Food Chemistry 185 (2015) 200–204

Contents lists available at ScienceDirect

Food Chemistry

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

The chemistry of sour taste and the strategy to reduce the sour taste of beer

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ARTICLE INFO

Article history:
Received 19 November 2014
Received in revised form 27 February 2015
Accepted 23 March 2015
Available online 4 April 2015

Chemical compounds studied in this article:
Acetic acid (PubChem CID 176)
Lactic acid (PubChem CID 612)
Pyruvic acid (PubChem CID 1060)
Oxalic acid (PubChem CID 971)
Fumaric acid (PubChem CID 444972)
Succinic acid (PubChem CID 1110)
Malic acid (PubChem CID 525)
Tartaric acid (PubChem CID 875)
Citric acid (PubChem CID 311)

Keywords:
Chemistry
Sour taste
Hydrogen ions
Protonated acid species
Beer

ABSTRACT

The contributions of free hydrogen ions, undissociated hydrogen ions in protonated acid species, and anionic acid species to sour taste were studied through sensory experiments. According to tasting results, it can be inferred that the basic substance producing a sour taste is the hydrogen ion, including free hydrogen ions and undissociated hydrogen ions. The intensity of a sour taste is determined by the total concentration of free hydrogen ions and undissociated hydrogen ions. The anionic acid species (without hydrogen ions) does not produce a sour taste but can intensify or weaken the intensity of a sour taste. It seems that hydroxyl or conjugated groups in anionic acid species can intensify the sour taste produced by hydrogen ions. The following strategy to reduce the sensory sourness is advanced: not only reduce free hydrogen ions, namely elevate pH value, but also reduce the undissociated hydrogen ions contained in protonated acid species.

1. Introduction

Sour taste is one of the five basic tastes, namely sweetness, sourness, saltiness, bitterness, and umami, and is often perceived on the sides of the tongue, towards the rear of the mouth (Bishop, 1971). Sour taste is one of the independently identifiable sensory attributes of beer (Clapperton, 1973; Clapperton, Dalgliesh, & Meilgaard, 1976; Langstaff & Lewis, 1993). Sour taste has an important effect on beer flavour. Generally speaking, a moderate sour taste is necessary for beer, as it can reduce the cloying feeling of the beer. Nevertheless, too strong a sour taste will destroy the harmony of the beer flavor, and is considered to be a kind of flavour deficiency except for sour beer. High levels of sour and acidic flavours used to be thought to be due to a sanitation problem (Kulka & Walker, 1946). Gram positive bacteria, such as *Lactobacillus* and *Pediococcus*, which are present in dust and saliva, can infect beer by generating haze or rope, causing unpleasant flavour changes, such as sourness (Vaughan, O'Sullivan, & Van Sinderen, 2005) (Menz et al., 2010). *Pectinatus* and *Megasphaera* often spoil beer in the later stages of processing, causing high turbidity in beer and formation of by-products that cause off-flavours and sour tastes, making the beer unsuitable for consumption (Paradh, Mitchell, & Hill, 2011). Beer without spoilage is also perceived to have a prominent sour taste, especially adjunct beers in which worts have weak buffering capacity. A consumer is unlikely to repurchase a sour product. Thus, it is highly important to control the sour taste of beer.

Knowledge of the chemistry of sour taste is necessary to control the sensory sourness of beer. A previous study proposed a newer hypothesis for the chemical basis for sour taste perception: that the intensity of a sour taste in acidic solutions or acidified foods is linearly related to the molar concentration of all organic acid species, with at least 1 protonated carboxyl group, plus the molar concentration of free hydrogen ions (Johanningsmeier, Mcfeeters, & Drake, 2005). Neta, Johanningsmeier, and Mcfeeters (2007) reviewed the effects of hydrogen ions, protonated acid species,

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http://dx.doi.org/10.1016/j.foodchem.2015.03.135
0308-8146/

titratable acidity, anions, molar concentration, and the physico-chemical properties of organic acids on sour taste (Neta et al., 2007).

In the present study, the contributions of free hydrogen ions, undissociated hydrogen ions in protonated organic acids, and anionic acid species to sour taste were studied through specially-designed tasting trials.

2. Materials and methods

2.1. Reagents and chemicals

Hydrochloric acid (36–38%), sodium acetate (⩾99%), and sodium hydroxide were of analytical grade and were purchased from the Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China). Acetic acid (⩾99.7%), pyruvic acid (⩾97.0%), lactic acid (⩾85.0%), oxalic acid (⩾99.0%), citric acid (⩾99.0%), succinic acid (⩾99.0%), fumaric acid (⩾99.0%) and malic acid (⩾97.0%) were supplied by Fluka (Buchs, Switzerland). Ultrapure water, with a resistivity of more than 18.2 MΩ cm, was used throughout the study for all experiments.

2.2. Sour taste threshold determination

The ascending method of limits (ASTM E679), as described in the ASBC Methods of Analysis (ASBC, 2007; Irwin, Bordeleau, & Barker, 1993), was used to determine the best estimate threshold (BET) of hydrogen ions and some common organic acids in water.

A solution containing an appropriate concentration of target compound in water was used to spike pure water. Six sets of three glasses of water at room temperature (one with target compound and two controls) were tasted by 16 assessors. The concentration of target compound was doubled from one set to the next, and the assessor was asked to identify the pair in each triangle. The individual BETs were calculated as the geometric mean of the highest missed concentration, and the next highest. The group BET was calculated from the individual results.

2.3. Sensory evaluation of the intensity of sour taste

A system of intensity scoring was used, with ten trained tasters asked to assess the samples on a scale of sourness from 0 to 5, where 0 = absent, 1 = slight, 2 = noticeable, 3 = obvious, 4 = strong and 5 = extreme. The arithmetical mean values of the tasting panel scores represented the extent of the sour taste.

3. Results and discussion

3.1. Difference in the intensity of sour taste between acetate solutions and acetic acid solutions

In order to obtain more knowledge about the chemistry of sour taste, a specially-designed sensory tasting test was conducted. In this tasting test, the intensity of sour taste from sodium acetate solutions of 50, 100, and 150 mg/l was assessed, along with the intensity of sour taste from acetic acid solutions of 50, 100, and 150 mg/l. The results are shown in Fig. 1. It can be clearly seen from Fig. 1 that all the sodium acetate solutions had no sour taste although they all contained anionic acetic acid species (AC^{-1}). However, all the solutions of acetic acid had an evident sour taste, and the intensity of sour taste increased as the concentration of all acetic acid species became elevated.

The reasons for the difference in sour taste between sodium acetate and acetic acid solutions can be speculated from the differences in composition between sodium acetate and acetic acid solutions. The major differences between solutions were the concentration of hydrogen ions and the concentration of protonated acid species. The pH was about 7.1 for the sodium acetate solution, and the pH values were 3.77, 3.59 and 3.49 for 50, 100 and 150 mg/l acetic acid solutions, respectively. In an aqueous solution there is an equilibrium between different acetic acid species, and the extent of the equilibrium is determined by the pKa value. The ratios of different acetic acid species can be calculated by the pH value. For acetic acid, its pKa value is 4.75 at 25 °C. Thus, it can be calculated that the anionic acetic acid species is more than 99% when the pH is over 6.75, and that the protonated acetic acid species accounts for more than 99% when the pH is less than 2.75. Therefore the sodium acetate solution just contained the anionic acetic acid species as its pH value was about 7.1.

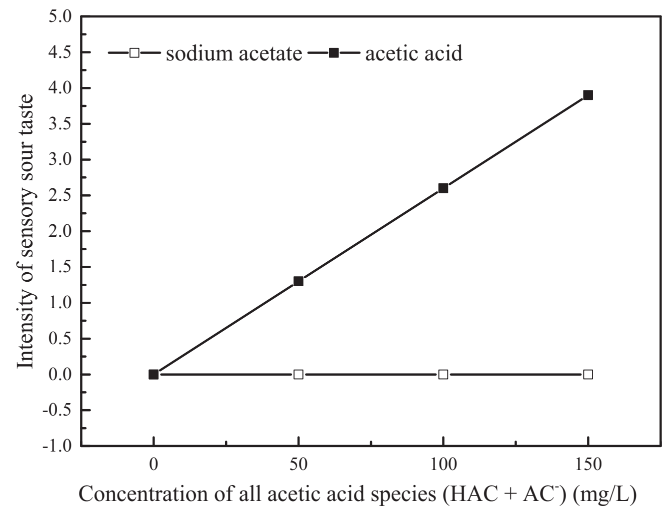

Fig. 1. The intensity of sour taste of acetic acid solutions and sodium acetate solutions.

Therefore it can be concluded that the anionic acid species makes no contribution to sour taste, and that hydrogen ions and protonated acid species could be the chemical substances producing sour taste.

3.2. The contribution of the protonated organic acid species to sour taste

In order to verify whether the protonated acid species makes a contribution to sour taste, different concentrations of sodium acetate solutions were prepared and adjusted to pH 4.0 using hydrochloric acid. The intensity of sour taste of these solutions was then scored (Fig. 2). Fig. 2 shows that the intensity of sour taste for these sodium acetate solutions increased with an increase in concentration of protonated acetic acid species. In the acetate solutions, the concentrations of hydrogen ions were identical, but the concentrations of protonated acetic acid species were different. Thus the results suggested that the protonated acetic acid species cannot only produce a sour taste, but the higher its concentration, the stronger is the sour taste.

3.3. The contribution of free hydrogen ions to sourness

3.3.1. The threshold of sour taste of free hydrogen ions

To ascertain that free hydrogen ions are one of the chemical substances that produce a sour taste, aqueous solutions with different concentrations of free hydrogen ions were evaluated with regard to the intensity of sour taste. It was discovered that the lower the pH value, the higher was the intensity of sour taste (data