Food Chemistry 151 (2014) 182–190

Contents lists available at ScienceDirect

Food Chemistry

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

Optimisation of low temperature extraction of banana juice using commercial pectinase

Sorel Tchewonpi Sagu [a], Emmanuel Jong Nso [a], Sankha Karmakar [b], Sirshendu De [b,*]

[a] Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI), University of Ngaoundere, P.O. Box 455, Adamaoua, Cameroon
[b] Department of Chemical Engineering, Indian Institute of Technology, Kharagpur, Kharagpur 721 302, India

ARTICLE INFO

Article history:
Received 29 July 2013
Received in revised form 31 October 2013
Accepted 6 November 2013
Available online 16 November 2013

Keywords:
Banana juice
Extraction
Enzymatic treatment
Optimization
Response surface methodology

ABSTRACT

The objective of this work was to develop a process with optimum conditions for banana juice. The procedure involves hydrolyzing the banana pulp by commercial pectinase followed by cloth filtration. Response surface methodology with Doehlert design was utilised to optimize the process parameters. The temperature of incubation (30–60 °C), time of reaction (20–120 min) and concentration of pectinase (0.01–0.05% v/w) were the independent variables and viscosity, clarity, alcohol insoluble solids (AIS), total polyphenol and protein concentration were the responses. Total soluble sugar, pH, conductivity, calcium, sodium and potassium concentration in the juice were also evaluated. The results showed reduction of AIS and viscosity with reaction time and pectinase concentration and reduction of polyphenol and protein concentration with temperature. Using numerical optimization, the optimum conditions for the enzymatic extraction of banana juice were estimated. Depectinization kinetics was also studied at optimum temperature and variation of kinetic constants with enzyme dose was evaluated.

1. Introduction

Banana, mango, guava, and pineapple are major fruits planted widely in tropical and subtropical regions of Africa, Asia and South America. Banana has a high nutrition value and is a good source of energy due to its high level of starch and sugar. It is also a source of vitamins A and C, potassium, calcium, sodium and magnesium (Fabiano, Sueli, Odisse, Gaspareto, & Edson, 2006). Banana is highly appreciated due to its aroma and flavour. It is consumed mainly as fresh fruit and only a small quantity is stored. Banana is very susceptible to deterioration due to rapid decomposition when ripened, and techniques of cold storage are not quite suitable. Considerable amount of this fruit is wasted due to inadequate processing and preservation techniques (Maskan, 2000). For valorisation of this product, the common processed banana products manufactured are banana puree, banana figs, banana powder or flour, banana chips, canned banana slices, banana jam and banana vinegar (Tsen & King, 2002). Studies were carried out to remove water. For this, previous works focused predominantly on drying banana. Mowlah, Takano, Kamoi, and Obara (1983), Mulet, Berna, and Rossello (1989) and Wang and Chen (1998) worked on modelling of the drying kinetics of banana. Minh-Hue and Price (2007) worked on influence of experimental parameters like slab thickness, banana maturity and harvesting season on air-drying of banana. Fabiano et al. (2006) optimised osmotic dehydration of banana followed by air-drying. Several works also focused on banana puree (Tsen & King, 2002).

Bananas are also suitable for juice production but the processing of the banana after harvesting is a major challenge (Mohapatra, Mishra, Singh, & Jayas, 2011). One of the biggest problems is the pectinaceous nature of the banana fruit that makes juice extraction difficult. Gensi, Kyamuhangire, and Carasco (1994) accomplished extraction of banana juice from ripe peeled or unpeeled bananas by a traditional method of mashing with hands in plastic basins using *Imperata cylindrica* grass as a processing aid. This study was conducted to elucidate traditional methods to produce banana juice in Uganda. Byarugaba-Bazirake (2008) applied commercial enzymes (Rapidase CB, Rapidase TF, Rapidase X-press and OE-Lallzyme) in the processing of banana juice for wine production. The objective was to vary enzyme concentration at different range and observe the parameters influencing wine processes. Dhamsaniya and Varshney (2013) developed a process to evaluate whey beverage with ripe banana juice. Banana slices along with water in the ratio of 1:2 (banana slice:water, w/w) were heated at 100 °C for 45 min followed by the cooling, pressing, centrifuging, filtration, pasteurization (at 90 °C for 10 min) and again cooling at room temperature and no enzyme was used. Besides that, some works have led to the optimization of operating conditions of banana juice extraction. A three-level rotatable design was used by Shahadan and Abdullah (1995) to determine optimum conditions for the extraction of banana juice. The effects of temperature

* Corresponding author. Tel.: +91 3222 283926; fax: +91 3222 255303.
E-mail address: sde@che.iitkgp.ernet.in (S. De).

0308-8146/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodchem.2013.11.031

Nomenclature

ANOVA	Analysis of variance
AIS	Alcohol insoluble solids, g of residue/g of the sample in %
AAD	Average absolute deviation
A_f	Accuracy factor
B_f	Bias factor
C	AIS concentration
GAE	Gallic acid equivalent, mg GAE/100 ml of sample
I	Number of variables
k	Kinetic constant, min^{-1}
N	Number of experiments
P	Probability level
R^2	Coefficient of determination
RSM	Response surface methodology
x_i	Coded variables given par the Doehlert table
X	Real variables
X_i	Middle (centre) of variable
ΔX_i	Increment
Y	Response variable
$Y_{i,cal}$	The calculated response
$Y_{i,exp}$	The experimental response
TSS	Total soluble sugar, degree brix
v	Volume, l
w	Weight, g

Greek symbols

β_{ij}	Coefficient of the interactions terms
β_{ii}	Coefficient of the quadratic terms
β_i	Coefficient of the linear terms
β_0	Constant term

(20–50 °C), pH (2.7–4.3) and enzyme concentration (0.13–0.47%) on the yield of banana juice were studied after 4 h reaction time. In this work, yield was taken as the only experimental response and the effect of incubation time was not taken into account. Lee, Yusof, Hamid, and Baharin (2006a) used response surface methodology (RSM) and the central composite experimental design to optimize conditions for hot water extraction of banana juice and then used commercial pectinolytic enzymes and amylolytic enzyme both to accomplish clarification processes (Lee, Yusof, Hamid, & Baharin, 2006b). Pieces of banana were treated with temperature range (35–95 °C) and time (30–120 min). The optimum conditions found were 95 °C for 120 min. The effect of hot water extraction on juice yield, total soluble sugar and sensory evaluation of the juice were studied and the results showed that temperature was the most important factor affecting the characteristics of the banana juice.

It appears from the previous works that the heating up to 95 °C is often used as the first step of extraction of the juice and enzymes are subsequently used for clarification, to reduce high viscosity due to banana pulp. It is not shown by Lee et al. (2006a), the effect of the processing on the preservation of nutritional quality of the final product like protein concentration, total polyphenol, vitamins, Na, K, and Ca. In this regard, Yuanshan et al. (2013) conducted a study on comparing characteristics of banana juice from banana pulp treated by high pressure carbon dioxide and mild heat. The temperatures were 45, 50, 55, and 60 °C, and treatment time was 30 min. The results showed that residual polyphenol oxidase in the juice from high pressure carbon dioxide treated banana pulp was lower than that from mild heat treated banana pulp and its minimum was 11.6% at 60 °C. These results motivate us to investigate and find new procedure to extract banana juice that does not require significant energy input (lower temperature), lower enzyme concentration along with evaluation of nutritional properties of the product obtained and optimize operating parameters.

Optimizing refers to improving the performance of a process in order to obtain the maximum benefit from it. During long time, optimization has been carried out by monitoring the influence of one factor at a time on an experimental response and while only one parameter is changed, others are kept at a constant level (one-variable-at-a-time optimization) (Granato, Branco, & Calado, 2010). The disadvantages of this technique are many. These are: large number of experiments; interactive effects among the variables are not studied and complete effects of the parameters on the response are not depicted (Lundstedt et al., 1998). Response surface methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes in which a response of interest is influenced by several variables and the objective is to optimize this response (Granato et al., 2010). To apply the RSM methodology, many experimental designs are available. Box–Behnken design is a three-level factorial arrangement. All factor levels have to be adjusted only at three levels with equally spaced intervals between these levels (Bezerra, Santelli, Oliveiraa, Villar, & Escaleira, 2008). It is efficient and economical for using less number of experiments but lacks accuracy (Lundstedt et al., 1998). Central composite designs are based on a full or fractional factorial design, with an additional number of center points and two axial points on the axis of each design variable at a distance α from the center. All factors are studied in five levels ($-\alpha$, -1, 0, +1, $+\alpha$). It requires a large number of experiments including experiments outside the studied domain that may not be possible for some systems. Developed by Doehlert, the Doehlert design is a practical and economical alternative in relation to other second-order experimental matrices. This design describes a circular domain for two variables and spherical for three variables, which increases the uniformity of the studied variables in the experimental domain (Bezerra et al., 2008). Each variable is studied at a different number of levels and presents some advantages, such as requiring few experimental points for its application and high efficiency.

In this regard, the objectives of this work were firstly to use the commercial pectinase to treat banana pulp for juice extraction under lower range of temperature and use the response surface methodology (RSM) with Doehlert design to determine the optimal conditions. In addition to clarity and viscosity, some nutritional parameters like total polyphenol, protein concentration, calcium, sodium and potassium were also evaluated. Secondly, different concentrations of pectinase were used to study the kinetics of depectinization on banana pulp.

2. Materials and methods

2.1. Materials

2.1.1. Experimental material

Fresh, mature and ripe bananas of *Musa acuminate* (with green skin), commonly referred as Dwarf Cavendish banana variety were obtained from a local market at Kharagpur in West Bengal, India.

2.1.2. Enzyme and other chemicals

Pectinase (EC 3.2.1.15) from *Aspergillus niger* with activity 3.5–7 units/mg was purchased from Sisco Research Labratory, Mumbai,