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Agronomic, Nutritional, and Sensory Characterization and Horticultural Quality of Two Jerusalem Artichoke Biotypes from Northern Argentine Patagonia

Susana Diez ^{1,2} , Daniela Marisol Salvatori ^{1,2,*}  and Lorena Franceschinis ^{1,2} 

- ¹ Instituto de Investigación y Desarrollo en Ingeniería de Procesos, Biotecnología y Energías Alternativas—PROBIEN (CONICET-Universidad Nacional del Comahue), Buenos Aires 1400, Neuquén 8300, Neuquén, Argentina; susana.diez@probien.gob.ar (S.D.); lorena.franceschinis@probien.gob.ar (L.F.)
- ² Facultad de Ciencias y Tecnología de los Alimentos, Universidad Nacional del Comahue, 25 de Mayo 131, Villa Regina 8336, Río Negro, Argentina
- * Correspondence: daniela.salvatori@probien.gob.ar

Abstract

Despite its high inulin content, Jerusalem artichoke (*Helianthus tuberosus* L.) remains an underutilized vegetable for human consumption. Organic field trials of two biotypes adapted to Northern Patagonia, Argentina, were conducted. Since no cultivars are formally registered in the country, two biotypes, “elongated” (E) and “rounded” (R), defined according to tuber morphology, were planted and characterized. Agronomic performance was evaluated through soil analysis and crop yield. Tubers were analyzed for horticultural quality (e.g., respiration rate, inulin, firmness) and microstructure. A nutritional profile was determined, including protein, fat, dietary fiber, sugars, organic acids, minerals, phenolic content, and antioxidant capacity. Sensory evaluation (overall liking, free association, and penalty–reward analysis) was performed with 128 consumers, most of them unfamiliar with the tuber. The biotype R exhibited twice the yield and higher consumer preference, whereas E showed a higher respiration rate, a better nutritional profile, a harder texture, and lower overall liking. Initially, 76% of participants expressed willingness to incorporate it into their diet, which increased to 96.6% after they were informed of its health benefits. This multidimensional study, support the revalorization of Jerusalem artichoke and its inclusion in human diets as a fresh vegetable for biotype R or functional ingredient for biotype E.

Keywords: *Helianthus tuberosus* L.; yield; inulin; postharvest performance; mechanical properties; nutritional value; consumer perception



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1. Introduction

The Jerusalem artichoke (*Helianthus tuberosus* L.) is a perennial herbaceous species of the *Asteraceae* family, closely related to the sunflower (*Helianthus annuus* L.) [1,2], since both species belong to the same genus. Native to North America, this plant produces high tuber yield, which can be used for human consumption as a vegetable, for animal feed, and for industrial purposes. The extraction of fructans and fructose from this species is of significant interest for food, pharmaceutical, and bioenergy applications, including bioethanol, methane, and biogas production [2–5]. Its aboveground biomass also serves as a medicinal herb, grazing crop, and bioenergy resource [1–3]. The plant exhibits vigorous growth, effectively suppressing weeds and thriving without fertilizer inputs [3,4].

Adaptable to poor and contaminated soils, it can be cultivated on marginal lands for fodder and bioremediation purposes [4,6–8]. Additionally, its resilience to frost and plant diseases enhances its potential for sustainable agricultural and environmental uses [1,3]. All these characteristics make it a promising crop for minimizing environmental impact and reducing competition for land use between food and fodder crops [5].

The agronomic characterization of its cultivars allows for guiding their use toward specific purposes. Those with high tuber yield and elevated inulin content are suitable for the food and pharmaceutical industries, whereas those with greater aboveground biomass are optimal for renewable energy production [1,3]. Some cultivars combine both traits, offering versatile potential that supports their development as a multifunctional crop of relevance in both energy and industrial sectors [9].

As a horticultural resource for human nutrition, the Jerusalem Artichoke tuber (JA) has been largely underutilized worldwide, except in some European countries where its culinary use is increasing. In South America, specifically in Argentina, this vegetable is rarely available in the market, making it unfamiliar to most consumers [10]. The raw tuber is a versatile vegetable with a nutty flavor and crisp texture [1,11], and it has a high nutritional profile with associated health benefits [1,2]. It contains well-known health-promoting compounds, including vitamins, minerals, and the prebiotic fiber inulin [12].

A complete sensory profile of raw JA remains largely undocumented in the existing literature. Only three studies addressed the sensory analysis of the raw vegetable, and two of them also compared it with boiled JA. These authors worked with tubers harvested in Europe, specifically in Italy [4] and Denmark [11,12]. To drive increased JA consumption, it is essential to expand the knowledge of sensory properties, culinary quality, and overall suitability to meet consumer demand [4,12].

To effectively promote the market-oriented application of JA resources, a limited, single-trait evaluation is insufficient. Given JA has multifunctional potential (industrial, energy, and food uses), its characterization must be multidimensional, linking agricultural productivity directly to nutritional quality and consumer acceptance. Therefore, this study integrates distinct yet complementary evaluation metrics to ensure a comprehensive assessment.

Although studies have been conducted in Europe on the sensory characteristics and nutritional composition of Jerusalem artichoke, an integrative agronomic, nutritional, and sensory study on locally adapted biotypes is still lacking in South America. In particular, the absence of formally registered JA cultivars in Argentina has resulted in a lack of data on their most important features, thereby limiting local cultivar selection and market promotion. In this context, the present study aimed to characterize two Jerusalem artichoke biotypes, adapted to Northern Patagonia, Argentina, focusing on their horticultural quality, physicochemical and nutritional properties, as well as sensory attributes.

2. Materials and Methods

2.1. Plant Material

Experimental organic crop trials of two Jerusalem artichoke biotypes adapted to the edaphoclimatic conditions of Northern Patagonia were conducted. These trials took place on a farm located in Villa Regina city, Río Negro province, Argentina (39°07′10″ S, 67°06′37″ W). Both biotypes yielded light-brown-skinned tubers. Since no cultivars are formally registered in Argentina, the two Jerusalem artichoke biotypes were classified and designated as elongated (E) and rounded (R) based on their characteristic tuber morphology. In September 2022, seed tubers of each biotype were planted 30 cm apart at an average depth of 10 cm on a single, East–West-oriented ridge. For the biotype E, seed tubers weighing over 40 g were selected, while for the biotype R, those weighing more than 150 g were chosen. Immediately after planting, flood irrigation was applied every six days and

continued from September to April. Both biotypes showed 100% sprouting within 15 days of planting, although emergence occurred approximately one week apart. Manual harvest was performed in June 2023. After delimiting the area around each planted tuber, all aboveground biomass was first removed, followed by the belowground biomass.

2.2. Edaphoclimatic Conditions

After the tubers were harvested, soil samples were collected at a depth of 20 cm from the plots where each biotype was planted (approximately 4 linear meters per biotype). A soil extract was prepared using a 1:2 soil-to-distilled water ratio. The extract's pH was then determined by potentiometry, and its salinity, expressed in deciSiemens per meter (dS/m), was measured by electrical conductivity [13]. Soil texture was assessed by the tactile method. Organic matter and oxidizable carbon content were determined [13]. Temperature and rainfall data were obtained from the INTA database for the Alto Valle of Río Negro [14].

2.3. Crop Yield Assessment

Aboveground biomass was quantified by recording the number of stems and their maximum lengths for each seed tuber. The average yield of belowground biomass was calculated from the harvested tubers and expressed in kg per seed tuber planted. Tuber size distribution was determined by classifying tubers into weight ranges adjusted to the characteristic size profiles of each biotype. The total mass for each tuber size category was recorded. Results are expressed as the average of the three samples, relative to the number of plants harvested.

2.4. Tuber Conditioning

Harvested tubers underwent a thorough conditioning process. They were first washed with potable water and brushed to remove adhering soil. The tubers were then disinfected in a 280 ppm sodium hypochlorite solution for 20 min, followed by a 10 min rinse with water. Finally, they were dried with absorbent paper and stored in low-density polyethylene (LDPE, 20 μ m thick) bags at 0 ± 0.5 °C and 90% relative humidity until further use.

2.5. Horticultural Quality Variables

A representative sample of unpeeled tubers of various sizes was collected from each biotype for the following determinations performed in triplicate ($n = 3$). Dry matter was determined gravimetrically; 10 g of grated tubers were dried in a convection oven SL60S (San Jor, San Martín, Buenos Aires, Argentina) at 105 ± 1 °C for 24 h. Soluble solid content was measured using refractometry and expressed as Brix [15]. pH and total acidity were determined by potentiometry [15]. Total acidity was quantified by acid-base titration with 0.1 N NaOH to an endpoint of pH 8.1, and expressed as mg malic acid per 100 g fresh JA.

The respiration rate (RR) was measured as CO₂ emission per kg of tuber per hour (mL CO₂ kg⁻¹ h⁻¹). To ensure comparable measurements, 8 tubers of different sizes were selected to constitute samples of equivalent volume, which were then placed into airtight containers. Sample weights were recorded. The CO₂ concentration in the container headspace was periodically measured using a Dansensor headspace analyzer (Ametek Mocon, Brooklyn Park, MN, USA), and the RR at 4 h was reported.

Weight loss (WL) of 1 kg of tubers was measured to assess the effects of evapotranspiration and respiration during a 30-day storage period (0 ± 0.5 °C, 90% RH) in LDPE bags. Samples were weighed at the beginning and end of the storage period, and WL was expressed as g kg⁻¹ of fresh weight (FW).

Superficial color was determined using a Minolta CR 400 photocolormeter (Konica Minolta Sensing Inc., Osaka, Japan), with illuminant C and a 2° observer angle. The CIELAB parameters L*, a*, and b* were recorded, where L* indicates luminosity, ranging

from 0 (black) to 100 (white), a^* represents chromaticity along the green (–) to red (+) color axis, and b^* indicates chromaticity along the blue (–) to yellow (+) color axis. Calibration was performed using a white ceramic plate ($L^* = 95.55$; $a^* = -0.10$; and $b^* = +2.69$). Measurements were taken on both tuber skin and tuber pulp ($n = 10$).

The mechanical properties of the tuber flesh ($n = 18$) were analyzed using a puncture test performed with a universal testing machine model 3344 (Instron Corporation, Norwood, MA, USA), connected to Bluehill 2 Material Testing Software (Instron, version 2.14). A 1000 N load cell, a 2 mm diameter cylindrical probe, and a penetration speed of 50 mm/min were used. For each measurement, 2.5 cm thick tuber slices were centrally positioned in the testing fixture, and force-displacement curves were obtained, as illustrated in Figure 1.

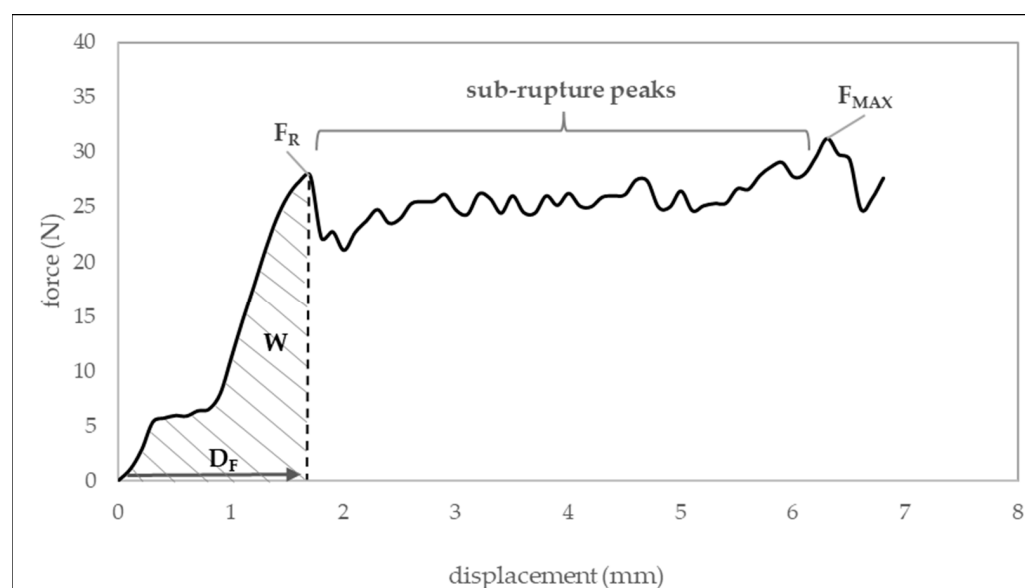


Figure 1. Force versus displacement curve illustrating the typical mechanical response of raw JA pulp during a puncture test.

From these curves, the following key points were analyzed: the fracture resistance (F_R), defined as the force at the first tissue fracture peak, and its corresponding displacement (D_F). The work to fracture (W), related to the energy consumed during rupture, expressed in Joules (J), was calculated as the area under the force-displacement curve up to D_F . The maximum force (F_{MAX}), representing tissue firmness, was also recorded.

2.6. Microstructural Analysis

Ultrastructural observations of biotypes E and R were performed by scanning electron microscopy (SEM). After immobilization of the tuber tissue through lyophilization (48 h at a condenser temperature of $-84\text{ }^{\circ}\text{C}$ and a chamber pressure of 0.22 mbar), pieces were transversely and longitudinally sectioned with a scalpel into 2 cm cubes, ensuring that both pulp and epidermis were preserved in each sample. The cubes were mounted on an aluminum support using conductive carbon double-sided adhesive tape, and then coated with gold nanoparticles using a cathodic sputter coater model 108 (Cressington Scientific Instruments, Watford, UK). The samples were examined using a scanning electron microscope Zeiss Gemini 360 (Carl Zeiss, Oberkochen, Germany), operating at an accelerating voltage of 20 kV and magnification of $300\times$.

2.7. Proximate and Bioactive Compound Analysis

Protein, fat, and dietary fiber were determined according to AOAC methods [15].

The water content was determined at 105 ± 1 °C for 24 h.

The calculation of the energy value (EV) was carried out using the following conversion factors, in accordance with the Argentine Food Code [16], as shown in Equations (1) and (2), in kcal and kJ, respectively:

$$\text{EV (kcal)} = (\text{g carbohydrate} \times 4 \text{ kcal/g}) + (\text{g protein} \times 4 \text{ kcal/g}) + (\text{g fat} \times 9 \text{ kcal/g}) \quad (1)$$

$$\text{EV (kJ)} = \text{kcal} \times 4.184 \quad (2)$$

The content of sugars (glucose, fructose, sucrose), inulin and organic acids were determined by high performance liquid chromatography (HPLC), using an equipment Agilent 1260 HPLC (Agilent Technologies, Santa Clara, CA, USA) equipped with an automatic injector (5 µL), employing a diode array detector (DAD) for the detection of organic acids and a refractive index detector (RID) for the detection of sugars and inulin. Separation was achieved using a HIPLEX H column (300 mm × 7.7 mm, 8 µm particle size, Agilent Technologies, USA), at 348 K. The mobile phase was composed of 0.001 M H₂SO₄ at a flow rate of 0.4 mL min^{−1}. For inulin determination, a 100% pure powdered organic inulin (FOS) from Jerusalem artichoke (Piping Rock Brand, Bohemia, NY, USA) was used as the standard. For the determination of sugars and organic acids by HPLC, the standards D-(+)-glucose, D-(−)-fructose, and L-malic acid were purchased from Sigma Aldrich Chemie GmbH (Steinheim am Albuch, Germany); sucrose and succinic acid were purchased from Merck KGaA (Darmstadt, Germany); citric and acetic acids from Reactivos Cicarelli S.A (Santa Fe, Argentina). The extracts to be analyzed were obtained by hydrothermal extraction from 1 g of JA in 100 mL of volume, according to the technique proposed by Zuleta and Sambucetti [17].

The carbohydrate content reported in nutritional information was determined by summing the amounts of digested, absorbed, and metabolized [16]. Particularly, for Jerusalem artichoke biotypes, mono- and disaccharides such as glucose, fructose, and sucrose were considered.

The mineral content was determined in an ICP–OES spectrometer, model JY2000-2 (Horiba, Kyoto, Japan), using the adapted heavy metal determination method described by AOAC [15]. Digestion of 0.3 g of dried JA was carried out by adding 10 mL of HNO₃ 65% at 180 °C for 3 h with agitation. After cooling, the extracts were diluted to a final volume of 25 mL, and 1 mL of this solution was further diluted to 50 mL with ultrapure water. Calibration was conducted using a standard solution containing 26 elements (100 ppm in HNO₃ 5%). Elemental concentrations were determined using ICP JOBIN YVON software (HORIBA, Version 5.4), based on the intensity values of the spectral lines (nm).

Phenolic compounds and antioxidant capacity were determined on extracts obtained from 5 g of JA by performing two successive extractions in distilled water (65 °C, 500 rpm, 30 min) to a final volume of 25 mL. The total polyphenol content (TPC) was determined using the Folin–Ciocalteu reagent according to Gomez Mattson et al. [18]. Spectrophotometric measurements were carried out using a Shimadzu UV 1800 spectrophotometer (Kioto, Japón), and the calibration curve was prepared using gallic acid as standard. The results were expressed as mg gallic acid equivalents (mg GAE) per 100 g JA. Total flavonoids (TF) were determined by the AlCl₃ complex formation method according to Diez et al. [19]. The results were expressed as mg catechin equivalent per 100 g JA. Antioxidant capacity was measured by two methods: the ferric reducing-antioxidant power (FRAP) following the technique described by Gomez Mattson et al. [20] and the bleaching of 2,2-azinobis-[3-ethylbenzothiazoline-6-sulfonic acid] radical cation (ABTS^{•+}) according to Gomez Mattson et al. [18]. Gallic acid was used as standard for the calibration curve, and results were expressed as mg gallic acid equivalent (GAE) per 100 g of fresh tuber.

2.8. Sensory Analysis and Consumer Perception

Consumers ($n = 128$) were invited to participate in a sensory study conducted in the central square of Villa Regina city, Río Negro province, Argentina. Each participant was asked to try raw JA and rate their Overall Liking (OL) using a 9-point structured hedonic scale, ranging from 1 = “dislike extremely” to 9 = “like extremely”, with 5 = “neither like nor dislike”. Samples were presented monadically following a balanced complete block design. Additionally, a free association technique was employed; participants were asked to describe everything that came to their minds, including words, sensations, and emotions. Surveyed individuals were also asked about the feasibility of incorporating JA into their diet. Those who responded affirmatively were then required to specify their preferred biotype or indicate whether both were equally acceptable for inclusion. Participants who initially rejected including JA in their diet were subsequently provided with nutritional information on its health benefits and were asked to reconsider their consumption intention. The categorization of all words provided by participants was performed independently by three researchers, with a consensus established afterward [18,21]. Relative frequencies of category usage were calculated, and word clouds representing each biotype were generated using the free software Tagul Word Cloud Art—Word Art (<https://wordart.com/create>, accessed on 15 September 2025).

A penalty/reward analysis was conducted for each JA biotype by calculating the difference between the OL mean when a specific category was mentioned versus when it was not [10].

2.9. Statistical Analysis

The results were expressed as the mean and the standard deviation (SD). The significant differences between means were assessed using one-way ANOVA, and multiple comparisons were conducted using the Tukey test ($p < 0.05$). Infostat software (version 2020) was used [22].

3. Results

3.1. Agronomic Characterization of Crops

The soil and climate conditions under which Jerusalem artichoke crops were grown, in this study, correspond to those of Alto Valle region of Río Negro, Argentina. The 2022–2023 season was characterized by an average temperature of 14.7 °C. A wide temperature range was recorded, with a minimum of −8.7 °C in June and a maximum of 40.6 °C in January. Seasonal precipitation averaged 23 mm. The highest monthly precipitation (76.8 mm) occurred in February, whereas the lowest (1 mm) was observed in March [14]. Table 1 presents the characteristics of the aboveground and underground biomass of Jerusalem artichoke crops, as well as the properties of the soil where the crops were harvested. The soil characteristics were consistent across the biotype cultivation areas. The silty loam texture showed a balanced composition of sand, silt, and clay, whereas the electrical conductivity and pH values, along with the contents of organic matter and oxidizable carbon, indicated that the soil properties fell within the typical range for irrigated soils of moderate fertility in the Alto Valle region.

An evaluation of crop yield was carried out, considering both aboveground and below-ground biomass. As presented in Table 1, which summarizes plant growth characteristics, the number of stems did not differ significantly between biotypes. In contrast, the biotype R exhibited a significantly greater maximum height, a difference that was also evident in the field. These findings are consistent with those of previous studies. It has been reported that plant height ranges from 1.40 m to 2.80 m [5]. Baldini et al. [23] found average heights of 2.42 m to 2.71 m when studying the ‘Violette de Rennes’ variety and five clones cultivated

in Italy. In Argentina, Rébora [24] studied five varieties of Jerusalem artichoke at two sites in Mendoza. The plants showed a height variation ranging from 1.46 m to 2.56 m, a difference attributed to the distinct geographical areas where the crops were grown.

Table 1. Agronomic characteristics of Jerusalem artichoke crops, aboveground and underground biomass.

Agronomic Characteristics		Biotype E	Biotype R
aboveground biomass			
	number of stems per seed tuber	6 ± 3^a	7 ± 2^a
	maximum height of stems (m)	2.9 ± 0.1^a	3.3 ± 0.2^b
underground biomass			
	yield (kg per seed tuber)	2.0 ± 0.2^a	4.62 ± 0.16^b
	tuber size (g)	10–40	20–140
soil characteristics			
	electrical conductivity (dS/m)	0.04 ± 0.006^a	0.03 ± 0.004^a
	pH	6.0 ± 0.05^a	6.0 ± 0.05^a
	organic matter (%)	1.70 ± 0.05^a	1.81 ± 0.07^a
	oxidizable carbon (%)	0.99 ± 0.02^a	1.05 ± 0.05^a

Different lowercase letters in the same row indicate significant differences ($p < 0.05$).

Figure 2 illustrates the morphological characteristics of leaves, stems, flowers, and tubers for both Jerusalem artichoke biotypes. The leaves of the biotype E were consistently darker green and lanceolate along the entire stem. In contrast, biotype R exhibited leaf dimorphism, with ovate leaves on the lower part of the stem that transitioned to lanceolate shape higher up, becoming similar to those of biotype E. Both biotypes have slightly serrated leaf margins and pubescence on the underside of the upper leaf surface, as well as on the petioles and stems. The leaves are attached to the stem in opposite pairs at successive nodes, forming a decussate arrangement. This characteristic is also observed in sunflowers, likely reflecting the shared traits of species within the genus *Helianthus*.

The flowers of both biotypes appear in capitula, the characteristic inflorescence of the family *Asteraceae*. These heads developed singly or in clusters at the apices of stems and branches. The capitula were deep yellow and, although morphologically similar to those of sunflower, were smaller in diameter [25]. Inflorescences of biotype E differed slightly from those of biotype R, with floral ligules positioned more closely together and often overlapping. In the Alto Valle region, full flowering generally occurs in late summer (March–April) and continues until the first frosts, which lead to the senescence of the aerial parts. Biotype E, in particular, flowered earlier than biotype R.

From 13 planted seed tubers, a total of 26 kg of biotype E and 60 kg of biotype R were harvested. This represents a marked difference in productivity, with biotype E yielding an average of 2.0 kg per seed tuber compared to 4.6 kg for biotype R (Table 1). Supplementary Figure S1 shows the average tuber size distribution for both biotypes. Biotype E predominantly produced small tubers (Figure S1a), with only 39% exceeding 20 g, the threshold generally considered suitable for horticultural use [26]. Tubers larger than 40 g were reserved as seed stock for the subsequent cropping cycle.

In contrast, biotype R produced substantially larger tubers, with 90% weighing more than 20 g (Figure S1b). Of the total harvest, 80% of the R biotype tubers fell within the commercially valuable size range of 20–140 g. The remaining 20% was evenly distributed, with 10% consisting of small tubers (<20 g) and 10% classified as very large tubers, one of which reached 225 g. The larger R tubers (>150 g) were designated as seed stock, underscoring their potential agricultural and economic value. These size differences appear to be biotype-specific. Since all cultivation conditions—including soil fertility, irrigation

regime, and harvest time—were uniform for both biotypes, the observed variation in tuber size and yield can be attributed to intrinsic differences between biotypes.



Figure 2. Agronomic characterization of Jerusalem Artichoke (*Helianthus tuberosus* L.), comparison of biotypes E (left) and R (right), (a,b) leaf shape and margin; (c,d) petiole insertion on the stem; (e,f) flower morphology; (g,h) tuber characteristics.

3.2. Horticultural Quality Parameters of Fresh Jerusalem Artichoke

3.2.1. Chemical Properties

Table 2 summarizes the horticultural quality of Jerusalem artichoke biotypes E and R. Several parameters commonly analyzed in vegetables were determined, considering their chemical, physiological, and physical properties. Among the chemical characteristics, significant differences between biotypes were found in dry matter, soluble solids, and total acidity, whereas pH values (close to neutral) were similar in both. Dry matter, soluble solids,

and inulin content were significantly higher in the biotype E. The dry matter values for both biotypes fell within the 18.8–27.2% range reported by Wang et al. [7] for seven Jerusalem artichoke varieties. These results confirm that inulin, the primary storage carbohydrate, is the main contributor to both dry matter and soluble solids in JA. Some studies have reported a wide range of soluble solids values. For instance, Baldini et al. [23] found values ranging from 15.8 to 24 Brix for JA cultivated in northern Italy, while Rubel [27] obtained 24–25 Brix from tubers in Córdoba, Argentina. Similarly, De Santis and Frangipane [4] reported values between 10.85 and 22.57 Brix in four Italian clones. In our study, the soluble solids were high for both biotypes and fell within the ranges reported in the literature for R, whereas values for the E were slightly higher. The inulin contents found in this study fell within the ranges previously reported in the literature, such as 7.4–12% [28], 10–25% [29], 9.6–12% [12], and 12.8–17.4% [4]. The pH and acidity values obtained in this study were comparable to those reported for other tubers such as potatoes. Palle et al. [30] reported pH values between 6.20 and 6.50. On the other hand, Obregón and Repo [31] found pH values ranging from 6.30 to 6.90 and acidity levels from 0.13 to 0.28 mg/100 g, which they attributed to the organic acid content of the tubers.

Table 2. Horticultural quality parameters of fresh Jerusalem artichoke tubers, biotypes E and R.

Horticultural Quality Parameters		Biotype E	Biotype R
chemical properties			
	dry matter (%)	27.6 ± 0.5 ^b	20.3 ± 1.2 ^a
	soluble solids (Brix)	25.9 ± 0.3 ^b	19.7 ± 0.1 ^a
	inulin (g/100 g)	18.5 ± 0.4 ^b	11.1 ± 0.5 ^a
	pH	6.44 ± 0.05 ^a	6.46 ± 0.05 ^a
	total acidity (mg malic acid/100 g)	0.18 ± 0.01 ^b	0.12 ± 0.02 ^a
physiological properties			
	weight loss, WL (g kg ^{−1} FW)	4.02 ± 0.02 ^b	2.91 ± 0.18 ^a
	respiration rate, RR (mL CO ₂ kg ^{−1} h ^{−1})	12.2 ± 0.6 ^b	7.1 ± 0.5 ^a
physical properties			
color skin			
	L*	52 ± 5 ^a	53 ± 4 ^a
	a*	5.4 ± 0.8 ^a	4.8 ± 1.1 ^a
	b*	27.3 ± 1.3 ^a	27.7 ± 1.6 ^a
color pulp			
	L*	73 ± 3 ^a	73 ± 3 ^a
	a*	−3.3 ± 0.3 ^a	−3.2 ± 0.4 ^a
	b*	15.6 ± 1.7 ^a	12 ± 2 ^b
mechanical properties			
	fracture resistance, F _R (N)	23 ± 4 ^b	20 ± 3 ^a
	displacement at F _R , D _F (mm)	1.6 ± 0.4 ^b	1.3 ± 0.3 ^a
	maximum force, F _{MAX} (N)	27 ± 4 ^b	22 ± 2 ^a
	fracture work, W (J)	13.0 ± 0.2 ^b	9.6 ± 0.2 ^a

Different lowercase letters in the same row indicate significant differences ($p < 0.05$).

3.2.2. Physiological Properties

Like other fruits and vegetables, JA continues to respire and transpire after harvest, consuming its carbohydrate reserves and causing a progressive loss of quality (senescence). Postharvest shelf life and respiration rate of fresh vegetables are inversely correlated. The rate of deterioration and perishability of harvested products is generally related to their respiration rate and water loss from transpiration [32]. Given that the RR is a key indicator of tuber physiological activity, WL is often used as a stability parameter for postharvest and shelf-life quality control [33]. Both physiological properties are influenced

by multiple variables, including cultivar, growing conditions, harvest maturity, handling practices, mechanical damage, disease incidence, sprouting, and storage conditions such as temperature and relative humidity [32,34,35]. Table 2 shows that the RR values measured at 20 °C were significantly higher in biotype E ($12.2 \pm 0.6 \text{ mL CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$), and this difference could be ascribed to the influence of tuber geometry on transpiration rate, as a higher surface-to-volume ratio in elongated shapes leads to faster shriveling [32]. RR in JA has not been extensively studied. For instance, Kays and Nottingham [36] reported a higher RR of $27.5 \text{ mL CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$ at 20 °C for JA. In comparison, other underground storage organs, such as potatoes and sweet potatoes, have a low RR of around $5\text{--}10 \text{ mL CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$ [37,38], while carrots have a moderate RR ranging from 10 to $20 \text{ mL CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$ [37]. Therefore, the values obtained in this study correspond to a low RR for JA biotype R and a moderate RR for JA biotype E. After one month of storage the WL, was low for both biotypes, with E being greater ($\text{WL} = 0.42 \pm 0.02\%$) than R ($\text{WL} = 0.48 \pm 0.03\%$). Danilčenko et al. [39] reported a considerably higher value ($\text{WL} = 4.89\%$) for JA under similar postharvest storage conditions ($2 \pm 0.5 \text{ }^\circ\text{C}$, 90–95% RH, one month), probably due to the use of a different packaging material (polypropylene bags). Other roots and tubers also show a wide range of WL under refrigerated storage. WL of 2–4% was reported for potatoes after six months of storage at $5 \pm 1 \text{ }^\circ\text{C}$ under 90% RH [34], and 7.5% ($74.7 \text{ g kg}^{-1} \text{ FW}$) for carrots packaged in low-density polyethylene (LDPE) pouches (95 μm thick, 16 holes of 5 mm) stored for 24 days at $4 \pm 0.5 \text{ }^\circ\text{C}$ and 95–96% RH [40].

3.2.3. Physical Properties

The most relevant physical properties of fresh vegetables that make them appealing to consumers are chromatic and mechanical properties, the latter being closely related to sensory-perceived texture. Both properties influence appearance and constitute important attributes in defining overall quality. With respect to chromatic parameters no significant differences were observed between the two biotypes in L^* , a^* , and b^* values of the skin, showing a light brown color. The pulp of both tubers is off-white, exhibiting high luminosity and negative a^* values corresponding to subtle greenish tones. Only b^* values significantly differed, the biotype E showed a slightly more pronounced yellowish hue (higher b^*), in agreement with the visual observation upon cutting.

Regarding mechanical properties, Figure 3 shows examples of force–displacement curves obtained from puncture tests on the pulp of raw JA. The tissue penetration resistance of both biotypes exhibited a similar pattern. At the beginning of the test, the force rose sharply to approximately 5 N, followed by a short plateau during the first millimeter of penetration. This plateau reflects the initial accommodation of the cellular structure as the probe makes contact with the tissue. Thereafter, the force increased abruptly due to progressive compression until reaching the first peak (F_R), which corresponds to the first non-visible fracture of the material. The distance corresponding to this peak represents the deformation the material undergoes before fracture [41]. This first peak was also associated with the greatest relative drop in force. Subsequently, successive microfracture peaks were recorded, among which the maximum rupture force (F_{MAX}), considered tissue firmness, was identified.

The sub-rupture peaks are associated with the repetitive deformation and fracture of successive tissue layers, which depend on the characteristic cellular structure [42]. The jagged profile of these curves is a typical feature of certain fresh raw vegetables, such as carrot [42], radish [43], celery [42], spring onion [44], potato [42], apple [43,45], and pear [46], among others. This mechanical behavior has been linked to tissue crunchiness, which is a sensory texture attribute. The extent of fracture can often be perceived audibly

during the first bite and subsequent mastication, defining the sensation of crunchiness [42]. Generally, as crunchiness decreases, the number of fracture events (peaks) diminishes and the peaks become wider and smoother [41], which appears to describe the behavior of biotype R. The distance D_F at which the fracture peak F_R is observed is related to the brittleness or fracturability of the material.

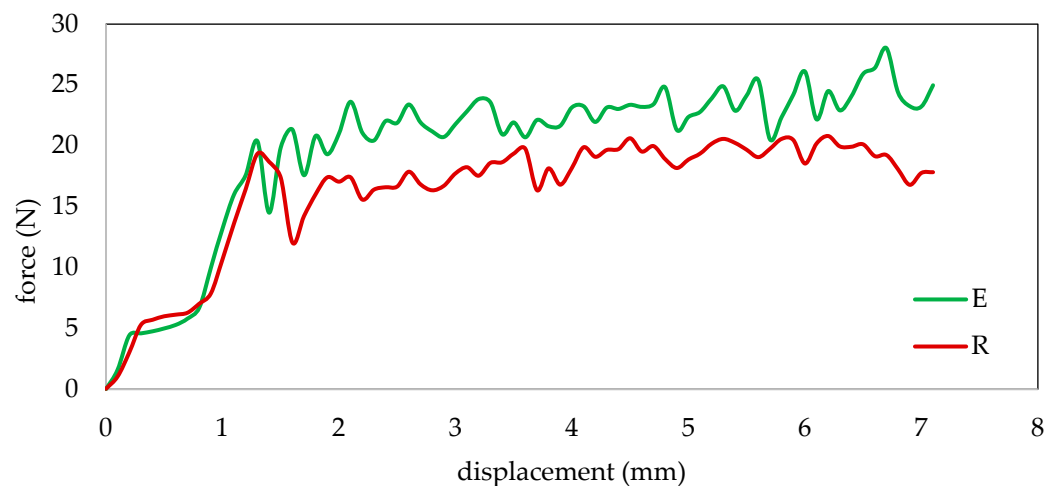


Figure 3. Force-displacement curves for a puncture test on raw Jerusalem artichoke (JA) pulp from biotypes E and R.

The biotype E exhibited higher F_R , F_{MAX} , and W values compared to the biotype R, indicating a harder material with greater resistance to penetration (Table 2). In tubers R, tissue fracture occurred at a shorter distance (lower D_F values), reflecting greater fragility of the pulp structure. Considering the difference between F_R and F_{MAX} , both biotypes showed increased resistance exerted by the internal microstructure during probe penetration ($F_R < F_{MAX}$). The variation observed for biotype E was twice that of the biotype R, which could be ascribed to the higher dry matter content of elongated tubers (Table 2).

3.3. Tissue Microstructure

Photomicrographs of the pulp microstructure of tubers are presented in Figure 4. Scanning electron microscope (SEM) images revealed parenchyma tissues composed of thin-walled cells with large vacuoles and variable geometry.

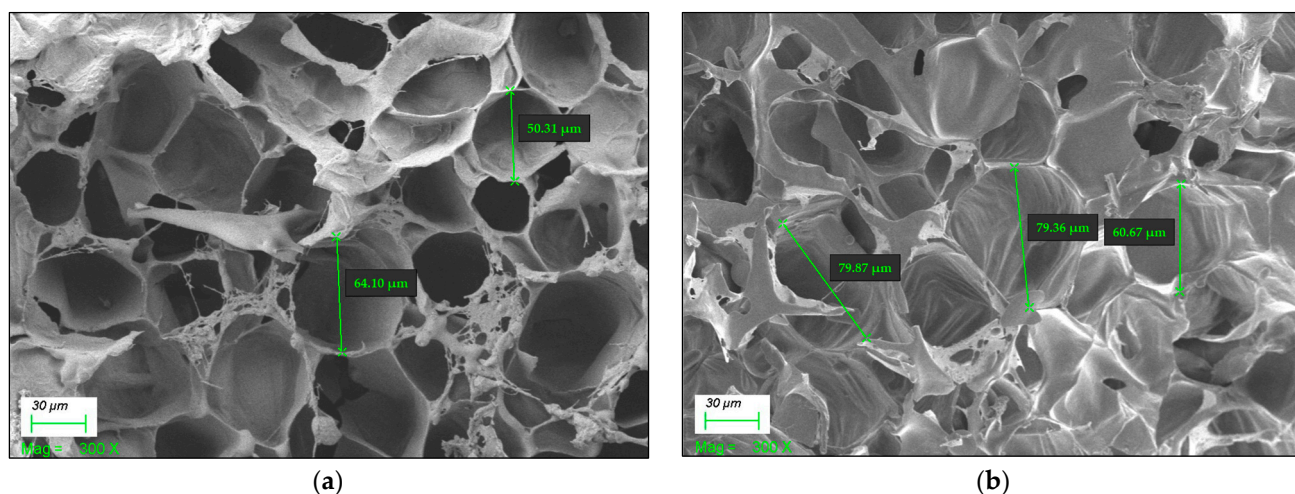


Figure 4. Microstructure of Jerusalem artichoke pulp. (a) biotype E, (b) biotype R, magnification 300×.

The cells are arranged with their walls in direct contact, forming a continuous matrix with very small intercellular spaces. This close and compact cell arrangement is typical of storage parenchyma tissue [47]. The biotype E exhibited a more heterogeneous cell distribution, with variable cell sizes and polyhedral contours, including some large cells (~65 µm), medium-sized cells (~50 µm), and several small cells (~30 µm). In contrast, the biotype R presents parenchyma tissue with larger, more rounded cells. In terms of size distribution, most cells were large (~80 µm) and medium (~60 µm), with only a few small cells (~25 µm). The cell arrangement observed in both biotypes could explain the differences found in their mechanical properties (Figure 3), since, for the same penetration distance, the probe must pass through a greater number of cells and cell walls in biotype E (tighter packing), resulting in a higher resistance to penetration and a greater work required to the tissue rupture (>W). Biotype E exhibited a higher proportion of dry matter and inulin, and consequently a lower water content (72%). The observed correlation between tighter packing, with smaller cells, and higher dry matter content is consistent with the findings of Gancarz [48], who reported a similar pattern in parenchyma tissue of potatoes from different cultivars. In contrast, the parenchyma cells of biotype R were larger and more rounded, likely due to the presence of bigger and rounder vacuoles responsible for turgor, consistent with its higher water content (79%).

3.4. Nutritional Information

The nutritional information of JA is presented in Table 3. Significant differences were observed between the two biotypes in all components analyzed, except for the total fat content and energy value. As can be observed, the fat content is very low, in agreement with the ranges of 0.10–0.60% and 0.17–0.78% reported by Bach et al. [28] and Wang et al. [49], respectively. It is noteworthy that biotype E showed a higher protein content (5.85%) while biotype R presented a higher content of assimilable carbohydrates (5.1%), mainly due to its sucrose concentration; these differences effectively compensated for the energy value, resulting in an equal caloric value for both biotypes. The protein content is higher in biotype E compared to biotype R, whose concentration falls within the range reported in the literature: 2.3–3.6% [4,28] and 0.8–2.8% [49]. Regarding sucrose content, biotype R contained 1.9-fold higher levels compared to biotype E. On the other hand, biotype E was characterized by its high inulin content (Table 2) and low content of simple sugars. With a total dietary fiber content of 6–8 g per 100 g fresh weight, these tubers can be classified as “high-fiber food”, exceeding the threshold established by international nutritional guidelines of Foods and Drugs Administration [50] and providing levels comparable to those of legumes (8–12 g/100, cooked) and superior to most of fresh vegetables and fruits, such as apple or pear (2–3 g/100 g) [51,52]. It should be noted that the technique commonly used to determine dietary fiber is not suitable for matrices rich in soluble fiber, as inulin-rich matrices, leading to an underestimation of values [10].

Regarding mineral content, the biotype R exhibited significantly higher concentrations of all analyzed minerals compared to the biotype E. Both biotypes were noteworthy for their substantial contributions of iron and potassium. The iron levels observed were comparable to the range reported for leafy vegetables rich in non-heme iron, such as spinach and chard (2.7–5 mg/100 g). Biotype R shows a higher potassium content than biotype E, which supports their classification as a medium-to-high-range vegetable potassium source (500–1100 mg/100 g). The calcium and magnesium contents were low in both biotypes, comparable to the majority of fruits and vegetables (<100 mg/100 g), and the sodium content was very low, consistent with values typically found in the same plant matrices (<50 mg/100 g) [53].

Table 3. Nutritional information per 100 g of fresh Jerusalem artichoke, biotypes E and R.

Nutritional Information 100 g Portion		Biotype E	Biotype R
energy value	(kcal)	37 ± 1 ^a	37 ± 1 ^a
	(kJ)	154 ± 2 ^a	154 ± 2 ^a
carbohydrate (g)		2.72 ± 0.03 ^a	5.1 ± 0.2 ^b
	glucose	0.020 ± 0.001 ^a	0.020 ± 0.001 ^a
	fructose	0.12 ± 0.01 ^a	0.155 ± 0.007 ^a
	sucrose	2.58 ± 0.04 ^a	4.9 ± 0.3 ^b
protein (g)		5.85 ± 0.11 ^b	3.45 ± 0.05 ^a
total fats (g)		0.29 ± 0.01 ^a	0.28 ± 0.02 ^a
total dietary fiber (g)		8.2 ± 0.1 ^b	6.0 ± 0.1 ^a
minerals (mg/100 g)			
		Na	7.9 ± 0.2 ^a
		K	14.7 ± 1.4 ^b
		Mg	1197 ± 52 ^b
		Ca	68.2 ± 1.2 ^b
		Fe	63.3 ± 1.4 ^b
			5.3 ± 0.2 ^b
organic acids (mg/100 g)			
		malic acid	0.39 ± 0.02 ^b
		succinic acid	0.52 ± 0.04 ^a
		acetic acid	0.47 ± 0.03 ^a
			0.43 ± 0.03 ^a
phenolic compounds			
		TPC (mg GAE/100 g)	100 ± 4 ^b
		TF (mg catechin/100 g)	39.5 ± 0.5 ^a
			23.5 ± 0.8 ^a
antioxidant capacity (mg GAE/100 g)			
		ABTS ^{•+}	52 ± 3 ^b
		FRAP	16.1 ± 0.9 ^a
			14.1 ± 0.9 ^b
			6.4 ± 0.3 ^a

Different lowercase letters in the same row indicate significant differences ($p < 0.05$).

Biotypes were also evaluated in terms of antioxidant potential. Bach et al. [28] reported that the phenolic content depends on the variety and on the part of the tuber analyzed, with the skin containing between 2 and 12 times more than the pulp. They also attributed this variation to the degree of maturity at harvest, since during growth the content of phenolic acids increases until reaching a maximum, and then decreases once growth is completed. Accordingly, higher concentrations have been observed in autumn than in the following spring [54]. As shown in Table 3, the biotype E had 2.5 times higher polyphenol concentration (100 vs. 39.5 mg GAE/100 g) and twice the flavonoid concentration of the biotype R (46.6 vs. 23.5 mg catechin/100 g). Amarowicz et al. [55] evaluated three Jerusalem artichoke varieties and reported polyphenol values more similar to those of the biotype E (78.1–97.6 mg GAE/100 g), concluding that their levels increased when crops were fertilized. In contrast, Takeuchi and Nagashima [56] reported 32.72–46.05 mg GAE/100 g, while Showkat et al. [57] reported values of 35 mg GAE/100 g, which were closer to those observed in the biotype R. Antioxidant capacity is the ability of a compound to inhibit oxidative degradation and mitigate processes such as DNA damage, carcinogenesis, and mutagenesis [58]. In this study, antioxidant activity was assessed using ABTS^{•+} and FRAP assays, which evaluate radical scavenging capacity and ferric reducing power, respectively. Biotype E exhibited 3.3-fold greater antiradical capacity and 2.2-fold greater reducing power than biotype R, consistent with its higher polyphenol and flavonoid content.

Considering the compositional differences and antioxidant potential, the biotype E exhibits superior nutritional advantages over the biotype R.

3.5. Consumer Sensory Analysis

A total of 128 consumers (52% female), aged 18–65 years, participated in the study, with young adults representing the largest segment (53%), including 31% aged 18–20 years and 22% aged 21–25 years. The remaining 39% of participants were between 31 and 65 years old. Significant differences in acceptability were found between the evaluated biotypes (Table 4). Tubers of the biotype E showed a lower mean overall liking score, with 60% of responses falling in the rejection zone (“dislike to dislike a lot”), whereas tubers of the biotype R exceeded the 6-point hedonic threshold and received 64% of their ratings in the acceptance zone (“like to like a lot”).

Table 4. Overall liking (OL) of raw JA across four subgroups of the hedonic scale.

	Biotype E	Biotype R
% dislike a lot (1–3)	29	9
% dislike (4–5)	31	27
% like (6–7)	31	41
% like a lot (8–9)	9	23
OL	5 ± 2 ^a	6.1 ± 1.8 ^b

Different lowercase letters in the same row indicate significant differences ($p < 0.05$).

These findings highlight a clear consumer preference for biotype R, which is particularly noteworthy given the limited familiarity of participants with Jerusalem artichoke.

The terms obtained from the categorization of free descriptions provided by consumers after tasting biotypes E and R are presented in the Supplementary Material, in Tables S1 and S2, respectively. None of the participants used the name of the vegetable, consistent with their general lack of knowledge about it. Regarding JA biotype E, 17 categories were identified to describe the sensations experienced during consumption. Consumers predominantly used sensory terms (52%) in their descriptions, with 30% referring to texture (e.g., “crunchy,” “hard,” “dry,” “fresh”), and the rest related to flavor attributes (e.g., “tasteless,” “flavor,” “bitter,” “intense”). Cognitive associations (33%) reflected comparisons with other vegetables and fruits (e.g., “carrot,” “potato,” “vegetables,” “fruits”) as well as value judgments using categories such as “raw” or “unfamiliar.” Hedonic terms (14%), including “unpleasant” and “tasty,” accounted for the remaining responses.

For biotype R, 16 categories were identified from the analysis. Sensory descriptors accounted for 58% of mentions, of which 31% referred to flavor attributes (e.g., “tasteless,” “sweet,” “flavors”) and the remaining 28% to texture (e.g., “crunchy,” “fresh,” “juicy,” “texture”). Cognitive associations represented 30% of mentions, with 23% linking with other plant foods (e.g., “fruits,” “potato,” “carrot,” “vegetables”), while terms such as “unfamiliar” and “healthy” appeared in 7% of the total responses. Finally, hedonic terms (e.g., “tasty,” “unpleasant”) were used in 11% of cases.

Figure 5 presents word clouds illustrating the perceived attributes of JA biotypes.

For biotype E, the most frequently mentioned categories were “carrot,” “crunchy,” and “hard,” accounting for 30% of the total mentions, which are more representative in word cloud. This finding supports the previously described mechanical properties and underscores the strong cognitive association with textural sensations during eating a carrot. As appreciated in Table S1, the examples proportioned by consumers were: “like a carrot,” “crunchy like carrot,” “carrot texture,” “carrot consistency and fiber,” “carrot consistency”.

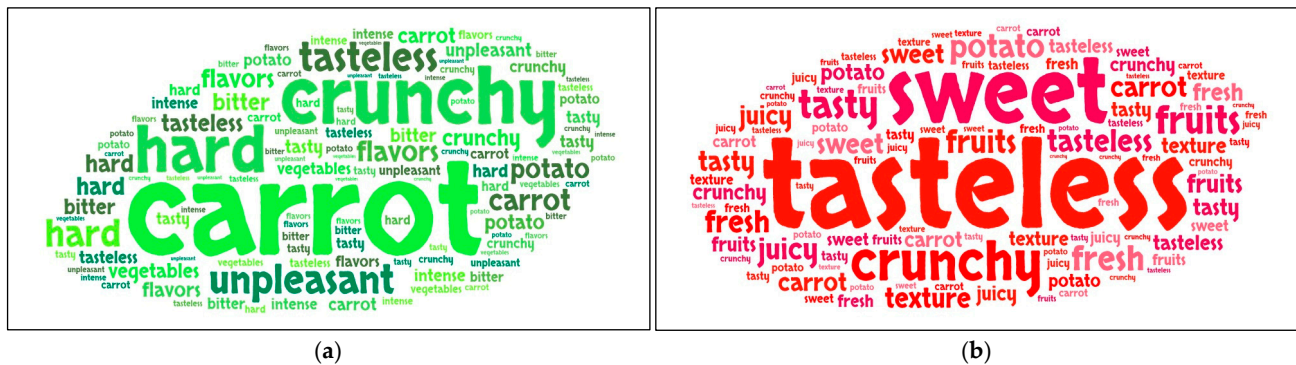


Figure 5. Word cloud corresponding to (a) biotype E; (b) biotype R.

For biotype R, the most frequently mentioned categories were “tasteless,” “sweet,” and “crunchy,” which collectively accounted for 38% of all mentions. Flavor-related descriptors, particularly “tasteless” and “sweet,” were the most prevalent (28%), while “crunchy” was the most frequently named textural attribute.

The term “tasteless” likely reflects the absence of a dominant flavor, resulting in a neutral sensory perception. In contrast to biotype E, consumers described biotype R as “sweet,” a characteristic that may be associated with its higher sucrose content. The descriptor “crunchy” was linked to “fruits”, “fresh”, and “juicy”, probably due to the textural sensations perceived upon biting—a phenomenon instrumentally recorded as successive sub-rupture peaks (Figure 3). The perception of juiciness can be attributed to the higher water content and the release of cellular sap following cell wall rupture. This combination of attributes led consumers to associate biotype R with various fruits, providing examples such as “green pear,” “apple taste,” “apple texture,” “apple,” “unripe pear,” “fruit,” and “coconut” (Table S2).

The descriptors provided by consumers in this study are consistent with those reported in previous sensory analyses of raw JA with trained panels. De Santis and Frangipane [4] identified flavors and aromas reminiscent of apple, sweet potato, carrot, and artichoke, along with salty and earthy notes. Similarly, Bach et al. [12] described raw tubers using terms associated with fruits and vegetables (potato, carrot, apple), crunchy texture, and the negative attribute earthy flavor.

In the present study, since some of the characteristics reported by consumers may be interpreted ambiguously, a penalty/reward analysis was conducted to better identify the drivers of preference or rejection for each biotype. As observed in Figure 6a, consumers who described the tuber E as “unpleasant”, “unfamiliar”, “bitter”, “hard”, “raw”, or “dry”, scored negatively in overall liking. Among these, only “unpleasant” (−2.08) imposed a significant penalty, while the remaining categories were not significant. Conversely, the terms “tasty” (+2.35), “fruits” (+1.41), “crunchy” (+1.38), “flavors” (+1.37), and “fresh” (+1.07) contributed positively to overall liking in overall liking. Interestingly, the “carrot” category—which presented the highest mention frequency in the free association technique and stood out in the word cloud—was not significant in the penalty/reward analysis and therefore did not influence the assigned overall liking score. In contrast, other characteristics with low mention frequencies, such as “fruits”, “fresh”, and “flavors,” were found to be significantly positive, influencing the assigned score by providing a reward.

Consumers who described biotype R as “unpleasant” gave it a negative score for overall liking, with a strong impact of -3.0 . The term “unfamiliar” also received a significant penalty (-1.35). In contrast, the category “tasty” conferred a reward ($+1.26$). The negative effect of “unfamiliar” may be explained by food neophobia, a natural human behavior (an evolutionary reminiscence) characterized by fear or rejection of new or unknown foods, as

well as reluctance and resistance to innovation [59]. In acceptability tests, food neophobia has been shown to reduce scores for novel foods compared with familiar products [10]. In this study, 92.1% of consumers reported not being familiar with JA prior to the sensory evaluation. Nevertheless, biotype R achieved high acceptability, particularly when compared with biotype E.

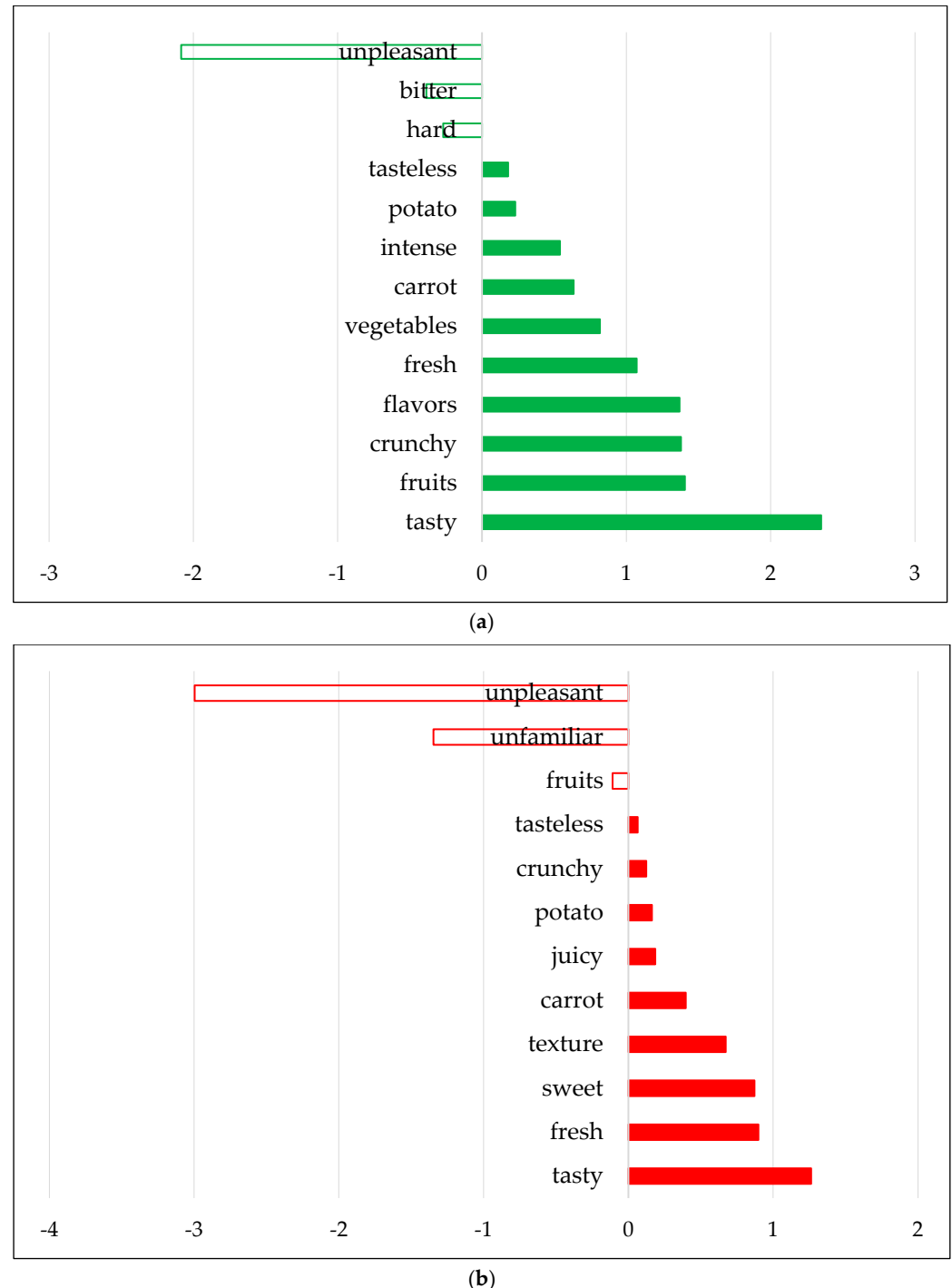


Figure 6. Penalty/reward analysis: (a) biotype E; (b) biotype R.

Regarding consumption intention, 75.7% of participants indicated that they would include Jerusalem artichoke in their diet, with 23.5% expressing no specific biotype preference and 60% favoring biotype R. Participants who initially reported no intention to add this vegetable to their diet were subsequently provided with additional information on its

nutritional value and potential health benefits. Following this intervention, consumption intention increased to 86.4%, and among those informed, it rose to 96.6%. Consumer perceptions and food preferences are often influenced by product-related information [60]. Nevertheless, the specific effect of providing information on the health benefits of fresh fruits and vegetables has been less frequently studied. These findings are promising and highlight the potential of nutritional information as a strategy to promote the consumption of Jerusalem artichoke as a novel vegetable.

4. Discussion

The comprehensive characterization of the two Jerusalem artichoke biotypes E and R carried out in this study, allowed for the observation of their agronomic characteristics, postharvest performance, comparison of their physicochemical and nutritional quality, as well as consumer appeal, positioning them for different markets. Compared with other underground vegetables with low to moderate RR, the storage conditions employed in the present study resulted in very low WL, indicating their effectiveness in preserving the freshness of JA, including biotype E. The higher metabolic activity, indicated by a higher RR, in biotype E resulted in greater WL. This physiological difference is consistent with our field observations, which show that tubers E sprouted and emerged earlier than tubers R when planted under identical conditions. The physical characteristics of color and mechanical properties provide valuable insights when correlated with other analytical data. Although both biotypes had similar color, the biotype E pulp was visually distinct, displaying a more yellowish tone. This specific coloration is likely a result of its higher flavonoid content, which contributes to yellow hues in the JA neutral pH range. Additionally, the biotype E higher phenolic content is associated with a greater rate of enzymatic browning, providing another reason for its limited use as a raw vegetable. Mechanical properties and microstructural analyses revealed behaviors that directly correlated with consumer perceptions. Texture was a key characteristic for both biotypes, representing a significant portion of consumer-generated descriptors (30% for E and 28% for R). Consumers described the biotype E using terms such as “crunchy”, “hard”, “dry”, and “fresh”. In contrast, the R was characterized as “crunchy”, “fresh”, and “juicy”. These results highlight texture as a primary driver of consumer perception for both biotypes.

The primary storage carbohydrate in JA is inulin, a fructan that remains unhydrolyzed in the human digestive tract because of the lack of inulinase [61]. Inulin is accepted as a prebiotic because it selectively stimulates the growth of beneficial endogenous bacteria, specifically lactic acid bacteria and bifidobacteria. This recognized ‘bifidogenic effect’ of inulin has been legally accepted [1]. Inulin molecules with a degree of polymerization (DP) of less than 10 are referred to as fructo-oligosaccharides (FOS) [28]. Both inulin and FOS are soluble fibers widely used as prebiotic food ingredients [10,12]. The inulin present in JA is naturally a mixture of polymers with different DP. In early cultivars, the DP reached a maximum of 8–11 and then decreased to 3–4 by the end of the growing season [28]. For instance, as previously reported by our group [10], the prebiotic activity score (PAS) of JA biotype E was verified to be greater than 1 (PAS = 1.30), and a dried ingredient developed from biotype E provided 76% of inulin, with an average DP of 8. Inulin functions as a prebiotic fiber that undergoes colonic fermentation, producing short-chain fatty acids (SCFAs) that contribute to host metabolic processes [62]. This property highlights the nutritional and functional relevance of Jerusalem artichoke as a source of soluble dietary fiber. It is well known that all dietary fibers, with the exception of lignin, undergo fermentation by gut microbioma, contributing to the body’s energy supply, with an estimated caloric value of 100–200 kcal per day depending on intake [53]. The FAO [63] has recommended an energy factor of 2 kcal/g for dietary fiber, based on the assumption

that approximately 70% of ingested fiber is fermentable. However, part of this energy is lost as gas, and some is incorporated into bacterial biomass and excreted. Despite such considerations, neither national (e.g., Argentine Food Code) nor international (e.g., Codex Alimentarius) regulations have yet established a specific energy conversion factor for dietary fiber in food energy calculations. This regulatory gap represents a significant challenge to the accuracy of nutritional labeling and highlights the need for a standardized approach. For the nutritional analysis of JA biotypes, carbohydrates were quantified as their digestible and assimilable components (mono- and disaccharides). We chose this approach because the standard calculation of carbohydrates by difference introduces an intrinsic error, given the high inulin content within the total dietary fiber measurement [10]. Consequently, the caloric value was derived solely from the assimilable carbohydrates.

The main characteristic of JA that distinguishes it from other tubers and roots like potatoes and sweet potatoes is its lack of starch, which allows it to be consumed raw. Other root vegetables, such as beetroot (*Beta vulgaris*) and carrot, which are also suitable for raw consumption, primarily accumulate sucrose [31,35,40]. The type of assimilable carbohydrates found in these vegetables (starch and sucrose) makes them foods with a higher glycemic index compared to JA.

Jerusalem artichoke tubers also exhibit a noteworthy mineral profile. Particularly relevant is the combination of low sodium and adequate potassium found in both biotypes. Incorporating these tubers into the diet may therefore contribute to lowering blood pressure and reducing cardiovascular risk [53,64]. Considering their nutritional profile, which is characterized by a low assimilable carbohydrate content, low caloric load, high levels of soluble fiber derived from inulin, and a significant contribution of K and Fe, Jerusalem artichoke tubers are especially suitable for inclusion in specialized diets, such as those for individuals with diabetes or requiring a low glycemic index. During the sensory evaluation, consumers employed a wide range of descriptors, including flavor, textural, and cognitive associations, to characterize their perceptions of the tubers. The high impact of hedonic terms in the penalty-reward analysis was probably due to the fact that Jerusalem artichoke is a novel vegetable. Thus, providing health-related information may therefore enhance consumption intention and mitigate the penalty commonly associated with food neophobia.

It is essential to acknowledge the limitations inherent in the current study design. Firstly, the trial was conducted over a single year and in a single location within Northern Patagonia, Argentina. This design implies that the influence of interannual environmental variability (e.g., specific precipitation and temperature patterns) on agronomic performance and yield requires long-term validation across multiple seasons. Secondly, the study was limited to a specific region—the most austral registered Jerusalem artichoke cultivation zone in the existing literature—which implies that the derived results may not be directly replicable in other Argentine provinces or in countries with significantly different dietary cultural habits. However, this systematic, multidimensional approach provides the knowledge necessary to guide future research.

The comprehensive characterization carried out in this study enables the valorization of JA by establishing the scientific foundation for cultivar registration in Argentina and identifying distinct potential applications for each biotype, either as a fresh vegetable or as a raw material for the subsequent transformation into high-value-added functional products.

5. Conclusions

This study demonstrated that the elongated and rounded Jerusalem artichoke biotypes, adapted to Argentine Norpatagonia, exhibited distinct agronomic characteristics, post-harvest performance, physicochemical properties, nutritional profiles, and consumer appeal, positioning them for different market applications for human nutrition. The

rounded biotype could be considered the most promising for horticultural production and the fresh market due to its superior yield, a higher proportion of commercially suitable sizes, and crucially, its high overall acceptability driven by a subtle sweet flavor and a pleasant texture. In contrast, the elongated biotype, while less suitable as a raw vegetable due to its low acceptability and hard texture, presents superior nutritional and functional value. Its high inulin and polyphenol contents make it an ideal raw material for the production of functional ingredients. This study highlights the importance of selecting biotypes not only based on their agronomic characteristics but also on their comprehensive quality profiles, which enable the optimization of production for different market niches, covering fresh consumption to the functional food industry.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/agronomy15102397/s1>, Figure S1: Average size distribution of tubers of Jerusalem artichoke: (a) biotype E; (b) biotype R. Table S1: Results of the free association technique, examples of individual terms, categories assigned by consensus, and frequency of mention to describe Jerusalem artichoke, biotype E. Table S2: Results of the free association technique, examples of individual terms, categories assigned by consensus, and frequency of mention to describe Jerusalem artichoke, biotype R.

Author Contributions: Conceptualization, S.D., D.M.S. and L.F.; methodology, S.D., D.M.S. and L.F.; software, S.D. and L.F.; validation, S.D. and L.F.; formal analysis, S.D., D.M.S. and L.F.; investigation, S.D., D.M.S. and L.F.; resources, D.M.S. and L.F.; data curation, S.D. and L.F.; writing—original draft preparation, S.D., D.M.S. and L.F.; writing—review and editing, S.D., D.M.S. and L.F.; visualization, S.D., D.M.S. and L.F.; supervision, D.M.S. and L.F.; project administration, D.M.S. and L.F.; funding acquisition, D.M.S. and L.F. All authors have read and agreed to the published version of the manuscript.

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Abbreviations

The following abbreviations are used in this manuscript:

JA	Jerusalem Artichoke tubers
E	Elongated
R	Rounded
LDPE	Low-density polyethylene
RR	Respiration rate
WL	Weight loss
FW	Fresh weight
F _R	Fracture resistance
D _F	Displacement
W	Work to fracture
F _{MAX}	Maximum force
SEM	Scanning Electron Microscopy
EV	Energy Value

TPC	Total polyphenol content
TF	Total Flavonoids
GAE	Gallic Acid Equivalent
FRAP	ferric reducing antioxidant power
ABTS ^{•+}	2,2-azinobis-[3-ethylbenzothiazoline-6-sulfonic acid] radical cation
OL	Overall Liking
SD	Standard deviation

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