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DEVELOPMENT OF METHODS FOR EXTRACTING LIQUID FROM JERUSALEM ARTICHOKE TUBERS WITH HIGH MOISTURE CONTENT

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Abstract. The high moisture content of freshly harvested tubers, while advantageous for juice extraction, also contributes to rapid deterioration and limits long-term storage. The development of efficient methods for extracting liquid from Jerusalem artichoke tubers can therefore provide an opportunity to obtain a valuable liquid fraction while simultaneously increasing the utilization of the crop. This study considers the development and technological evaluation of methods for extracting liquid from fresh Jerusalem artichoke tubers. The proposed methodology includes raw-material preparation, washing, crushing, mechanical pressing, filtration, and, where appropriate, enzymatic or combined treatment. The principal quality parameters include extraction yield, moisture content, soluble solids, pH, titratable acidity, color, turbidity, and inulin concentration. Mechanical pressing, centrifugal separation, and enzymatic pretreatment are considered as potential extraction approaches. The efficiency of the process is expected to depend on particle size, pressing pressure, temperature, pretreatment conditions, and the structural characteristics of the tubers. Development of an optimized extraction process could facilitate the production of Jerusalem artichoke juice or liquid extract suitable for subsequent concentration, fermentation, functional food production, or recovery of valuable soluble compounds.

Keywords: Jerusalem artichoke, *Helianthus tuberosus* L., liquid extraction, juice extraction, inulin, mechanical pressing, moisture content, extraction yield, tuber processing.

Introduction. Jerusalem artichoke (*Helianthus tuberosus* L.) is a perennial herbaceous plant of the Asteraceae family that is cultivated primarily for its underground tubers. The crop is characterized by its adaptability to different environmental conditions and by the nutritional and technological value of its tubers. Jerusalem artichoke has attracted considerable attention as a source of inulin-type fructans, dietary fiber, soluble carbohydrates, minerals, and other valuable compounds.

Freshly harvested Jerusalem artichoke tubers contain a high proportion of water. This characteristic makes the raw material suitable for obtaining liquid fractions through mechanical and physicochemical extraction methods. However, high moisture content also makes fresh tubers susceptible to microbial spoilage, enzymatic activity, respiration, and deterioration during storage. Rapid processing after harvesting is therefore desirable.

The liquid contained in Jerusalem artichoke tissue is present within plant cells and intercellular spaces. Efficient extraction requires disruption of the cellular structure and separation of the liquid fraction from the solid residue. Conventional approaches include crushing followed by pressing, centrifugal separation, filtration, or combinations of these operations.

The liquid obtained from Jerusalem artichoke tubers can contain soluble sugars, inulin-type fructans, organic acids, minerals, and other soluble compounds. Consequently, extraction is

potentially useful not only for juice production but also for obtaining a raw material for fermentation, functional beverages, concentrated extracts, syrup production, and other food or biotechnological applications.

However, extraction efficiency is affected by several factors. These include tuber variety, maturity, moisture content, particle size after crushing, pressing pressure, pressing time, temperature, and the degree of cell disruption. Excessive mechanical treatment may increase extraction yield but can also increase turbidity and the transfer of undesirable compounds from the solid fraction.

The objective of this research is therefore to develop and evaluate effective methods for extracting liquid from Jerusalem artichoke tubers with high moisture content, while identifying the technological parameters that provide a high extraction yield and desirable physicochemical quality.

Characteristics of Jerusalem artichoke tubers. Jerusalem artichoke tubers are primarily composed of water and carbohydrates. Their carbohydrate fraction is particularly valuable because it contains inulin-type fructans, which have nutritional and functional properties. The composition of the tubers varies according to cultivar, geographical location, soil conditions, climatic conditions, stage of maturity, harvesting period, and storage conditions.

The high moisture content of fresh tubers has two important technological consequences. First, it facilitates mechanical extraction of liquid. Second, it makes the raw material relatively unstable and difficult to store for extended periods without appropriate preservation.

Therefore, extraction shortly after harvesting can serve as an alternative method for utilizing fresh tubers and preserving their valuable soluble components.

Principles of liquid extraction. Liquid extraction from plant tissues generally involves three principal stages:

1. Disruption of plant tissue;
2. Release of intracellular and intercellular liquid;
3. Separation of the liquid from the solid residue.

Crushing is particularly important because intact plant cells retain a substantial portion of their liquid. Reduction of particle size increases the exposed surface area and facilitates liquid release.

Following crushing, pressure can be applied to the resulting pulp. The liquid passes through the porous structure of the material while the solid particles form a press cake.

The effectiveness of mechanical extraction can be expressed through extraction yield:

$$Y=\frac{m_l}{m_r}\times 100$$

where:

- Y— extraction yield, %;
- m_l— mass of extracted liquid, kg;
- m_r— initial mass of raw tubers, kg.

A high yield is desirable, but extraction yield alone is insufficient for evaluating the process because the chemical composition and quality of the extracted liquid must also be considered.

Mechanical pressing. Mechanical pressing is one of the simplest potential methods for extracting liquid from high-moisture agricultural materials.

The tubers are first washed and crushed. The resulting pulp is then placed into a press or transferred into a screw-type extraction system.

The main process parameters are:

- particle size;

- pressing pressure;
- pressing time;
- temperature;
- pulp moisture;
- equipment configuration.

Increasing pressure can improve liquid recovery up to a certain point. However, excessive pressure may produce very compact press cake and increase the amount of fine suspended solids in the extracted liquid.

Plant tissues contain pectin, cellulose, hemicellulose, and other structural components that contribute to cell-wall integrity. Enzymatic pretreatment using suitable food-grade enzyme preparations may weaken the cell-wall matrix and increase the release of liquid. Pectinolytic and cellulolytic enzymes are frequently considered in plant juice-processing technologies.

An enzymatic treatment may therefore increase extraction yield without requiring extremely high mechanical pressure. However, enzyme concentration, temperature, pH, and treatment time must be optimized because excessive treatment can alter the characteristics of the extracted liquid.

Research methodology. Fresh Jerusalem artichoke tubers should be collected immediately after harvesting or after a defined storage period.

Tubers should be selected according to the following criteria:

- absence of visible mold or decay;
- absence of severe mechanical damage;
- approximately uniform maturity;
- comparable size;
- high moisture content.

Before processing, the tubers should be weighed to determine the initial raw-material mass. The tubers should be thoroughly washed to remove soil and foreign materials.

Depending on the intended application, peeling may either be omitted or included as an experimental factor. Since valuable compounds may be present near the surface of the tuber, peeling can influence both yield and chemical composition.

The cleaned tubers should then be cut into smaller pieces before crushing.

Method 1: Mechanical pressing

The crushed tuber pulp is placed into a laboratory hydraulic or screw press.

The pulp is subjected to controlled pressure, and the extracted liquid is collected and weighed.

The extraction yield is calculated according to:

$$Y=\frac{m_e}{m_0}\times 100$$

where $m_e$is the mass of extracted liquid and $m_0$is the initial mass of tubers.

Method 2: Crushing followed by centrifugation

The crushed pulp is transferred to a centrifuge and processed at a predetermined rotational speed and time.

After centrifugation, the liquid phase is separated from the sediment.

This method allows the influence of centrifugal force on liquid recovery and clarification to be evaluated.

Method 3: Combined enzymatic-mechanical extraction

The crushed tuber pulp is treated with an appropriate food-grade enzyme preparation.

The treatment should be conducted at controlled temperature, pH, enzyme concentration, and time. After enzymatic treatment, the pulp is subjected to mechanical pressing or centrifugation.

This method can be evaluated to determine whether enzymatic disruption of cell-wall structures improves liquid recovery.

Moisture content. Moisture content can be determined using a standard gravimetric method.

The result can be calculated as:

$$W=\frac{m_1-m_2}{m_1}\times 100$$

where:

- m_1— initial sample mass;
- m_2— mass after drying.

Because inulin is one of the major value components of Jerusalem artichoke, its concentration in the liquid fraction should be determined using an appropriate analytical method, such as HPLC or another validated carbohydrate-analysis technique.

The recovery of inulin can be calculated as:

$$R_I=\frac{C_I V}{m_0}\times 100$$

where:

- C_I— inulin concentration in the extract;
- V— extract volume;
- m_0— initial mass of tubers.

Color should be evaluated using the CIE L^* a^* b^* system.

Measurements can be performed immediately after extraction and after a defined storage period to evaluate oxidation and browning.Turbidity is an important characteristic when the liquid is intended for beverage production or further clarification.

It can be measured using a turbidimeter and expressed in NTU.

High turbidity may indicate the presence of suspended cell fragments, starch-like particles, pectin, and other insoluble materials.

Effect of crushing on extraction yield. The degree of crushing is expected to have a substantial influence on liquid recovery. Coarse particles may retain a significant amount of liquid because many cells remain relatively intact. Increasing the degree of crushing should therefore increase the amount of released liquid.

However, excessively fine grinding may produce a highly viscous pulp containing large quantities of fine particles. Such material may be difficult to press or filter and may increase turbidity. Consequently, an optimum particle size should be identified rather than simply maximizing the degree of grinding.

Increasing pressure during mechanical pressing generally increases liquid recovery by forcing liquid through the capillary spaces of the pulp. Nevertheless, the relationship is not necessarily linear. After a certain pressure level, additional pressure may result in only a small increase in liquid recovery.

Therefore, the optimum pressure should be determined based on the combination of extraction yield, energy consumption, processing time, and quality of the liquid fraction. Enzymatic treatment may improve extraction by weakening structural components of the cell wall.

The expected mechanism involves partial hydrolysis of pectic and cell-wall polysaccharides, resulting in easier release of intracellular liquid.

This approach could be particularly useful when mechanical pressing alone leaves a relatively wet press cake. However, enzyme treatment adds a processing stage and increases the complexity of the technology. Therefore, its economic and technological advantages should be evaluated against the additional cost and processing time.

The concentration of soluble solids in the extracted liquid provides information about the amount of dissolved material recovered. An efficient extraction method should ideally produce both a high liquid yield and high recovery of valuable soluble compounds.

Mechanical pressing may recover a substantial fraction of the freely available liquid, whereas additional tissue disruption or enzymatic treatment may increase the transfer of soluble compounds into the liquid fraction. In particular, monitoring inulin concentration and total inulin recovery is important because the primary technological value of Jerusalem artichoke is closely associated with its fructan content. A major technological challenge in extracting liquid from Jerusalem artichoke is the separation of the liquid from fine suspended particles.

Fine grinding can increase extraction yield but simultaneously increase turbidity. Therefore, filtration, sedimentation, centrifugation, or membrane separation may be required after extraction.

The appropriate clarification method depends on the intended final product. A cloudy extract may be acceptable for some applications, whereas a clear liquid would be preferable for beverages or concentrated extracts.

Conclusion. The development of methods for extracting liquid from high-moisture Jerusalem artichoke tubers is a promising approach for increasing the technological utilization of this crop. The high-water content of freshly harvested tubers makes them suitable for liquid extraction but also creates significant storage and transportation challenges. Mechanical crushing followed by pressing represents a relatively simple and potentially economical extraction method. Centrifugal separation can improve separation of the liquid fraction from fine solid particles, while enzymatic pretreatment may increase liquid recovery by facilitating disruption of plant-cell structures.

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