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RESEARCH ARTICLE

Jerusalem Artichoke (Helianthus Tuberosus L.): A Comprehensive Review of Cultivation Technology and Its Significance as A Medicinal and Functional Food Plant

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Abstract

Jerusalem artichoke (Helianthus tuberosus L.) is a hardy perennial tuberous plant of the Asteraceae family that has attracted renewed scientific and industrial attention as a multipurpose crop combining low-input cultivation requirements with exceptional functional-food and medicinal value. This review synthesizes evidence from 25 international peer-reviewed sources published between 2007 and 2024, with the dual objective of summarizing modern cultivation technology and elucidating the plant's significance as a source of bioactive compounds for human health.

The review demonstrates that Jerusalem artichoke produces tuber yields of 30–80 t/ha with minimal fertilizer input (60–90 kg N/ha) and exhibits strong tolerance to drought, frost (–30 °C), and pest pressure. Tubers contain 14–20% inulin on a fresh-weight basis (60–80% of dry matter), 1–3% protein with a complete essential amino acid profile, substantial potassium and iron, and bioactive phenolics including chlorogenic and caffeic acids. Inulin acts as a non-digestible fructan prebiotic that selectively stimulates Bifidobacterium and Lactobacillus, lowers postprandial glycemia, reduces serum LDL cholesterol by 7–15%, enhances calcium and magnesium absorption by 18–25%, and supports satiety and weight management. Clinical and preclinical evidence further supports antidiabetic, hepatoprotective, antioxidant, immunomodulatory, and anti-carcinogenic activities. As a functional food ingredient, Jerusalem-artichoke inulin and powder are successfully applied in bakery (5–10% wheat-flour substitution), dairy fermented products, gluten-free pasta, low-calorie confectionery, meat fiber enrichment, infant formula, and as a coffee substitute. The review identifies tuber storage instability, limited variety improvement, and underdeveloped processing infrastructure as principal constraints, and highlights the strong potential for cultivation expansion in Uzbekistan and other Central Asian countries given the crop's low water demand and high resilience under continental-arid conditions.

KEYWORDS

Jerusalem artichoke, Helianthus tuberosus, inulin, prebiotic, functional food, cultivation technology, medicinal plant, fructan, gut microbiota, type 2 diabetes, Central Asia, Uzbekistan.

INTRODUCTION

The global demand for functional foods — defined as foods that provide health benefits beyond basic nutrition — has grown rapidly over the past two decades, driven by rising consumer awareness of diet-related non-communicable diseases including type 2 diabetes, obesity, cardiovascular disorders, and disturbances of the gut microbiome [1,2]. In parallel, agricultural research has increasingly turned toward low-input, climate-resilient crops capable of delivering multifunctional value — food, feed, medicine, and bioenergy — from a single species. Jerusalem artichoke (Helianthus tuberosus L.), often referred to as "topinambur" in European, Russian and Central Asian usage, occupies a particularly favorable position at the intersection of these two trends [3,4].

Helianthus tuberosus is a hardy perennial herbaceous species native to North America, where it was domesticated by indigenous peoples and subsequently introduced to Europe in the early seventeenth century by French explorers. The plant produces edible underground tubers rich in inulin — a chain of β(2→1)-linked fructose units terminated by a glucose residue — which functions as a dietary storage carbohydrate analogous to starch in potato but with profoundly different metabolic and prebiotic properties [5,6]. Whereas starch is rapidly hydrolyzed by human α-amylase, inulin resists digestion in the small intestine and reaches the colon intact, where it undergoes selective fermentation by beneficial bacteria of the genera Bifidobacterium and Lactobacillus [7,8]. This single biochemical feature underlies the great majority of the plant's recognized health benefits.

From an agronomic standpoint, Jerusalem artichoke is remarkable for its exceptional adaptability. It tolerates a wide range of soils, requires lower fertilizer inputs than most root and tuber crops, withstands prolonged drought once established, and produces marketable yields under temperatures ranging from −30 °C in winter (tubers in the ground) to over 35 °C in summer [9,10]. Tuber yields of 30–80 t/ha and total biomass yields exceeding 100 t/ha have been documented under temperate-zone cultivation [4,11]. These yield characteristics, combined with the plant's tolerance of marginal lands, make Jerusalem artichoke an attractive option for diversification of farming systems in arid and semi-arid regions including Central Asia, the Mediterranean basin, and parts of sub-Saharan Africa.

Despite this combination of agronomic and nutritional virtues, Jerusalem artichoke remains an under-utilized crop in many parts of the world, particularly in Uzbekistan and the broader Central Asian region, where domestic cultivation is sporadic and largely confined to peri-urban smallholdings. The reasons for this under-utilization include limited consumer awareness, the rapid post-harvest deterioration of tubers under ambient storage, the relatively undeveloped processing infrastructure, and the historical dominance of competing root crops such as potato. Nevertheless, the rising prevalence of type 2 diabetes in Uzbekistan — estimated by the International Diabetes Federation at over 850,000 cases — and the strategic emphasis on functional foods in the national agricultural development agenda [12] suggest that Jerusalem artichoke deserves systematic re-evaluation as a candidate for expanded production.

The present review is structured to provide a comprehensive synthesis of current knowledge on Jerusalem artichoke. Following a description of the literature search methodology, the review addresses, in sequence, the botanical characteristics and origin of the species; the modern technological framework for its cultivation; the chemical composition of the tubers with particular attention to inulin and accompanying bioactive compounds; the pharmacological and medicinal properties supported by preclinical and clinical evidence; and the functional-food and industrial applications. The review concludes with an analysis of current challenges and future prospects, with specific reference to the opportunities for Uzbek and Central Asian agriculture.

METHODOLOGY

This narrative-systematic review was conducted between June and September 2024 using a structured literature search across Scopus, Web of Science, PubMed, Google Scholar, and eLibrary.ru. The search was restricted to publications appearing between January 2007 and August 2024, with priority given to peer-reviewed journal articles, authoritative books, and technical reports from international institutions (FAO, ISAPP, EFSA). Search terms combined the botanical name "Helianthus tuberosus" with the keywords "inulin", "prebiotic", "functional food", "cultivation", "medicinal", "diabetes", "gut microbiota", "antioxidant", and "Jerusalem artichoke". Additional searches were performed in Russian and Uzbek using equivalent terminology ("топинамбур", "инулин", "функциональное питание") to capture region-specific evidence.

Inclusion criteria comprised: studies presenting quantitative data on cultivation, composition, pharmacology or food technology of Jerusalem artichoke; peer-reviewed publications and authoritative monographs; and methodological transparency permitting cross-comparison. Exclusion criteria included opinion pieces without empirical content, duplicate reports, and studies of unrelated Helianthus species. After screening 96 candidate sources, 25 publications were retained for in-depth analysis. The reference list at the end of this article follows GOST 7.0.5-2008 formatting, with sequential numbering and bracketed in-text citations [X], in accordance with the standard adopted by Uzbek academic publications.

BOTANICAL CHARACTERISTICS AND ORIGIN

Helianthus tuberosus L. belongs to the family Asteraceae (Compositae), tribe Heliantheae, and is closely related to the common sunflower (Helianthus annuus L.). Cytogenetic studies establish it as a hexaploid (2n = 6x = 102) of probable hybrid origin between H. hirsutus and H. grosseserratus, indicating significant genetic plasticity that contributes to its broad ecological tolerance [3,5]. The species is native to the eastern and central regions of North America, where archaeological evidence places its cultivation by indigenous peoples — particularly the Haudenosaunee (Iroquois) and Algonquian groups — at least 2,000 years before European contact. Following Samuel de Champlain's observation of its cultivation in present-day Massachusetts in 1605, the plant was introduced to France in 1607 and subsequently spread throughout Europe within two decades, reaching the Russian Empire by the early eighteenth century [3,13].

Morphologically, Jerusalem artichoke is a robust herbaceous perennial reaching heights of 1.5 to 3.0 m, with rough, erect, often branched stems of green to reddish-purple coloration. The leaves are large, ovate-lanceolate, opposite in the lower portion of the stem and alternate above, with hairy upper surfaces and serrated margins. Inflorescences appear in late summer and autumn as composite capitula 5–10 cm in diameter, with bright yellow ray florets surrounding tubular disc florets. Although the species can produce viable seed under suitable conditions, propagation in cultivation is almost exclusively vegetative, by means of the tubers themselves [3,4].

The agronomically and nutritionally relevant organ is the tuber — a swollen, modified underground stem (stolon-derived) ranging from 5 to 10 cm in length, weighing 25–150 g, and presenting a knobbly, irregular surface that complicates mechanical handling. Tuber skin color varies among cultivars from white and yellow to pink and deep purple, while the flesh is typically white to cream-colored. The tubers form in late summer and bulk progressively until the first hard frost, after which the aboveground biomass dies back and translocation to the tubers ceases [10,14]. Importantly, tubers in the ground are extraordinarily frost-tolerant, surviving soil temperatures as low as –30 °C, which allows over-wintering and progressive spring harvest in many continental climates.

Modern cultivar development, although still less intensive than for major commercial crops, has produced a number of improved varieties with enhanced uniformity of tuber shape, higher inulin content, and resistance to specific diseases. Notable cultivars include "Stampede" and "Sugarball" in North America; "Topianka", "Albik", "Volzhsky 2" and "Skorospelka" in the post-Soviet space; "Rote Zonenkugel" and "Bianka" in central Europe; and "Fuseau" and "Bouche Étroite" in France. Genetic and chemical screening of these cultivars has revealed substantial variability in inulin degree of polymerization (DP), with values ranging from DP 3–10 in early-season tubers to DP 30–60 in late-autumn tubers, a feature with direct technological implications for inulin extraction [14,15].

MODERN CULTIVATION TECHNOLOGY

The technological framework for Jerusalem artichoke cultivation is characterized by simplicity, low input intensity, and strong reliance on the natural resilience of the species. Soil requirements are broad: the crop performs adequately on sandy, loamy, and even heavy clay soils, provided drainage is sufficient to prevent waterlogging during the tuber-formation period. The optimum soil pH lies between 6.0 and 7.5, although the plant tolerates moderately acidic (pH 5.5) and slightly alkaline (pH 8.0) conditions without significant yield penalty [4,16]. Loamy soils with good organic-matter content (≥2%) consistently produce the highest yields. In Uzbekistan and similar Central Asian environments, where typical soil pH ranges from 7.5 to 8.5 and organic matter is often low (<1.5%), pre-planting incorporation of organic amendments (20–30 t/ha well-rotted manure or compost) substantially improves performance.

Climatic adaptation is the species' most striking agronomic asset. Jerusalem artichoke completes its growth cycle in 120–180 days depending on cultivar and latitude, requires a minimum effective accumulated temperature of approximately 2,000 °C, and tolerates summer temperatures up to 35 °C without significant photosynthetic depression. Water requirements during the growing season are modest, in the range of 400–600 mm of total precipitation or equivalent irrigation, with the critical period for moisture supply being the tuber-formation phase from August to September [9,10]. Drought during this window may reduce yield by 20–40%, but the plant rarely suffers complete failure even under severe water stress, recovering vigorously when moisture is restored. These characteristics align well with the climatic profile of Uzbekistan's irrigated and rain-fed zones.

Land preparation follows standard practice for root crops: autumn plowing to a depth of 25–30 cm, followed by spring harrowing and surface leveling. Where the field has been previously cropped with potato, sunflower or other Asteraceae, a minimum rotation interval of three to four years is recommended to manage soil-borne pathogens, especially Sclerotinia sclerotiorum [10,17]. Planting material consists of whole or sectioned tubers weighing 50–80 g, with at least two healthy buds per piece. The seeding rate ranges from 1.5 to 2.5 t/ha, depending on tuber size and target plant density. Planting is performed in early to mid-spring when soil temperature at 10 cm depth reaches 5–8 °C — typically late March to early May in Uzbekistan.

Optimal planting geometry varies with intended end use. For tuber production, row spacing of 70–100 cm and within-row spacing of 30–50 cm (yielding 25,000–47,000 plants/ha) is generally recommended; for combined biomass and tuber production, denser plantings up to 60,000 plants/ha are used. Planting depth is 8–12 cm, with shallower placement in heavy soils and deeper in light, sandy soils. Mechanical planters originally designed for potato can be adapted for Jerusalem artichoke with minor modifications [16,17].

Fertilization requirements are notably lower than for potato. Recommended rates are 60–90 kg N/ha, 60–80 kg P_2O_5/ha, and 100–150 kg K_2O/ha, applied as a combination of basal application before planting and topdressing during early growth. Excessive nitrogen application reduces tuber inulin content and promotes lodging of the tall stems; potassium is particularly important for inulin accumulation and tuber quality [10,18]. The crop responds well to organic fertilization and integrates well into low-input and organic farming systems. Irrigation, where required, is typically supplied as 3–5 events totaling 200–400 mm during the growing season, with emphasis on the tuber-bulking period.

Weed control is most critical during the first 40–50 days after planting, before the canopy closes; subsequently, the dense, tall growth of Jerusalem artichoke effectively suppresses competing vegetation. Mechanical inter-row cultivation, complemented where necessary by pre-emergence herbicides registered for sunflower, is the standard approach. Pest pressure on Jerusalem artichoke is generally low compared with potato or sunflower; sporadic problems have been reported with aphids, sunflower moth (Homoeosoma electellum), and stem-boring larvae, but rarely require chemical intervention. Disease incidence is similarly limited; the most economically significant pathogens are Sclerotinia sclerotiorum, Rhizoctonia solani, and rust caused by Puccinia helianthi, all of which are best managed through crop rotation, balanced fertilization, and use of resistant cultivars [10,17].

Harvesting is performed in late autumn after the aboveground biomass has senesced from frost (typically October–November in Uzbekistan's cooler zones) or alternatively in early spring before bud break. The latter strategy exploits the natural in-ground cold storage capacity of the tubers and is particularly suited to small-scale and household production. Mechanical harvesting employs modified potato lifters or specialized tuber harvesters. Tuber yields under recommended technology typically range from 30 to 60 t/ha, with well-managed plots in optimal environments producing up to 80 t/ha; aboveground biomass yields of 40–60 t/ha provide an additional resource that can be ensiled for livestock feed or used for bioenergy production [4,11,19].

Post-harvest handling is the most problematic aspect of Jerusalem artichoke production. The tubers possess a thin, easily damaged skin and a high water content (75–80%), which together result in rapid moisture loss, shriveling, and microbial spoilage under ambient storage. Cold storage at 0–2 °C with 90–95% relative humidity can maintain marketable quality for 4–6 months, but introduces significant cost. The most widely used solutions are in-ground over-wintering, immediate processing into stable forms (dried slices, powder, or extracted inulin), and refrigerated bulk storage for the fresh market. Research on edible coatings, controlled atmosphere storage, and high-humidity cold rooms is ongoing [14,20].

CHEMICAL COMPOSITION AND BIOACTIVE COMPOUNDS

The nutritional and pharmacological significance of Jerusalem artichoke is determined primarily by the chemical composition of its tubers, which is dominated by inulin-type fructans. Comprehensive analyses across cultivars, harvest dates, and growing environments place fresh-tuber inulin content in the range of 14–20% by weight, equivalent to 60–80% of total tuber dry matter [6,15,21]. This is comparable to the highest inulin contents found among all cultivated plants, exceeding both chicory root (15–20% fresh weight) and onion (1–8%). Inulin in Helianthus tuberosus consists of linear chains of β(2→1)-linked D-fructose units, capped at the reducing end by an α(1→2)-linked D-glucose, with degree of polymerization (DP) varying widely from 3 to 60. The DP profile is strongly influenced by cultivar and harvest date: tubers harvested in early autumn contain predominantly long-chain inulins (DP > 20), whereas late-spring tubers — having undergone partial enzymatic depolymerization during overwintering — contain shorter-chain fructans and free fructose [15].

Beyond inulin, Jerusalem-artichoke tubers contain minor amounts of free sugars (fructose 0.5–2.5%, glucose 0.2–1.0%, sucrose 0.5–2.0% on a fresh-weight basis), 1.0–3.0% crude protein with a notably complete essential-amino-acid profile (including lysine, tryptophan, methionine and threonine), 1.5–2.5% dietary fiber other than inulin, and less than 0.5% lipids [22]. The protein-to-energy ratio is favorable relative to potato, and the lysine content (typically 4.0–5.5 g/100 g protein) is high enough to complement cereal-based diets. The energy content of fresh tubers is approximately 73 kcal/100 g, considerably lower than that of potato (77 kcal/100 g) when inulin's reduced caloric availability (1.5 kcal/g vs. 4 kcal/g for digestible starch) is accounted for.

Mineral composition is dominated by potassium (420–650 mg/100 g fresh weight) — among the highest concentrations recorded in any cultivated vegetable — followed by phosphorus (78 mg), magnesium (17 mg), calcium (14 mg), iron (3.4 mg), and zinc (0.12 mg). The vitamin profile includes appreciable concentrations of thiamine (B1, 0.20 mg/100 g), riboflavin (B2, 0.06 mg), niacin (B3, 1.3 mg), pyridoxine (B6, 0.08 mg), folate (B9, 13 μg), and vitamin C (4 mg). The plant also synthesizes pantothenic acid and biotin in concentrations that make a meaningful contribution to dietary intake [21,22].

Phenolic compounds constitute the most pharmacologically active non-carbohydrate fraction of the tuber. Chlorogenic acid, an ester of caffeic acid and quinic acid, is the dominant phenolic, with concentrations of 80–250 mg/100 g dry weight; caffeic, ferulic, and p-coumaric acids occur in lower but significant amounts [23]. These polyphenols exhibit substantial antioxidant activity in vitro and in vivo and contribute to the hepatoprotective and anti-inflammatory effects documented in animal studies. Additional bioactive compounds isolated from various plant parts include sesquiterpene lactones (predominantly in leaves and stems), polyacetylenes (helianthols, tridecapentaenes), and small quantities of carotenoids and tocopherols [24].

Table 1 summarizes the principal compositional parameters of Jerusalem-artichoke tubers in comparison with potato — the most commonly displaced crop in production-system planning.

Table 1. Comparative composition of Jerusalem artichoke and potato tubers (per 100 g fresh weight)

Component	Jerusalem artichoke	Potato	Unit
Energy	73	77	kcal
Water	75–80	79	g
Inulin (fructan)	14–20	0	g
Starch	trace	15–17	g
Protein	1.0–3.0	2.0	g
Dietary fiber (non-inulin)	1.5–2.5	2.2	g
Potassium	420–650	425	mg
Iron	3.4	0.8	mg
Chlorogenic acid	16–50	1–5	mg
Glycemic index (approx.)	15–20	70–85	—

The data presented in Table 1 illustrate the qualitative — not merely quantitative — distinction between the two crops. While potato is essentially a starch-storage organ optimized for rapid digestible-carbohydrate supply, Jerusalem artichoke is a fructan-storage organ optimized for slow colonic fermentation, with attendant metabolic and microbial benefits. The glycemic index difference (15–20 vs. 70–85) is particularly noteworthy from a public-health perspective in countries with rising prevalence of type 2 diabetes [25].

PHARMACOLOGICAL AND MEDICINAL PROPERTIES

The pharmacological evidence base for Jerusalem artichoke and its principal bioactive — inulin — is now extensive, encompassing in vitro, animal, and human clinical studies. The prebiotic function of inulin is the best-established and most consensually accepted health benefit. The International Scientific Association for Probiotics and Prebiotics (ISAPP) explicitly recognizes inulin-type fructans among the small number of substances meeting the formal definition of a prebiotic: "a substrate that is selectively utilized by host microorganisms conferring a health benefit" [7]. Oral intake of 5–15 g/day of inulin produces measurable increases in fecal Bifidobacterium and Lactobacillus counts within two to four weeks, with concomitant elevations in short-chain fatty acid (SCFA) production — particularly butyrate, acetate, and propionate — which underpin many downstream physiological effects [8,21].

In the domain of glucose metabolism, multiple randomized controlled trials have established that inulin and Jerusalem-artichoke powder reduce postprandial glycemia and improve insulin sensitivity in both healthy and dysmetabolic subjects. A meta-analysis of 33 trials reported by Le Bastard and colleagues [8] found average reductions of 0.55 mmol/L in fasting blood glucose and 0.30 percentage points in HbA1c following 8–12 weeks of inulin supplementation at 10–20 g/day. The mechanisms include direct slowing of carbohydrate absorption, SCFA-mediated stimulation of glucagon-like peptide-1 (GLP-1) secretion, and reduced hepatic gluconeogenesis. These findings support the dietary recommendation of Jerusalem-artichoke products for individuals with type 2 diabetes or impaired glucose tolerance — a particularly relevant consideration in Uzbekistan, where diabetes prevalence has risen sharply over the past decade [12,25].

Inulin also exerts significant effects on lipid metabolism. Pooled analyses of human trials indicate average reductions of 7–15% in serum total and LDL cholesterol, 5–10% in triglycerides, and modest but consistent increases in HDL cholesterol following 6–12 weeks of supplementation at doses above 8 g/day [21,26]. The proposed mechanisms include inhibition of hepatic fatty-acid synthesis through suppression of lipogenic enzymes (acetyl-CoA carboxylase, fatty acid synthase) by propionate, increased fecal excretion of bile acids leading to enhanced hepatic cholesterol catabolism, and reduced ileal absorption of dietary lipids. Combined with the antioxidant activity of accompanying phenolic compounds, these effects translate into a meaningful cardioprotective profile.

A particularly well-documented effect of inulin concerns mineral bioavailability. Clinical studies in adolescents and post-menopausal women have shown that daily intake of 8–15 g of inulin-type fructans enhances calcium absorption by 18–25% and magnesium absorption by 12–20%, with measurable improvements in bone mineral density over 12 months [21,27]. The mechanism involves SCFA-mediated acidification of the colonic lumen, which solubilizes mineral salts, and trophic effects on enterocyte mucosa that increase absorptive surface area. These findings are particularly relevant in the context of osteoporosis prevention in aging populations.

Beyond these primary effects, accumulating evidence supports several additional pharmacological actions. Hepatoprotective effects have been demonstrated in animal models of induced hepatitis and non-alcoholic fatty liver disease, with reductions in serum ALT and AST and improvements in histological liver scores [4,23]. Immunomodulatory effects, mediated by SCFA-driven regulatory T-cell expansion and by direct interaction of inulin oligomers with gut-associated lymphoid tissue, contribute to a broad anti-inflammatory profile and have been investigated as adjuncts in inflammatory bowel disease management [8]. Anti-carcinogenic effects on colon cancer have been documented in animal studies, mediated by butyrate-driven apoptosis of transformed colonocytes and by modulation of bile-acid metabolism [21,26]. The antioxidant activity of chlorogenic and caffeic acids, accompanied by free-radical scavenging assays showing trolox-equivalent capacities of 4–10 μmol/g fresh weight, contributes to overall oxidative-stress protection [23,24].

Importantly, the safety profile of Jerusalem-artichoke products is favorable. Inulin has received Generally Recognized as Safe (GRAS) status from the United States Food and Drug Administration and is approved for use in foods in the European Union. The principal reported adverse effect is mild gastrointestinal discomfort — bloating, flatulence — at intakes exceeding 20–30 g/day, attributable to rapid colonic fermentation; this is dose-dependent and resolves with gradual habituation [7,21]. Long-term studies have identified no toxicological concerns at intakes within normal dietary ranges.

FUNCTIONAL FOOD AND INDUSTRIAL APPLICATIONS

The combination of nutritional density, prebiotic activity, and favorable techno-functional properties has driven the rapid expansion of Jerusalem-artichoke-derived ingredients in functional food formulation. Three principal product forms are commercially significant: extracted inulin powder (purity 85–99%), dried tuber powder (containing 60–80% inulin together with the full mineral, vitamin, and phenolic profile), and fresh or freshly processed tubers for direct culinary use [4,28].

In bakery applications, the substitution of 5–10% of wheat flour with Jerusalem-artichoke powder produces breads with enriched fiber and prebiotic content, distinctive nutty-sweet flavor, and improved moisture retention contributing to extended shelf life. Praznik and colleagues [29] demonstrated that substitution levels up to 10% maintain acceptable loaf volume and crumb structure, while delivering 4–6 g of inulin per 100 g of bread. Higher substitution levels (15–20%) compromise gluten network development but remain viable for specialty products such as dense whole-grain breads. Particularly promising is the formulation of breads for individuals with prediabetes, where the lowered glycemic response — typically 20–30% below that of standard white bread — offers a direct clinical benefit.

Dairy applications represent perhaps the largest single market segment for inulin. In yogurts and fermented milk products, inulin serves simultaneously as a fat replacer (mimicking the creamy mouthfeel of milk fat at half the caloric density), a texture stabilizer, and a synbiotic enhancer when combined with probiotic cultures of Lactobacillus and Bifidobacterium. Studies indicate that the addition of 2–5% inulin enhances probiotic viability during refrigerated storage by 0.5–1.5 log units, prolonging functional shelf life [21,28]. Comparable benefits have been documented in cheese, ice cream, and dairy desserts.

Gluten-free formulations represent a rapidly growing application area, driven by celiac disease and non-celiac gluten sensitivity. Jerusalem-artichoke powder improves the structure, palatability and nutritional profile of gluten-free breads, pasta, and biscuits, partially compensating for the absence of gluten-derived viscoelastic structure. In confectionery, inulin functions as a low-glycemic, low-calorie bulking agent and sugar replacer in chocolates, candies and gummies, with particular utility in "sugar-free" and "low-sugar" product lines targeting diabetic and weight-conscious consumers [4,28].

Meat-product applications exploit inulin's capacity to bind water and lipid, producing reduced-fat sausages, hams and emulsified meat products with sensory characteristics close to full-fat references. Replacement of 30–50% of fat with inulin gels has been shown to maintain texture and juiciness while reducing total energy by 20–30% [22,28]. Infant formula represents another high-value application: many commercial formulas now include short-chain inulin (oligofructose) to mimic the prebiotic effect of human-milk oligosaccharides, supporting the development of a Bifidobacterium-dominant infant gut microbiota. The roasted, ground tuber also serves as a traditional caffeine-free coffee substitute, with a distinctive bittersweet flavor profile.

Industrial applications extend beyond food. Jerusalem-artichoke biomass and tubers are increasingly studied as feedstocks for bioethanol production: the inulin can be hydrolyzed enzymatically (using exo- and endo-inulinases from Aspergillus and Kluyveromyces species) to fructose, which yeasts ferment with efficiencies approaching 90% of theoretical [3,4]. Aboveground biomass provides high-quality silage for ruminant livestock and a feedstock for biogas production. Cosmetic and pharmaceutical applications of inulin as a humectant, prebiotic for skin microbiota, and excipient in tablet formulation are also under active development. Collectively, these multiple value chains support the increasingly common characterization of Jerusalem artichoke as a "multipurpose biorefinery crop" [4,30].

CHALLENGES AND FUTURE PROSPECTS

Despite its evident promise, the broader adoption of Jerusalem artichoke is constrained by a set of interrelated challenges that future research and policy must address. The first and most pressing constraint is post-harvest tuber instability: the thin skin, high water content, and absence of a robust cuticle render tubers vulnerable to dehydration, mechanical damage, and microbial spoilage within days of harvest under ambient conditions. Solutions under investigation include rapid post-harvest cooling, controlled atmosphere storage, edible coatings based on chitosan or alginate, and immediate processing into stable forms [14,20]. The integration of solar drying — particularly relevant in sun-rich regions such as Uzbekistan — represents a low-cost pathway to producing shelf-stable powder and chips.

The second constraint is the relatively limited intensity of breeding effort. Compared with major commercial crops, Jerusalem artichoke has received only modest investment in genetic improvement, and there is substantial scope to develop cultivars with higher inulin content, improved tuber uniformity for mechanized harvesting, increased disease resistance, enhanced drought tolerance, and extended storage life. Marker-assisted selection and emerging genomic technologies offer accelerated breeding pathways [5,15]. The third constraint is processing infrastructure: high-purity inulin extraction requires specialized equipment and technical knowledge that are unevenly distributed globally. Localized, small-scale processing technologies — particularly those producing dried tuber powder rather than purified inulin — represent a more accessible entry point for smallholder-based value chains.

The fourth constraint concerns consumer awareness and market development. In many countries, Jerusalem artichoke remains an unfamiliar crop, with limited culinary tradition and weak consumer demand. Building markets requires coordinated investment in nutrition education, product development, branding, and supply-chain integration. For Uzbekistan and Central Asia more broadly, the alignment between Jerusalem artichoke's agronomic profile (drought tolerance, low input demand, climatic resilience) and regional needs (water scarcity, soil salinization, rising diabetes prevalence, agricultural diversification) is particularly favorable. A coordinated approach combining pilot cultivation, processing-facility development, clinical-validation studies in Uzbek populations, and integration into school-meal and hospital-nutrition programs could accelerate adoption.

Climate-change projections add further weight to the case for Jerusalem artichoke. Models for Central Asia consistently project rising summer temperatures, declining mountain snowpack, and intensifying drought episodes [12]. Under these projections, the comparative advantage of drought-tolerant, low-input crops over conventional irrigation-intensive alternatives will widen. Jerusalem artichoke is well-positioned to contribute to both adaptation and mitigation: adaptation through productivity stability under variable conditions, and mitigation through carbon sequestration in extensive root systems and substitution of fossil-derived sweeteners by inulin-based alternatives.

CONCLUSION

This comprehensive review of 25 contemporary scientific sources confirms that Jerusalem artichoke (Helianthus tuberosus L.) is a crop of exceptional and underappreciated value, combining undemanding cultivation requirements with a chemical composition that supports a wide range of demonstrated health benefits. Agronomically, the species delivers tuber yields of 30–80 t/ha under low-input conditions, tolerates drought, frost, and marginal soils, and integrates well into diversified and climate-resilient farming systems. Nutritionally and pharmacologically, the tubers are dominated by inulin-type fructans (14–20% fresh weight, 60–80% of dry matter), accompanied by a complete protein profile, abundant potassium and iron, and bioactive phenolic compounds. Inulin functions as a clinically validated prebiotic, lowers postprandial glycemia and LDL cholesterol, enhances mineral absorption, and contributes to weight management, hepatoprotection, and anti-inflammatory and anti-carcinogenic effects.

Functional food applications are well-developed and continue to expand, with inulin and Jerusalem-artichoke powder used successfully in bakery, dairy, gluten-free, confectionery, meat-product, infant-formula, and coffee-substitute formulations. Industrial applications extend to bioethanol, animal feed, biogas, and cosmetic sectors. The principal challenges — post-harvest tuber instability, limited breeding investment, underdeveloped processing infrastructure, and weak consumer awareness — are tractable through coordinated research and policy action.

For Uzbekistan and Central Asia, the alignment between the agronomic profile of Jerusalem artichoke and regional priorities — water scarcity, soil constraints, diversification of farming systems, and the public-health imperative to address rising diabetes and metabolic-syndrome prevalence — creates a particularly compelling case for expanded cultivation. Recommended priority actions include: (i) establishment of pilot cultivation trials across distinct agro-ecological zones to validate yields and quality under local conditions; (ii) introduction and evaluation of improved international cultivars alongside germplasm-collection efforts; (iii) development of small-scale processing facilities for dried powder and basic inulin extraction; (iv) clinical-validation studies of Jerusalem-artichoke products in Uzbek populations with prediabetes and type 2 diabetes; and (v) integration of functional Jerusalem-artichoke products into national nutrition programs. Together, these actions would position Jerusalem artichoke as a strategic crop in the modernization of Uzbek agriculture and the promotion of public health.

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