IMPACT OF OHMIC TREATMENT ON ASCORBIC ACID CONTENT OF RED RASPBERRY JUICE

Mircea Oroian
Faculty of Food Engineering, Stefan cel Mare University of Suceava
Universitatii Street, No. 13, Suceava, Romania
e-mail: m.oroian@fia.usv.ro

Abstract
The aim of this study is to evaluate the influence of ohmic treatment on ascorbic acid content of red raspberry juice using an HPLC-UV method. The ascorbic acid was eluted using a KH_2PO_4 0.02 M corrected with o-phosphoric acid to pH 3.5 mobile phase, with a flow rate of 0.6 mL/min. The wavelength of the diode array detector (DAD) was set at 254 nm; the elution time was observed at 7.003 minutes. The ohmic treatment consisted in using 3 voltages (60 V, 100 V and 140 V, respectively) during an exposure time (1 min, 2 min, 3 min, 4 min and 5 min respectively). The ascorbic acid content ranged between 973 mg/L (initial concentration) to 941 mg/L (the lowest concentration reached at 140 V for 5 minutes). The evolution of ascorbic acid with voltage and exposure time has been modelled using a quadratic model, based on two parameters: voltage (60 V, 100 V and 140 V, respectively) and exposure time (1 min, 2 min, 3 min, 4 min and 5 min respectively), obtaining a model with a good regression coefficient (R^2 = 0.922%). The optimization applied to the experimental data it seems that the suitable conditions for the ohmic treatment are 98 V for 5 min as the ascorbic acid not to be damaged noticeable (972.13 g/L).

Keywords: red raspberry, ohmic treatment, ascorbic acid, HPLC, modelling, optimization

Submitted: 10.11.2014 Reviewed: 10.02.2015 Accepted: 02.03.2015

1. INTRODUCTION

Ohmic heating of food products involves the passage of alternating electrical current through them, thus generating internal heat as the result of electrical resistance (Reznick, 1996). This technology provides rapid and uniform heating when the absence of a hot surface in ohmic heating reduces fouling problems and thermal damage to a product (Sastry & Barach 2000). The energy generation is proportional to the square of the local electric field strength and the electrical conductivity of the product (Ruan et al. 2001). This technology is one alternative to thermal processing that allows high-temperature/short-time processing (Stirling 1987, Mercali et al. 2014)

Ohmic heating application have a tremendous potential in such field of food processing technology as preheating, blanching, sterilization, extraction, evaporation or dehydration. Ohmic heating was used, for example, to increase the efficiency of sucrose extraction from sugar beet (Lima, Heskitt & Sastry, 2001). Its advantages, compared to conventional heating, include maintaining the colour and nutritional value of food, shorter processing times and highly yields (Castro, Teixeira, Salangke, Sastry & Vicente 2004, Jakob et al. 2010)

Non-uniform heating of foods (e.g. conventional pasteurization process) promotes such degradation reactions but also to production of potentially hazardous chemicals such as precursors of furans (e.g. 5-HMF and furfural) (Fan 2005) and losses of nutrients (sugars, amino acids, ascorbic acid).

Ascorbic acid is not only a natural antioxidant but a processing aid commonly used in foodstuffs formulations to prevent browning and enhance shelf-life, provided enough ascorbic level was present to consumer all oxygen in the product (Nicolas et al. 2003, Louarme & Billaud 2012).

The aim of this study is to evaluate the impact of ohmic treatment on the ascorbic acid level intro red raspberry juice using an HPLC-UV method.

2. MATERIALS AND METHODS

Materials
Red raspberry was purchased from the Suceava local market. The juice sample has been made using the red raspberry fresh and pressed using a laboratory device. The analysed juice had a 10 °Brix concentration.

Experiment
The juice sample has been heated up to 80 °C, after the heating, the juice sample (100 mL) was subjected at three different ohmic treatment (60, 100 and 140 V respectively) for 1, 2, 3, 4 and 5 min respectively. After the ohmic treatment the sample has been cooled down and the ascorbic acid content has been analysed.

Ascorbic acid determination
The chromatographic system consists into a High Performance Liquid Chromatography (HPLC) Shimadzu system equipped with a LC-20 AD liquid chromatograph, SIL-20A auto samples, CTO-20AC auto sampler and a SPD-M-20A diode.Data collection and subsequent processing were performed using the LC solution software. A stainless C18 steel analytical column (250 x 4.6 nm, 4.5 µm) was used. The mobile phase used was KH_2PO_4 0.02 M corrected with *o*-phosphoric acid to pH 3.5. The calibration curve has been made using 3 main concentration (25 mg/L, 50 mg/L and 100 mg/L). The flow rate was set at 0.6 mL/min, and λ = 254 nm.
4 g of sample is mixed up with 12 ml of acid solution (perchloric acid 10% and 1 % *o*-phosphoric acid). The mixture is transferred into a 50 ml flask and filled up with mobile phase. The solution is filtered twice using Whatman 5 filter paper. 20 µl of the sample is injected into HPLC system. The ascorbic acid was eluted at 7.003 minutes.

Ascorbic acid modelling
The experiment was conducted into two factor full factorial experiment. Each parameter (time and voltage) had at least 2 levels, as: time – 6 levels (0, 1, 2, 3, 4 and 5 min respectively) and voltage temperature – 3 levels (60, 100 and 140 V).
The full factorial design was designed and created using Design expert (trial version) to cover the range of investigated solutions. Voltage and time exposure were chosen as independent variables and the ascorbic acid was the design response.
The coded values (table 1) were applied for statistical calculations, according to the following equation (Poroch-Seritan et al. 2011, Myers 2002):

$$x_i = \frac{z_i - z_i^0}{\Delta z_i}, i = \overline{1,n} \, (1)$$

where: x_i denotes the coded level of the variable (dimensionless value, z_i is the actual value of the variable); $z_r$or z_i^0 is the centre point of the variable and Δz_i is the interval variation.
Central composite design (CCD), used extensively in RSM experimental design, was employed to evaluate the individual and interactive effects of four main controllable variables on the dye removal efficiency (output response). CCD with four input variables consists of 18 experiments with 30 orthogonal two levels full factorial design points (coded as ± 1).

Table 1 Correspondence between actual and coded values of design variables

Design variables	Symbol	Actual values of coded levels	
		-1	+1
Voltage (V)	X_1	60	140
Exposure time (min)	X_2	0	5

The model used for predicting the evolution of the extraction efficiency was a second-order (quadratic) polynomial response surface model which can be applied to fit the experimental results obtained by central composite design.
The second-order (quadratic) polynomial response surface model which describes the relationship between the experimental results is:

$$y = b_0 + \sum_{i=1}^{n}(b_i x_i) + \sum_{i=1}^{n}(b_{ii} x_{ii}^2) + \sum_{ij=1}^{n}(b_{ij} x_i x_j) (2)$$

where: y is the predicted response (removal efficiency, %), x_i denotes the coded levels of the design variable (time, temperature, humidity, lake width – table 1), b_0 is a constant, b_i - linear effects, b_{ii} - quadratic effects and b_{ij}- interaction effects. These coefficients were calculated by means of ordinary least square estimation that could be written as follows:

$$b = \left(X^T X\right)^{-1} X^T Y \quad (3)$$

where: b is a vector of coefficients, X in the design matrix for coded levels of variables and Y is the vector of response which is obtained experimentally and is in accordance with central composite design.
The optimization of parameters simultaneously is very important for predicting the ascorbic acid destruction. The desirability function approach is used to optimize the multiple characteristics concurrently. The optimization has been made based on the model proposed by Montgomery (2005).

2. RESULTS AND DISCUSSIONS

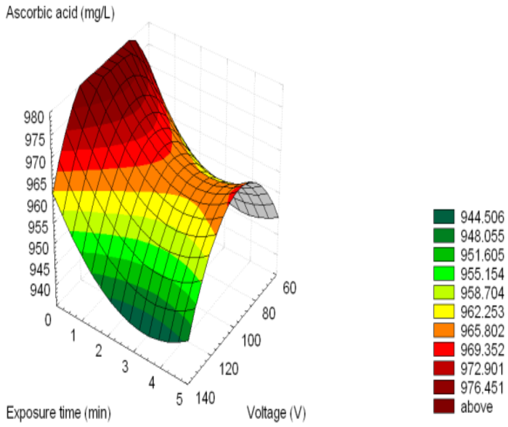
The initial ascorbic acid content and the percentage of the ascorbic acid during each ohmic treatment are presented in the table 2. In all the cases during the exposure time it seems that the ascorbic acid content is decreasing, the highest degradation is observed at 140 V/ 5 min. In the case of the ohmic treatment with 100 V it can be observed the lowest degradation. The highest degradation of ascorbic acid reached 3.29%.
Lima et al. (1999) verified that the presence of an electric field had no significant effect on the ascorbic acid degradation in orange juice. Although there was electrolysis and metal corrosion when stainless steel electrodes were used, these phenomena did not affect the final concentration of ascorbic acid. In other paper, Asisiry et al. (2003) observed that the ohmic treatment on a buffer solution (pH 3.5), the temperature, the power and the NaCl concentration affected the degradation rate of ascorbic acid.
Mercali et al. (2012) observed in their study regarding the influence of ohmic treatment of acerola pulp ascorbic acid that the degradation ranged between 3.08 % and 10.63%, higher percentages than in this work.

Table. 2. Ascorbic acid evolution with voltage and exposure time

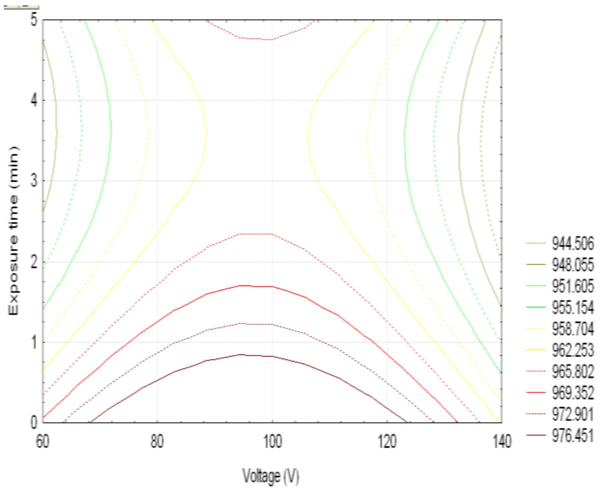
Voltage (V)	Time (min)	Ascorbic acid (mg/L)	Ascorbic acid degradation (%)
60	0	973	-
60	1	971	0.20
60	2	950	2.36
60	3	946	2.77
60	4	942	3.19
60	5	940	3.39
100	0	973	-
100	1	970	0.31
100	2	970	0.31
100	3	970	0.31
100	4	968	0.51
100	5	968	0.51
140	0	973	-
140	1	946	2.77
140	2	943	3.08
140	3	942	3.18
140	4	941	3.29
140	5	941	3.29

In the figure 1 is presented the ascorbic acid of red raspberry evolution with voltage and exposure time. It can be observed that at 100 V the ascorbic acid destruction during the ohmic treatment is the most inoffensive.
The degradation evolution of ascorbic acid during the ohmic treatment has been studied using a quadratic model (2^{nd} order polynomial equation) with two variables (voltage and exposure time). The equation of the proposed model (eq. 4) is presented below. The model achieved reached a 0.922 regression coefficient and it is a significant one (*P-value* < 0.05). In table 3 are presented the model summary information. From the equation of the model it can be observed that voltage and exposure time have a linear significant negatively influence on the ascorbic acid content from the red raspberry juice. In the figure 2 are presented the correlation between the experimental data versus predicted data for ascorbic acid content in red raspberry juice.

$$Ascorbicacid = 965.01 - 3.00 * X_1 - 9.26 * X_2 - 19.50 * X_1^2 + 11.05 * X_2^2 + 1.14 * X_1 * X_2 \quad (4)$$



a



b

Fig.1. Ascorbic acid evolution with voltage and exposure time – (a) Spatial representation, (b) – Contour representation

Table 3 Model summary

Model	Standard deviation	R^2	R^2 – adjusted	*P-value*
Quadratic	8.16	0.922	0.892	0.001

The optimization was conducted as the ohmic treatment (voltage and exposure time) to have a low impact on the ascorbic acid content. The suitable conditions to maintain the ascorbic acid content in good concentration are: 98 V and 5 min as exposure time. The condition reached the highest desirability value (d = 0.813).

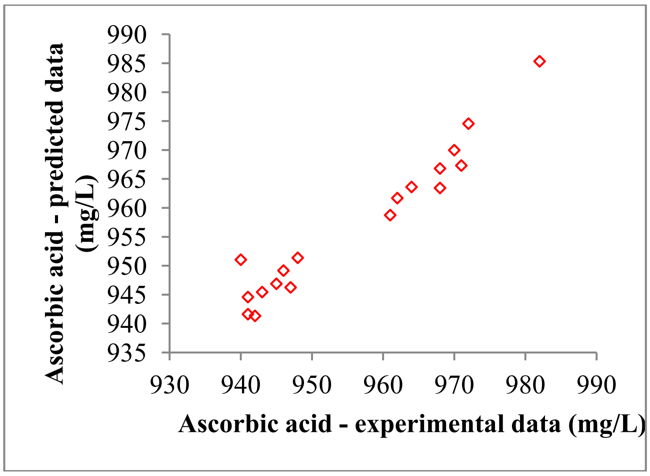


Fig. 2. Ascorbic acid content experimental vs. predicted data

4. CONCLUSIONS

Ascorbic acid is one of the most important antioxidant known with high positively influence on human body. The ohmic treatment of food has a lower influence on the ascorbic acid content from food than the traditional thermal treatments. The ascorbic acid from the red raspberry decreased with the exposure time of the ohmic treatment, but we observed that 100 V is the suitable voltage for preserving the vitamin content. The optimization applied to the experimental data it seems that the suitable conditions for the ohmic treatment are 98 V for 5 min as the ascorbic acid not to be damaged noticeable (972.13 g/L).

5. REFERENCES

[1] ASSIRY, A., SASTRY, S. K., SAMARANAYAKE, C., Degradation kinetics of ascorbicacid during ohmic heating with stainless steel electrodes.Journal of AppliedElectrochemistry, **33**,2003, 187-196

[2] CASTRO, I., TEIXEIRA, J. A., SALENGKE, S., SASTRY, S. K., VICENTE, A. A. Ohmic heating of strawberry products: Electrical conductivity measurements and ascorbic acid degradation kinetics. Innovative Food Science and Emerging Technologies, **5**(1), 2004, 27–36

[3] FAN, X., Formation of furan from carbohydrates and ascorbic acid following exposure to ionizing radiation and thermal processing. Journal of Agricultural and Food Chemistry, **53**, 2005, 7826-7831

[4] JAKOB, A., BRYJAK, J., WOJTOWICZ, H., ILLEOVA, V., ANNUS, J., POLAKOVIC, M.,Inactivation kinetics of food enzymes during ohmic heating, Food Chemistry, **123**, 2010, 369-376

[5] LIMA, M., HESKITT, B. F., & SASTRY, S. K.,Diffusion of beet dye during electrical and conventional heating at steady-state temperature. Journal of Food Process Engineering, **24**(2), 2001, 331–340.

[6] LIMA, M., HESKITT, B. F., BURIANEK, L. L., NOKES, S. E., SASTRY, S. K., Ascorbicacid degradation kinetics during conventional and ohmic heating.Journal ofFood Processing and Preservation, **23**(5), 1999, 421-443

[7] LOUARME, L., BILLAUD, C., Evaluation of ascorbic acid and sugar degradation products during fruit dessert processing under conventional or ohmic heating treatment, LWT- Food Science and Technology, **49**, 2012, 184-187

[8] MERCALI, G. D., SCHWARTZ, S., MARCZAK, L. D. F., TESSARO, I. C., SASTRY, S.,Ascorbic acid degradation and color changes in acerola pulp during ohmic heating: Effect of electric field frequency, Journal of Food Engineering, **123**, 2014, 1-7

[9] MONTGOMERY, D.C., Design and analysisof experiments (6th ed.), Hoboken: Wiley, 2005

[10] MYERS, R. H., DC process and product optimization using designed experiments.New York: Montgomery Wiley, 2002

[11] NICOLAS, J., BILLAUD, C., ROUET-MAYER, M.-A., PHILIPPON, J., Enzymatic browning -technical aspects and assays. In B. Caballero, L. Trugo, & P. M. Finglas (Eds.), Encyclopaedia of food sciences and nutrition (2nd ed.). (pp.686-692) London: Academic Press, 2003

[12] POROCH-SERITAN, M., GUTT, S., GUTT, G., CRETESCU, I., COJOCARU, C., SEVERIN, T., Design of experiments for statistical modelling and multi-resposnse optimization of nickel electroplating process, Chemical Engineering Research and Design, **89**, 2011, 136-147

[13] REZNICK, D.,Ohmic heating of fluid foods: Ohmic heating for thermal processing of foods: Government, industry, and academic perspectives. Food Technology, **50** (5), 1996, 250–251

[14] RUAN, R., YE, X., CHEN, P., DOONA, C.J., Ohmic heating. In: Richardson, P. (Ed.), Thermal Technologies in Food Processing. Woodhead Publishing Limited, Londres, 2001

[15] SASTRY, S. K., BARACH, J. T., Ohmic and inductive heating. Journal of Food Science, **65**, 2000, 42–46

[16] STIRLING, R., Ohmic heating – a new process for the food industry. Power Engineering Journal **1** (6), 1987, 365–371