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Extraction of aroma compounds of fruit juices by air stripping using a bubble column operating with antifoam and its effect on juice properties

Ricardo Schmitz Ongaratto, Marselle Marmo do Nascimento Silva, Paulo Laranjeira da Cunha Lage *, Cristiano Piacsek Borges

Programa de Engenharia Química, COPPE, Universidade Federal do Rio de Janeiro, P.O. Box 68502, 21941-972 Rio de Janeiro, RJ, Brazil

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ABSTRACT

The objective of this work was to evaluate the effect of air bubbling on the physicochemical properties and ascorbic acid concentration of fruit juices during the extraction of their volatile aroma compounds using a bubble column operated with antifoam. The ideal concentration of a commercial antifoam agent was also evaluated to ensure a non-foaming operation during air bubbling in the fruit juice for the range of gas superficial velocity between 1 and 2 cm/s. Besides, aroma extraction from a surrogate solution was evaluated, being the best extraction efficiency obtained for ethyl butyrate (97%), followed by hexanal (93%), ethyl acetate (81%) and linalool (32%). However, there was no significant variation of these efficiencies for the gas superficial velocities employed. Finally, after 4 h of air bubbling in fresh fruit juice, there were no changes of pH, total soluble solids, titratable total acidity and color of the juice and just a 15% reduction in the concentration of the ascorbic acid. Thus, the use of air stripping in a bubble column was proved to be an interesting alternative to extract aroma compounds from fruit juice without causing any appreciable change in its properties.

1. Introduction

Aroma extracts are widely used in food industry to improve the flavor of formulated foods or to compensate for the flavor loss during industrial processing of natural raw products. Food industries and aroma manufactures are thus seeking technologies that allow the selective extraction of aroma compounds from odorous wastewater.

The volatile compounds present in fresh and processed fruit juices are largely responsible for their flavor and aroma, which are a complex mixture of aldehydes, alcohols, ketones, esters, lactones, terpenes and other substances (Rui-Aumatell et al., 2004). During juice processing, its aroma can be seriously altered. Conventional thermal concentration of liquid foods presents major drawbacks such as the deterioration induced by heat and the loss of the nutritional value of the concentrated product. It is well known that most of the aroma compounds in the raw juice are lost in the first few minutes of evaporative concentration. The aroma profile degrades irreversibly causing a reduction in the product quality (Petrotos and Lazarides, 2001). A possible way of minimizing these changes is to use various separation techniques for the recovery of the aroma compounds.

Various methods such as distillation (Sahraoui et al., 2011; Yanniotis et al., 2007), solvent extraction (Cheong et al., 2013; Ramírez et al., 2010; Wang et al., 2013), adsorption (Diban et al., 2007; Edris et al., 2003; Yanniotis et al., 2007), gas stripping (Komthong et al., 2006; Ribeiro Jr. et al., 2004), supercritical fluid extraction (Gracia et al., 2007; Moldão-Martins et al., 2000; Opstaele et al., 2012) and membrane processes, as pervaporation (Isci et al., 2006; Lipnizki et al., 2002; Mafi et al., 2013; Pereira et al., 2006), vapor permeation (Ribeiro Jr. et al., 2004), vacuum membrane distillation (Bagger-Jorgensen et al., 2004; Hasanoglu et al., 2012; Viladomat et al., 2006) and liquid–liquid extraction with membrane contactors (Kertész and Schlosser, 2005; Souchon et al., 2004) have been utilized or studied to extract and/or recover the aroma compounds from the natural sources or waste streams. Distillation and liquid/liquid extraction, based on the volatility and hydrophobicity of the molecules to be extracted, respectively, cover the majority of industrial applications (Souchon et al., 2004). However, these techniques suffer from several

* Corresponding author. Tel.: +55 21 25628346; fax: +55 21 25628300.
E-mail address: paulo@peq.coppe.ufrj.br (P.L. da Cunha Lage).

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Nomenclature

A	area
C	concentration
D	diameter
H	height
k_x	mass transfer coefficient
N	rate of introduction of bubbles into the column
Q_0	gas flow rate through an orifice
t	time
t_b	mean bubble residence time in the column
t_c	characteristic time for aroma extraction
u_g	superficial gas velocity
V	volume
V_l	total volume of liquid in the bubble column
X_1	gas flow in model adjustment, Eq. (1)
X_2	antifoam concentration in model adjustment, Eq. (1)
Y	foaming rate in model adjustment, Eq. (1)

Greek symbols

α_g	global gas hold up
φ	dimensionless concentration
τ	dimensionless time

Subscripts

0	initial
b	bubble
c	column
eq	equilibrium

Superscripts

CL	clear liquid
L + G	liquid and gas

limitations, which have led to the search for a highly efficient and low-cost alternative technology.

The gas stripping is an alternative to extract aroma compounds from fruit juice. Ribeiro Jr. et al. (2004) studied a new aroma recovery process, in which aroma extraction was brought about by gas stripping in a bubble column and aroma concentration was performed by vapor permeation. Ribeiro Jr. et al. (2005) proposed an alternative route for fruit juice processing, whose first step was this process of extraction and recovery of aroma compounds. Komthong et al. (2006) removed terpene hydrocarbons from the freshly squeezed orange juice using a bubble column. In all cases, an aqueous solution containing aroma compounds was used as a surrogate of the fruit juice.

At the same time, foaming is a problem associated to the gas stripping process applied to fruit juice. Foaming is a phenomenon occurring in different industrial technologies involving gas–liquid processes, such as the processing of pulp, paper, food, detergents and paints, textile dyeing, fermentations, wastewater treatments, flotation of ores and several operations in the oil industry. There are two factors necessary to foam occurrence: the formation of gas bubbles in the liquid and their stabilization through the adsorption of surface-active agents at their interfaces. In order to decrease foam stability, a wide range of antifoams and defoamers are applied. Defoamers destroy existing foam, while antifoams prevent foam formation by enhancing bubble coalescence (Joshi et al., 2009).

The most representative studies applying bubble columns for flavor extraction from fruit juices are those of Ribeiro et al. (2004) and Komthong et al. (2006). The former work evaluated the effect of gas bubbling only using a surrogate solution, without analyzing foam formation or property changes in the actual fruit juice. The latter work performed experiments with fresh juice and used an antifoam, but the juice was heated and the physicochemical properties of the juice were not evaluated. In both cases, the extraction was carried out with inert gas (N_2). The usage of air would make the process cheaper. Thus, the aim of this work was to study the feasibility of implementing air stripping using a bubble column for extraction of volatile compounds from fruit juices.

In order to meet our goal, it was necessary to perform three kinds of experiments: the quantitative evaluation of the effect of air superficial velocities in the extraction efficiency of several volatile aroma compounds from a surrogate solution; the determination of the ideal concentration of an antifoam agent to prevent foam formation in bubbling air through a fruit juice and the evaluation of the effect of the aroma stripping using air on the juice physicochemical properties.

2. Materials and methods

2.1. Materials

The experimental set up used for conducting the experiments is shown in Fig. 1. The system was fed with dry compressed air (dew point at 273 K) whose flow rate was measured using a calibrated rotameter and controlled by a needle valve placed before the

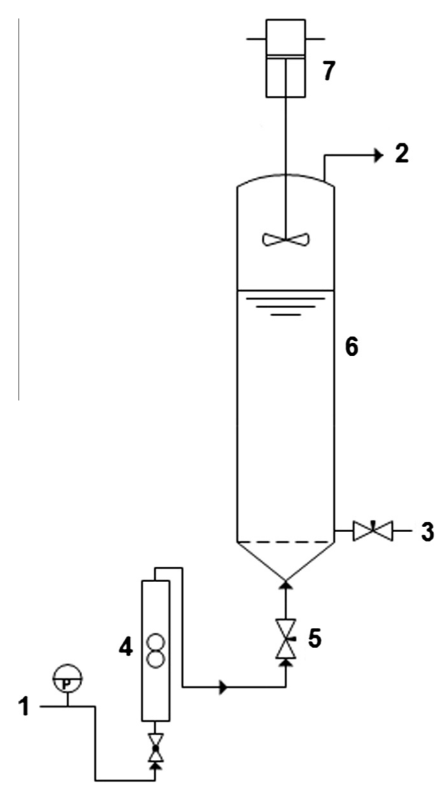

Fig. 1. Experimental set up: 1 – gas inlet; 2 – gas outlet; 3 – liquid removal; 4 – rotameter; 5 – needle valve; 6 – bubble column; 7 – agitator.