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SELECTING THE OPTIMAL METHOD FOR EXTRACTING JERUSALEM ARTICHOKE TUBER JUICE AND IMPROVING THE PROCESS

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Abstract: One promising approach is the preliminary extraction of juice from fresh tubers before subsequent dehydration or fractionation. The objective of this study was to analyze and select an appropriate method for extracting juice from Jerusalem artichoke tubers and to develop an improved technological scheme for increasing juice recovery while preserving valuable soluble components. Mechanical pressing, pulping followed by pressing, centrifugal separation, and combined mechanical-centrifugal separation was considered. Previous research has demonstrated that mechanical pressing of Jerusalem artichoke tuber mash can produce a protein-rich juice, while most of the inulin remains in the pressed solids, making subsequent extraction possible. Based on the technological analysis, mechanical pressing after controlled comminution is proposed as the primary juice-extraction method, while centrifugation can be applied as a secondary clarification step. The proposed process includes washing, surface-water removal, comminution, mechanical pressing, juice clarification, and separate utilization of the liquid and solid fractions.

Keywords: Jerusalem artichoke, tuber juice, mechanical pressing, juice extraction, centrifugation, inulin, moisture removal, process optimization, dehydration.

Annotatsiya: Istiqbolli yondashuvlardan biri yangi yig'ib olingan topinambur ildizmevalaridan keyinchalik quritish yoki fraksiyalarga ajratishdan oldin sharbatni dastlabki bosqichda ajratib olishdir. Mazkur tadqiqotning maqsadi topinambur ildizmevalaridan sharbat ajratib olishning maqbul usulini tahlil qilish va tanlash hamda qimmatli eruvchan komponentlarni saqlab qolgan holda sharbat chiqishini oshirishga qaratilgan takomillashtirilgan texnologik sxemani ishlab chiqishdan iborat. Mexanik presslash, maydalashdan so'ng presslash, sentrifugal ajratish hamda mexanik-sentrifugal kombinatsiyalangan ajratish usullari ko'rib chiqildi. Avvalgi tadqiqotlar topinambur ildizmevalari massasini mexanik presslash natijasida oqsilga boy sharbat olish mumkinligini, inulinning asosiy qismi esa presslangan qattiq qoldiq tarkibida qolishini ko'rsatgan. Bu esa keyingi bosqichda qattiq fraksiyadan inulinni ajratib olish imkonini beradi. Texnologik tahlil natijalariga ko'ra, boshqariladigan maydalashdan so'ng mexanik presslash sharbat ajratib olishning asosiy usuli sifatida taklif etildi, sentrifugalash esa ikkilamchi tiniqlashtirish bosqichi sifatida qo'llanilishi mumkin. Taklif etilayotgan texnologik jarayon yuvish, yuzadagi suvni olib tashlash, maydalash, mexanik presslash, sharbatni tiniqlashtirish hamda suyuq va qattiq fraksiyalarni alohida qayta ishlatish bosqichlarini o'z ichiga oladi.

Kalit so'zlar: topinambur, ildizmeva sharbati, mexanik presslash, sharbat ajratib olish, sentrifugalash, inulin, namlikni ajratish, texnologik jarayonni optimallashtirish, quritish.

Аннотация: Одним из перспективных подходов является предварительное извлечение сока из свежих клубней топинамбура перед последующей сушкой или фракционированием. Целью данного исследования являлись анализ и выбор подходящего метода извлечения сока из клубней топинамбура, а также разработка усовершенствованной технологической схемы, направленной на повышение выхода сока при сохранении ценных растворимых компонентов. Были рассмотрены такие методы, как механическое прессование, измельчение с последующим прессованием, центробежное разделение, а также комбинированное механико-центробежное разделение. Результаты предыдущих исследований показали, что механическое прессование массы клубней топинамбура позволяет получать сок, богатый белковыми компонентами, тогда как основная часть инулина остается в отпрессованном твердом остатке, что создает возможность его последующего извлечения. На основе технологического анализа в качестве основного метода извлечения сока предлагается механическое прессование после контролируемого измельчения, тогда как центрифугирование может применяться в качестве дополнительной стадии осветления сока. Предлагаемый технологический процесс включает мойку, удаление поверхностной влаги, измельчение, механическое прессование, осветление сока и раздельное использование

жидкой и твердой фракций.

Ключевые слова: топинамбур, сок клубней, механическое прессование, извлечение сока, центрифугирование, инулин, удаление влаги, оптимизация технологического процесса, сушка.

INTRODUCTION

Jerusalem artichoke is an important multifunctional crop that has attracted considerable attention because of its high content of inulin and fructooligosaccharides. These compounds make Jerusalem artichoke valuable for functional food, nutraceutical, pharmaceutical, and biotechnological applications.

A major technological characteristic of fresh Jerusalem artichoke tubers is their relatively high moisture content. High moisture negatively affects storage stability and increases the energy requirement of subsequent drying. A recent study on Jerusalem artichoke drying emphasized that high moisture content significantly limits storage stability and investigated convective and convective–microwave drying as approaches to improve dehydration efficiency.

Direct drying of fresh tubers requires removal of a large amount of water by thermal means. Therefore, preliminary mechanical removal of part of the liquid phase may represent an effective approach for reducing the moisture load entering the dryer.

The extraction of juice from Jerusalem artichoke is also important from the perspective of raw-material utilization. The liquid fraction can contain soluble proteins, sugars, minerals, and other soluble substances. At the same time, inulin is largely retained in the solid fraction during mechanical pressing, making the pressed residue suitable for subsequent extraction. Experimental research has shown that pressing Jerusalem artichoke tuber mash produced a protein-rich juice, while only a relatively small proportion of inulin was lost into the juice.

The objective of this study was to select an appropriate method for extracting juice from fresh Jerusalem artichoke tubers and to develop an improved technological process for efficient separation of liquid and solid fractions.

The study was designed to:

- characterize the technological properties of fresh Jerusalem artichoke tubers;
- compare potential juice-extraction methods;
- determine the major factors affecting juice yield;
- establish criteria for selecting the optimal extraction method;
- develop an improved technological sequence;
- identify parameters requiring experimental optimization;
- evaluate the relationship between juice extraction and subsequent drying.

REVIEW OF LITERATURE ON THE SUBJECT

Jerusalem artichoke (*Helianthus tuberosus* L.) tubers are considered a valuable raw material for obtaining inulin and other biologically and technologically important compounds. A considerable part of the existing research has focused on developing effective methods for extracting and purifying inulin. Lingyun et al. [1] investigated the technological conditions for extracting inulin from Jerusalem artichoke tubers and demonstrated the importance of extraction parameters such as temperature, extraction time, pH, and solvent-to-solid ratio. Their findings indicate that the efficiency of inulin recovery is strongly dependent on the appropriate combination of technological parameters.

Subsequent studies have further developed approaches to improve the extraction and purification of inulin. The study on sequential extraction of protein and inulin from Jerusalem artichoke tubers [2] is particularly relevant to the present research because it considered the possibility of separating different valuable components from the same raw material. Mechanical pressing was used as an initial separation operation, producing a protein-containing liquid fraction while retaining most of the inulin in the solid fraction. In the reported process, approximately 40.8% of the tuber protein was recovered in the juice, whereas only 2.3% of the total inulin was recovered during the pressing stage. The integrated process subsequently achieved overall protein and inulin recoveries of 71.88% and 67.6%, respectively. These results demonstrate the potential of preliminary mechanical separation for improving the utilization of Jerusalem artichoke tubers.

Another important direction of research concerns the optimization of inulin extraction. Response surface methodology has been widely applied to determine the interaction between technological parameters and extraction efficiency. Lingyun et al. [1] reported an optimum conventional extraction condition of approximately 76.65 °C, 20 min, and a solvent-to-solid ratio of 10.56:1, with an estimated inulin extraction yield of 83.6%. More recent research on the extraction and purification of inulin using response surface methodology and ion-exchange resins [5] demonstrates the continuing development of integrated approaches aimed not only

at increasing extraction efficiency but also at improving the purity of the obtained product. Similarly, recent research by Singh et al. [9] focuses on greener extraction of inulin, including optimization and purification, which indicates a growing interest in reducing the environmental and technological burden associated with conventional extraction procedures.

Alongside extraction studies, considerable attention has been given to the drying of Jerusalem artichoke tubers. Drying is technologically important because fresh tubers contain a high proportion of moisture, which affects their storage stability and increases the energy required for subsequent dehydration. Antal [3] compared different drying methods and investigated their effects on drying kinetics and product quality. Karacabey et al. [4] optimized microwave-assisted drying using response surface methodology and a genetic algorithm, demonstrating the importance of selecting appropriate drying conditions to improve process efficiency. These studies indicate that drying temperature, drying method, and process parameters have a significant influence on both dehydration kinetics and the quality characteristics of the final product.

Recent studies have continued to investigate the drying behavior of Jerusalem artichoke. Research published in Processes [6] examined the drying kinetics and physicochemical characteristics of dehydrated Jerusalem artichoke, while Slashcheva [7] investigated the determination of appropriate drying parameters for Jerusalem artichoke tubers. Beshimov [8] further examined drying regimes under the influence of a pulsed electric field. Collectively, these studies demonstrate that the efficient dehydration of Jerusalem artichoke requires careful control of process conditions and that alternative drying technologies can be considered to improve energy efficiency and preserve valuable components.

Despite the considerable body of research devoted to inulin extraction and drying, these two technological stages have generally been investigated separately. Most extraction studies focus on maximizing the recovery or purity of inulin, whereas drying studies primarily examine moisture removal, drying kinetics, energy consumption, and product quality. Comparatively less attention has been given to the preliminary mechanical separation of naturally occurring liquid from fresh Jerusalem artichoke tubers and its role in reducing the moisture load before thermal drying. The sequential extraction study [2] provides important evidence that mechanical pressing can serve not only as a dewatering operation but also as a selective separation step for recovering valuable soluble components while retaining most of the inulin in the solid fraction.

Therefore, mechanical pressing represents a potentially useful link between juice recovery, solid-fraction utilization, and subsequent drying or inulin extraction. Compared with hot-water extraction, mechanical pressing does not require the addition of an extraction solvent and can simultaneously reduce the amount of moisture entering the drying stage. At the same time, the efficiency of pressing depends on several interacting factors, including particle size, pressure, pressing time, raw-material temperature, and initial moisture content. Excessive comminution may increase viscosity and hinder drainage, while excessively high pressure may compact the solid matrix. Consequently, determining optimal pressing conditions is necessary to achieve an appropriate balance between juice yield, solid-fraction moisture, recovery of valuable compounds, and energy consumption.

The reviewed literature therefore indicates a clear technological research gap. Existing studies have established effective approaches for inulin extraction [1, 5, 9], demonstrated the potential of sequential recovery of protein and inulin [2], and developed various methods for improving the drying of Jerusalem artichoke [3, 4, 6–8]. However, the integrated optimization of mechanical juice extraction from fresh Jerusalem artichoke tubers as a preliminary dewatering stage followed by clarification and subsequent utilization of both liquid and solid fractions remains insufficiently developed. Addressing this gap can contribute to a more efficient technological scheme in which the liquid fraction is used for the recovery of soluble compounds, while the dewatered solid fraction is directed toward drying and/or subsequent inulin extraction. Such an integrated approach can improve raw-material utilization and provide a more comprehensive basis for optimizing the processing of fresh Jerusalem artichoke tubers.

RESEARCH METHODOLOGY

Fresh Jerusalem artichoke tubers were considered as the experimental material. Tubers should be selected according to the following criteria:

- absence of visible rot;
- absence of severe mechanical damage;
- relatively uniform size;
- similar physiological maturity;
- high initial moisture;
- absence of foreign materials.

Before processing, the tubers should be washed thoroughly and surface water should be removed.

The experimental process can be represented as:

Fresh tubers → washing → surface-water removal → comminution → juice extraction → clarification → liquid fraction + solid fraction

Mechanical pressing performs the primary separation, while centrifugation is used for clarification. This method is particularly attractive when the objective is to obtain a relatively clean liquid fraction while simultaneously reducing the moisture content of the solid residue.

ANALYSIS AND RESULTS

The literature and technological analysis indicate that mechanical pressing is the most appropriate candidate for the primary extraction of natural Jerusalem artichoke juice.

The main reason is that pressing can separate a significant liquid fraction without requiring the addition of water or organic solvents. Previous research demonstrated that pressing Jerusalem artichoke tuber mash generated a protein-rich juice, while the majority of the inulin remained in the solid material.

The four methods can therefore be compared as follows (Table 1):

Table 1. Comparative Assessment of Methods for Juice Extraction from Fresh Jerusalem Artichoke Tubers¹

Method	Juice recovery	Energy requirement	Equipment complexity	Solid/liquid separation	Suitability
Direct pressing	Medium	Low	Low	Moderate	High
Fine pulping + pressing	Potentially high	Medium	Medium	Moderate	High
Centrifugation	High for suspended-liquid separation	Medium–high	High	High	Medium–high
Pressing + centrifugation	High	Medium	Medium–high	Very high	Very high

The table represents a technological assessment, not measured experimental performance. Actual values should be determined experimentally. Comminution is a critical preliminary operation. Increasing the degree of comminution generally increases the exposed cellular surface and facilitates juice release. However, excessively fine particles may increase viscosity and create a compact press cake.

Therefore, the objective should not be maximum comminution but optimal comminution. A suitable experimental design should investigate at least three particle-size ranges.

For example:

- coarse comminution;
- medium comminution;
- fine comminution.

Juice yield, turbidity, press-cake moisture, and energy consumption should then be compared. At low pressure, a significant quantity of free liquid remains in the solid fraction. Increasing pressure generally increases liquid release. However, excessively high pressure may compact the solid matrix and reduce drainage.

Pressing time determines the extent to which liquid can migrate from the compressed matrix. A short pressing period may result in incomplete drainage, whereas excessively long pressing may increase energy consumption without a proportional increase in juice yield. Therefore, the optimal pressing time should be determined from the point at which additional processing produces only a small increase in juice recovery. Centrifugation is recommended primarily as a secondary clarification operation rather than as the principal juice-extraction method.

The primary purpose of centrifugation is to remove suspended solid particles remaining after mechanical pressing.

The proposed sequence is:

Comminution → pressing → preliminary filtration → centrifugation → clarified juice. This approach allows the mechanical press to perform the major water-removal function while the centrifuge improves liquid quality.

Research has demonstrated that mechanically pressed Jerusalem artichoke juice contains recoverable soluble components, particularly protein. In one sequential-extraction study, pressing recovered 40.8% of the tuber's protein into the juice, while only 2.3% of the inulin was recovered at this stage.

The juice can be subjected to additional separation for recovery of:

¹ Source: Author's own work.

- soluble protein;
- sugars;
- minerals;
- other soluble compounds.

Meanwhile, the solid fraction can be used for subsequent inulin extraction.

Such a system improves raw-material utilization.

If the primary objective is maximum recovery of soluble compounds, hot-water extraction can be highly effective. For example, conventional water extraction optimized using response surface methodology has produced high inulin extraction yields. However, if the objective is to obtain natural juice from fresh tubers while simultaneously reducing the moisture load before drying, mechanical pressing is more appropriate.

Hot-water extraction adds water to the system and is primarily intended for recovering soluble compounds. Mechanical pressing, in contrast, removes naturally occurring liquid from the raw material and therefore can function as a preliminary dewatering operation.

The sequential extraction study provides particularly strong support for this approach. The authors demonstrated that mechanical pressing followed by subsequent extraction improved overall protein and inulin recovery compared with extraction sequences that did not begin with pressing. Overall protein and inulin yield of 71.88% and 67.6%, respectively, were reported for the integrated process.

For experimental optimization, the following independent variables are recommended (Table 2):

Table 2. Recommended Experimental Factors and Levels for Optimization of the Juice Extraction Process²

Factor	Symbol	Suggested experimental levels
Particle size	X ₁	coarse / medium / fine
Pressing pressure	X ₂	low / medium / high
Pressing time	X ₃	short / medium / long
Raw-material temperature	X ₄	low / ambient / elevated
Initial moisture	X ₅	measured value / controlled range

The proposed method has an important energy-efficiency advantage.

Drying fresh Jerusalem artichoke requires substantial energy because of its high initial moisture. Recent research has shown that drying method and temperature strongly affect both drying kinetics and product quality. Combined convective–microwave drying can significantly shorten drying time, but high-temperature treatment can also increase degradation of sensitive compounds.

The proposed improved technology consists of:

washing → surface-water removal → controlled comminution → mechanical pressing → preliminary filtration → centrifugation → clarified juice + dewatered solid fraction.

The liquid fraction can be subjected to further processing for recovery of soluble compounds, while the solid fraction can be dried or used for subsequent inulin extraction.

The most important parameters requiring experimental optimization are particle size, pressing pressure, pressing time, raw-material temperature, initial moisture, juice yield, press-cake moisture, soluble solids, inulin recovery, and energy consumption.

Thus, the optimal technology should not be selected solely according to maximum juice yield. A comprehensive criterion that simultaneously considers juice yield, quality of the liquid fraction, residual moisture of the solid fraction, recovery of valuable compounds, and energy consumption provide a more scientifically justified basis for process optimization.

Future experimental research should use response surface methodology or another design-of-experiments approach to establish the interaction between pressing parameters and juice recovery. Such research would make it possible to determine statistically validated operating conditions and develop an industrially applicable technology for efficient processing of fresh Jerusalem artichoke tubers.

CONCLUSIONS AND SUGGESTIONS

The analysis demonstrates that mechanical pressing is a promising primary method for extracting juice from fresh Jerusalem artichoke tubers. The principal advantages of mechanical pressing are its relatively simple technological design, absence of extraction solvents, potential for continuous operation, and simultaneous reduction of the moisture content of the solid fraction.

2 Source: Author's own work.

Literature evidence demonstrates that pressing Jerusalem artichoke tuber mash can produce a protein-containing juice while retaining most of the inulin in the solid fraction. This makes the process particularly suitable for an integrated biorefinery approach in which both liquid and solid fractions are subsequently utilized.

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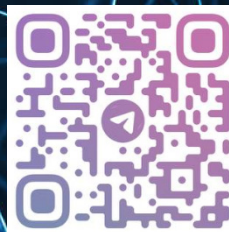
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