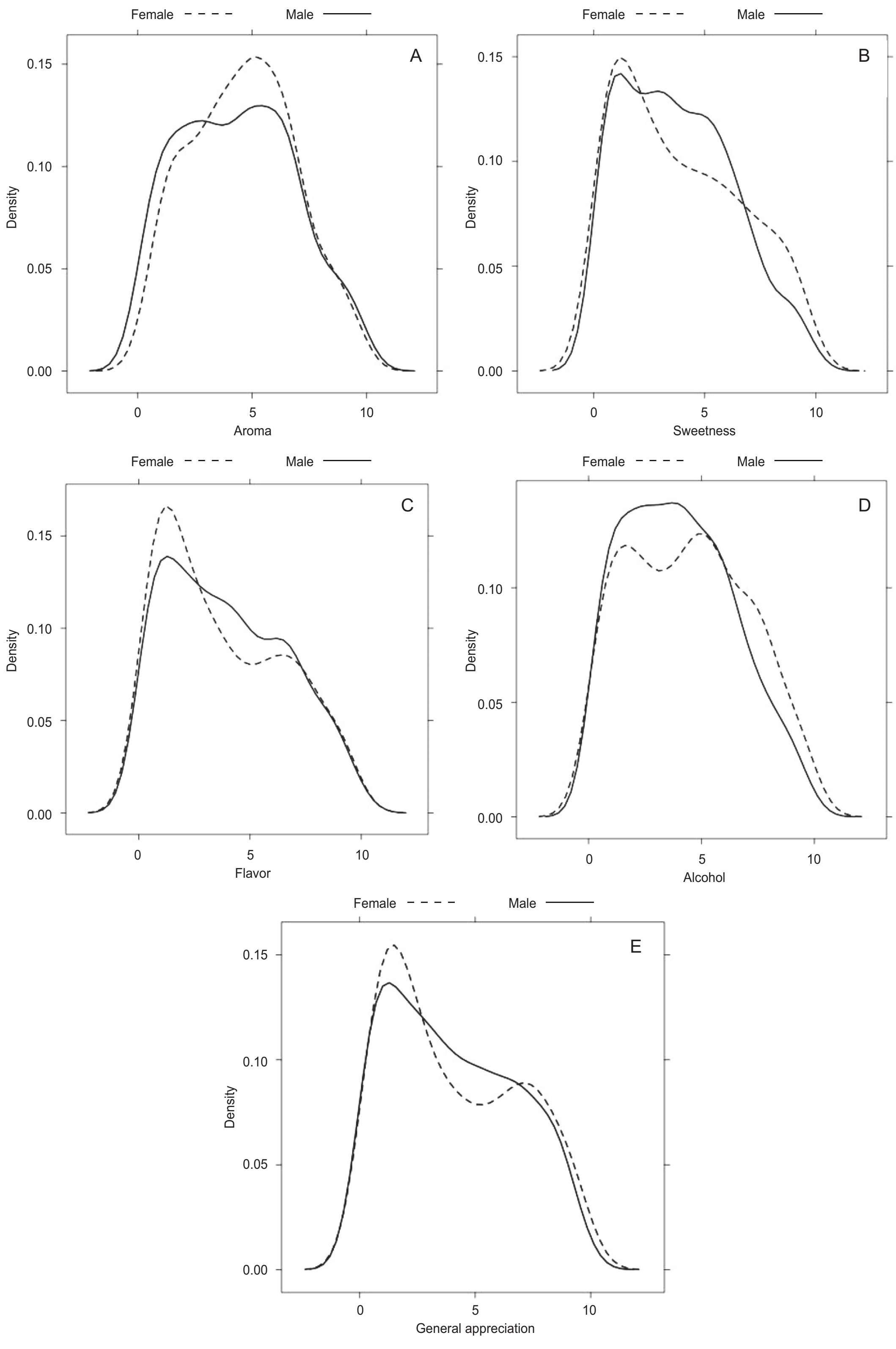

FIGURE 2. Density plots for consumers' evaluation of meads aroma (A), sweetness (B), flavour (C), alcohol feeling (D) and general appreciation (E) by gender.

Sensory analysis

The sensory evaluation scores of meads obtained by the consumers' panel are shown in Table 1.

The statistical analysis was performed using the full model presented in the Materials and Methods section. This analysis showed that the interaction between alcohol degree and sweetness was non-significant ($p>0.05$) for all sensory parameters evaluated. Thus, a reduced model was used without this interaction term.

The alcohol content of mead had no effect ($p>0.05$) on the sensory attributes studied, namely, aroma, sweetness, flavour, alcohol feeling and general appreciation. Even

TABLE 2. Correlations among mead sensory attributes.

Variables	General appreciation	Aroma	Sweetness	Flavour	Alcohol content
General appreciation	1				
Aroma	0.43	1			
Sweetness	0.76	0.44	1		
Flavour	0.82	0.51	0.79	1	
Alcohol content	0.69	0.40	0.65	0.62	1

though, three alcohol levels were studied (18, 20 and 22% (v/v)), no significant differences on consumers' scores regarding the alcohol feeling of the meads were observed. On contrary, sweetness had a significant effect on mead sensory evaluation of consumers. The sweet meads had always higher scores ($p<0.05$) in aroma, sweetness, flavour, alcohol feeling and general appreciation, than dry meads. Thus, the meads with the highest sugar content (sweet meads) were the most appreciated by the consumers' panel. Taking into account the scale from 0 (dislike extremely) to 10 (like extremely), the mean value obtained for general appreciation of 5.4 ± 2.56 suggested that consumers liked slightly the "sweet meads". On other hand, the "dry meads" were rated significantly ($p<0.05$) lower, 2.7 ± 2.23, showing their low acceptability by the consumers.

The correlations among the sensory attributes of meads varied from 0.40 to 0.82 as shown in Table 2. The general appreciation presented high correlations (> 0.75) with sweetness and flavour, indicating the relative importance of these two attributes for mead acceptability by consumers. The correlation between flavour and sweetness was high ($r=0.79$), showing the important effect of sweetness on mead flavour.

Regarding gender, no differences ($p>0.05$) were found between males and females for the sensory attributes of meads, as shown by the density plots (Figures 2A to 2E), where similar distributions were observed for men and women for all sensory parameters studied.

CONCLUSIONS

Different types of mead with different sweetness and alcohol content were successfully produced by halting the fermentation process at different times and by adding different quantities of brandy. Thus, this study showed that it is possible to produce meads with different sweetness and alcohol content by changing the fermentation conditions. Sweetness influences significantly the sensory properties of mead, unlike alcohol content on the range of 18 to 22% (v/v). The sweet meads were the most appreciated by the consumers regardless their alcohol contents, showing that mead sweetness is an essential requisite for consumers' acceptability.

In conclusion, the present work showed that the final sugar content in mead is a key point for guaranteeing its acceptance by consumers. In order to increase consumers' overall satisfaction, further studies should be conducted to define the optimum sugar content to be used in future mead production.

ACKNOWLEDGEMENTS

We acknowledge the financial support (Project PTDC/AGR-ALI/68284/2006) from Fundação para a Ciência e Tecnologia (FCT) of the Portuguese Republic Government.

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Submitted: 12 May 2014. Revised: 28 July 2014. Accepted: 11 September 2014. Published on-line: 15 April 2015.