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The effect of electrical processing on mass transfer and mechanical properties of food materials

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Abstract

A range of potential applications of electrical fields in the food industry has been investigated over the last decades. In this work the effect of electrical fields on mass transfer rates of cellular and hydrogel based foods was studied. Moderate Electrical Fields (MEF) of a continuous alternating current (50Hz frequency) at fields up to 1400 v/m were used. Results demonstrated that both electrical fields and thermal treatment had an enhancing effect the extraction of betanin from beetroot. Placing the sample at a position perpendicular to the electrical field was found to have an enhancing effect on the extraction. Application of MEF also appeared to enhance the rate at which rhodamine6G absorbed to hydrogels set with ions, with mass transfer increasing with an increasing electrical field. No significant mass transfer enhancement was observed for hydrogels that do not set ionically (e.g. gelatin and albumen)

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1. Introduction

Electrical processing has been suggested as an alternative technology for pasteurisation. Other potential applications are its capacity to affect mass transfer and structure of food material. Mass transfer in cellular materials under the application of electrical fields has been widely studied and has been shown to be improve for example extraction kinetics [1-3]. An enhancement of mass transfer was also reported when moderate electrical fields (MEF) were applied to the infusion of synthetic colorants in potato, potato-alginate mix and agar gels [4].

The diffusion of betanin from beet at MEF process using a range of frequencies (0 to 5000Hz) and field strengths (0 to 23.9 V/cm) for 3 min at a constant temperature (45°C) was found to increase with electric field strength and decrease with frequency [2]. The enhancement appeared to be significant when

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the product initially possessed an intact cell structure. No enhancement was observed in samples where cellular structure was either absent or previously completely permeabilised. The mechanism of diffusion enhancement was attributed to pores formation in cell membranes when a threshold potential above which significant increases in permeabilisation occur is trespassed. Red beet tissue samples were sandwiched between agarose, agar or alginate to study the effect of a DC voltage applied at electrical field strength of up to 40 V/cm, on the extraction of pigments and minerals from the red beet to the gels [5]. It was observed that the amount extracted decreased as the stiffness of the gel increased. Separation of different charged ions was detected in the different gel layers, i.e. cations in the gel near the cathode and anions in the gel near the anode.

MEF treatment has been reported to damage sugarbeet tissue [6]. The tissue was subjected to thermal, MEF (AC at 50Hz, electrical fields from 20 V/cm) and PEF (monopolar pulses of near-rectangular shape) treatments. Results showed that electrically stimulated damage of a sugarbeet tissue occurs even at relatively small electrical field strength (20 V/cm) if treatment time is long enough (around one hour). MEF treatment with field strength under 100 V/cm effectively disintegrated the sugarbeet tissue at temperatures of 50 to 60°C and treatment times below 100s. A dependence of damage efficiency on sample orientation with respect to the external electric field was observed.

In this work, the effect of moderate electrical fields on mass transfer in food materials was studied. Food materials used included cellular matrices and polymer networks.

2. Materials and Methods

MEF treatment was performed with continuous AC current (50Hz frequency) at electrical fields up to 1400 *V/m* using a jacketed processing cell to maintain constant temperature. Extraction of betanin from beetroot was monitored online and measured by spectrophotometry. Mass transfer of rhodamine6G into gel networks (alginate, albumin and gelatine) was measured by image analysis.

3. Results and Discussion

The application of MEF and thermal treatment had an enhancing effect on the extraction of betanin from beetroot. Fig. 1 shows the profiles of the average amount of betanin extracted vs. time from the triplicates done for each temperature and electrical field combination. Both the application of MEF up to 1000 V/m and the increase in processing temperature, enhanced the effusion of betanin from beetroot. The enhancement is proportional to the increase in temperature and electrical field. Temperature appears to have a more pronounced enhancing effect on extraction than the electrical field applied. At 60°C the enhancing effect of electrical processing was the highest compared with results at 40°C and 50°C. For example at 40°C, the average amount of betanin extracted increased approx. 40% from $3.95\text{x}10^{-5} kg_{Bet}kg_{Beet}^{-1}$ at $0 V\, m^{-1}$ to $5.50\text{x}10^{-5}\, kg_{Bet}kg_{Beet}^{-1}$ at $600 V/m$, increasing to $7.94\text{x}10^{-5} kg_{Bet}kg_{Beet}^{-1}$ at $1000 V/m$.

Kruskal-Wallis statistical analysis revealed that MEF had a significant effect on mass transfer at the temperatures above 40°C (i.e. 50 and 60°C) and at electrical field strength of 1000 V/m or higher.

Nevertheless, the results indicate that MEF and thermal treatment resulted in an increase in the extraction of betanin and cell structure damage. The betanin that is outside celld is removed by both thermal and electrical processes (appoplastic transport) then the cell membrane suffers temporary damage, caused by thermal and electrical heating as well, allowing the betanin to be extracted from the vacuole (symplastic transport). Although the disruption in the cell wall of the beetroot is caused by both thermal and electrical damage, for the range of conditions used in this study the effect of temperature to the cellular structure of the beetroot cells appeared to be more pronounced than the effect of MEF.

Results of the experiments performed to identify the effect of orientation are shown in Fig. 2. An electrical field of 1000 V/m was applied during 5 minutes at the beginning of the experiment. An enhancement in betanin extraction was observed when the slab was placed perpendicular to the electrical