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"PROSPECTS OF PULSED ELECTRIC FIELD TREATMENT FOR IMPROVING FLAXSEED PRESSING EFFICIENCY"

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Abstract: Flaxseed (Linum usitatissimum L.) is a valuable oilseed rich in α-linolenic acid, lignans, and other bioactive compounds. Conventional pressing methods are limited by the structural resistance of seed cell walls, which reduces oil recovery and leaves a significant portion of oil in the press cake. This study analyzes the prospects of Pulsed Electric Field (PEF) pre-treatment as an innovative technology to improve flaxseed pressing efficiency.Theoretical considerations show that electroporation induced by PEF causes pore formation in cell membranes, which reduces mechanical resistance and facilitates oil release. The effectiveness of PEF depends on medium properties such as seed moisture (optimal range: 7–10%) and temperature (40–50 °C), as well as treatment parameters including field strength (5–20 kV/cm), pulse duration (10–100 μs), number of pulses (10–50), and frequency (1–5 Hz). Experimental studies confirm that PEF pre-treatment increases flaxseed oil yield by approximately 4.9% compared to untreated pressing, while preserving heat-sensitive compounds such as omega-3 fatty acids, lignans, and tocopherols.In conclusion, PEF treatment is a non-thermal, energy-efficient, and environmentally friendly technology that enhances oil recovery, reduces energy consumption, and improves product quality. Its industrial application in flaxseed processing represents a promising innovation for sustainable oil production.

Keywords: Flaxseed, pulsed electric field (PEF), electroporation, oil pressing, process intensification.

INTRODUCTION

Flaxseed (Linum usitatissimum L.) has been widely used since ancient times as a valuable source of nutrients. Its seeds contain 35–45% oil, 20–25% protein, lignans, polyphenols, and other bioactive compounds. Flaxseed oil is one of the richest natural sources of omega-3 fatty acids (α-linolenic acid), which are essential for human health.In conventional pressing technologies, the strong structure of seed cell walls prevents complete release of intracellular oil. As a result, 8–12% of oil remains trapped in the press cake. Pre-treatment methods such as drying, moistening, or grinding are usually applied to improve pressing efficiency, but these methods are energy-intensive and can negatively affect oil quality.Recently, Pulsed Electric Field (PEF) technology has been recognized as a promising pre-treatment method for oilseeds. This technique is non-thermal, energy-efficient, and helps preserve bioactive compounds while increasing oil recovery during pressing by weakening seed cell walls and facilitating oil release.

MATERIALS AND METHODS

When exposed to a PEF, flaxseed cells undergo electroporation. Strong short-duration electrical pulses induce pore formation in the cell membranes:

- Reversible pores – temporary openings that reseal after treatment.
- Irreversible pores – permanent structural breakdown of the membrane, resulting in enhanced oil release.

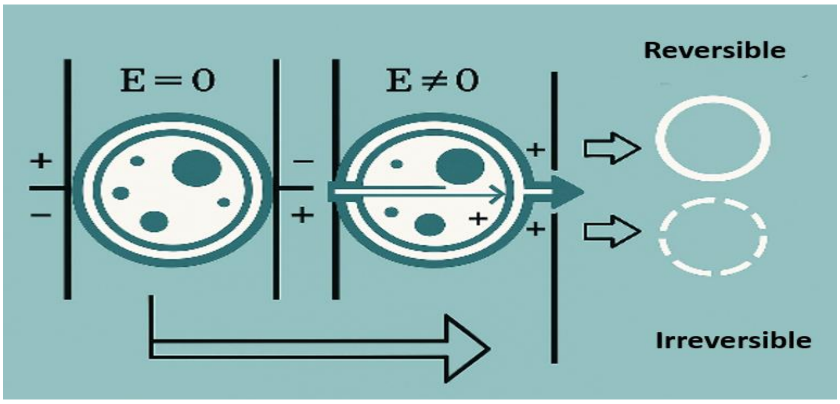

Figure 1. Electroporation in flaxseed cells under pulsed electric field treatment (reversible and irreversible pore formation).

This figure illustrates the mechanism of pore formation. On the left, the membrane is intact and oil bodies are encapsulated. In the middle, under the effect of an external electric field, pores form in the membrane. On the right, irreversible breakdown of the membrane is shown, which enables complete release of intracellular oil during pressing.During electroporation, polar molecules align along the electric field lines, causing a transmembrane potential to form. Once this potential exceeds the critical value (≈1 V), the membrane ruptures. Consequently, oil bodies are liberated, which significantly facilitates oil release during pressing. This mechanism reduces the mechanical resistance of the seed matrix, thereby lowering the required pressing force.
The efficiency of PEF treatment strongly depends on the electrical conductivity of the medium. For flaxseed, the optimal moisture content is 7–10%, ensuring sufficient conductivity for effective pore formation.The electric field strength is determined as:

$$E = \frac{U}{d}$$

where:- E – electric field strength (V/m), U – applied voltage (V),d – distance between electrodes (m)

For example, with U = 8000 V and d = 0.01 m:

E = 8000 / 0.01 = 800,000 V/m = 8 kV/cm

This value is within the effective range for disrupting flaxseed cell walls. Temperature also plays a synergistic role. At 40–50 °C, membrane phospholipids are in a more fluid state, making the cells more susceptible to electroporation. Studies confirm that combining moderate heating with PEF enhances treatment efficiency and improves oil release.

PEF parameters. Effective PEF parameters for flaxseed pressing are as follows:

- **Field strength**: 5–20 kV/cm
- **Pulse duration**: 10–100 μs

- **Number of pulses**: 10–50
- **Pulse frequency**: 1–5 Hz

The energy of a single pulse is calculated as

$$W_{imp} = U \times I \times t$$

where:U – pulse voltage (V),I – current (A),t – pulse duration (s).

The total specific energy input is given by:

$$W_{PEF} = \frac{W_{imp} \times f}{m \times 3.6}$$

where: – pulse frequency (Hz), – mass of the treated sample (kg).

According to Willems, Kuipers, and DeHaan, PEF treatment of flaxseed increased oil yield by 4.9% compared to untreated pressing.

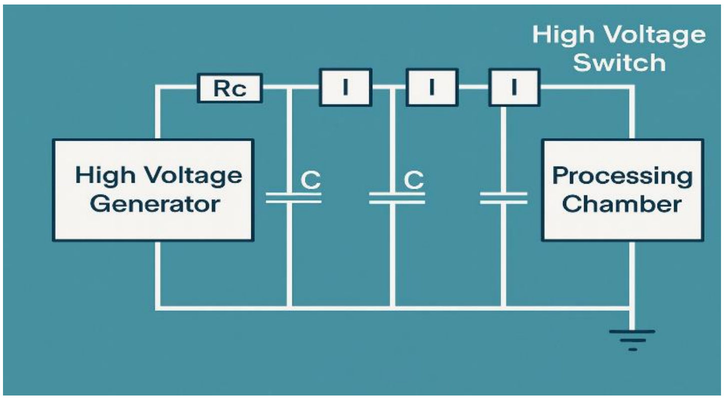

Figure 2. High-voltage pulse generator and treatment chamber for flaxseed processing.

This schematic shows the circuit of a Marx-type pulse generator. Energy stored in capacitors is released in short-duration high-voltage pulses. Flaxseed is placed between two electrodes in the treatment chamber, where it is subjected to controlled electric pulses. Rectangular pulses are preferred due to their high energy efficiency and wide controllability range.

Application of PEF in pressing.Unlike solvent extraction, pressing does not involve chemical agents. PEF treatment therefore acts as a "biophysical solvent", weakening cell structures prior to pressing.

Advantages in pressing:

- Reduced mechanical resistance of the seed matrix.
- Increased oil recovery (4–5% higher than conventional pressing).
- Reduced residual oil content in press cake.
- Preservation of heat-sensitive compounds (omega-3, lignans, tocopherols).
- Environmentally safe, as no organic solvents are required.

CONCLUSION. The application of **Pulsed Electric Field (PEF) treatment** for flaxseed pressing demonstrates significant scientific and practical advantages:

1. **Electroporation mechanism** – pore formation in cell membranes accelerates mass

transfer and facilitates oil release.

2. **Improved oil yield** – experimental studies indicate an increase of up to **4.9%** compared to untreated pressing.

3. **Preservation of quality** – as a non-thermal process, PEF preserves omega-3 fatty acids, lignans, and tocopherols.

4. **Energy efficiency** – electrical pulses directly disrupt cell membranes, minimizing energy losses compared to thermal pre-treatment.

5. **Environmental safety** – no solvents are required, ensuring ecological and food safety benefits.

Nevertheless, some limitations exist, including the need for high-voltage equipment and optimization of process parameters (field strength, pulse duration, frequency, moisture, and temperature conditions). With proper engineering solutions, these challenges can be addressed.

In summary, PEF treatment is a scientifically justified and promising technology for enhancing flaxseed pressing efficiency. Its industrial implementation has the potential to:Increase oil recovery,Reduce energy consumption,Minimize oil losses in press cake,Maintain high nutritional value of flaxseed oil,Improve sustainability of the oil processing industry.

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