Pulsed electric field technology for apple puree preservation: Escherichia Coli inactivation, quality and financial viability assessment

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Introduction

Food industries have been adopting more sustainable and resilient preservation processes aiming to provide safe and healthy products with a long shelf-life. Pulsed electric field (PEF) technology, based on pulsed power technology, is the application of an electric field to foods for a short time, to inactivate harmful bacteria by electroporation while maintaining food quality. Before fully implementing PEF technology in an industrial environment, a model that supports investment decisions is an extremely important factor that needs to be taken into account for a successful transfer. The objective of this study was to evaluate the inactivation of *Escherichia coli* WDCM00013 (ATCC 25922, ielab, a surrogate for the pathogenic *E. coli* O157:H7) in *Reineta Parda* apple puree treated by PEF and to present a model that supports investment decisions taken by Portuguese agri-food companies on using PEF equipment to apple puree processing with pasteurization replacement.

Materials and Methods

This study was carried out on an industrial environment at INOV.LINEA/TAGUSVALLEY. Apples were obtained from an industrial producer (Cooperfrutas) of Alcobaça, Portugal. Apple puree was processed by PEF (7, 10, and 12.5 kV/cm, 70 – 115 A, 44 – 604 kJ/kg, 2.5-45 s, with bipolar pulses, 8 μs per pulse) and by thermal pasteurization (CTP, 72 °C for 15 seg). Before any treatment, all samples were bleached at 100 °C for 2 min.

Figure 1. Sample preparation for PEF processing.

Before and immediately after all treatments, microbial, sensorial attributes and physicochemical characteristics such as colour, total soluble solids, and pH of puree were evaluated. Moreover, over the storage period (30 days under refrigerated storage 5 °C) the native microbial and inoculated *E. coli* loads were also evaluated.

Financial viability assessment was developed using 2021 data (CAE 10320) considering 20 Portuguese companies (table 1).

Table 1. Summary of the financial assessment.

Item	Scenario
Year of analysis	2021
1st year of project	2023
Project life (years)	5
Companies' samples	15 micro and 5 small companies
Conventional treated product price (Kg)	€ 5.75 + VAT
Annual product price increase (per year)	1%
Gross margin of cost of goods sold	42.77 %
External supply and services (2023)	€ 241.800
Personnel expenses (2023)	€ 118.620
Quantities sold (2023)	185.687 Kg
Growth rate of quantities sold (per year)	1%
Investment value (PEF Eq.)	€ 104.000
Annual amortization rate	12.5 %
Tangible fixed assets (2023)	€ 643.300

Results and Discussions

Microbial quality

The results showed that PEF treatment at 10 kV/cm, 115 A, 604 kJ/kg, 70 bipolar pulses of 8 μs, and 57.2°C was the most successful due to possible synergistic effects of mild heat, resulting in more than 5 log CFU/g of *E. coli* inactivation, meeting FDA requirements to achieve the pasteurization status.

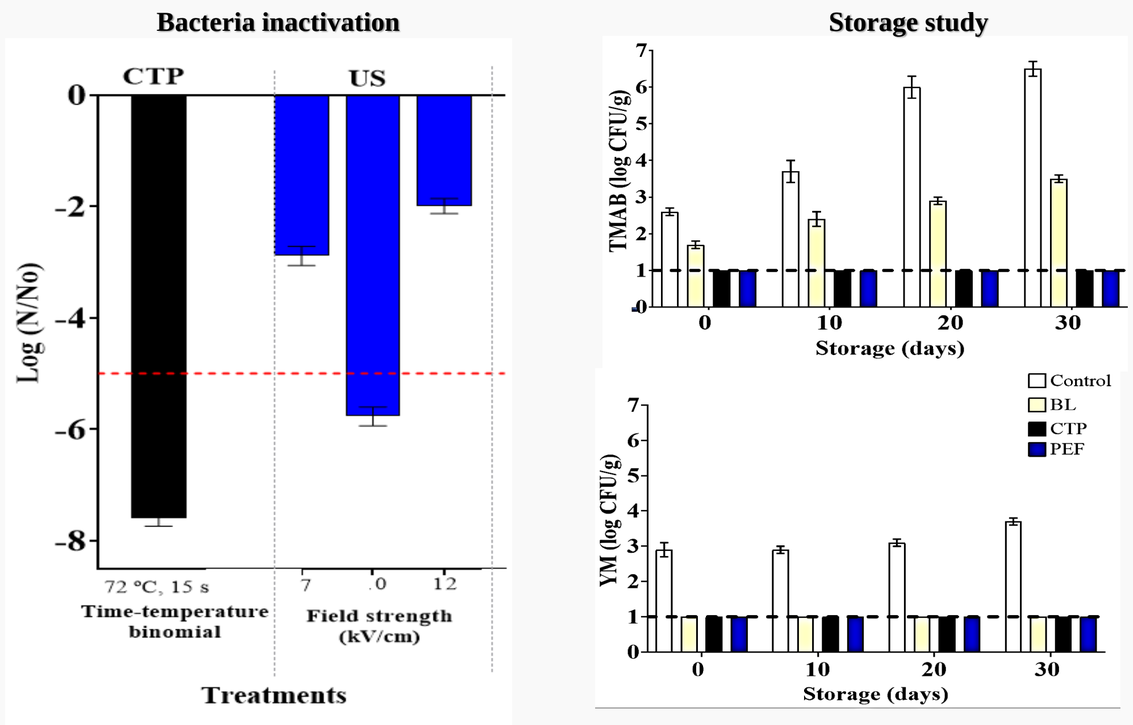

Figure 2. Inativation of inoculated *E. coli* and changes in the mean total aerobic mesophilic, mould and yeast populations in the samples puree during 30-day refrigerated storage at 5 °C.

Unsurprisingly, control (unprocessed) and BL (bleaching) samples revealed microbial growth throughout the 30 days of storage. Nonetheless, PEF and CTP reduced natural microbiota, total mesophilic aerobic bacteria (TMAB) and yeasts and moulds (YM), below to non-detectable levels (1 log CFU/g) ensuring the stability of the product for at least 30 days.

Quality characterization

Treated samples exhibited pH, acidity, °Brix and colour changes, which were dependent on the processing conditions. No negative changes on physicochemical characteristics of the product were found after PEF. Sensory analysis indicated that PEF samples had better's appearance and texture attributes than the CTP-treated samples.

Financial Viability Assessment

Project Evaluation

The results obtained suggest that the payback time occurs in 4 years. Nevertheless, when PEF technology is introduced into a production process, the company´s characteristic must be considered because its economic and financial indicators would change depending on its resources, assets, productivity, commercial structure, among others aspects.

Operational Breakeven Point

The breakeven point for the 1st year of project is reached when 163.500 kg of product are sold or when revenue is 1,03 M€, which means that these are the quantities needed to cover all costs (fixed and variable).

Conclusions

PEF technology is a novel alternative to apple puree non-thermal pasteurization. PEF pasteurization is a profitable investment for current or new companies that want to follow the technological changes in order to maintain their competitiveness in market with a more sustainable production process and product. PEF equipment can be integrated into the food processing plant like any other piece of equipment and its installation is not expensive. Based on this study's encouraging findings, PEF should be examined for pilot scale-up.

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