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Impact of planting date and tuber packaging on two Jerusalem artichoke cultivars and Its flour fortification on Diabetic-bakery products

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Abstract
Jerusalem Artichoke, a versatile vegetable with a high inulin content and an unique taste, is gaining popularity due to its adaptability, simple cultivation, and functional food benefits. The current study evaluated two varieties (Local and Fuseau) and planting dates (15th April and 15th May) under North Delta conditions over two seasons (2021 and 2022). The influence of different packaging materials (High-density polyethylene (HDPE) and Polypropylene (PP)) on the postharvest quality and storability of such two Jerusalem Artichoke varieties was also studied for five months at 4°C and 90-95% RHThe results showed that the Fuseau cultivar thrived under two planting schedules, particularly in April being the optimal planting time regarding growth, tuber yield, and chemical components. Tubers wrapped in perforated HDPE and PP showed market quality improvements by reducing weight loss, decay, and microbial counts. The Local cultivar performed better in most attributes except inulin, where Fuseau excelled. Perforated PP effectively reduced weight loss and decay, while HDPE better preserved inulin and minimized microbial loads. Both varieties maintained a good appearance for five months, making them suitable for diabetic bakery products preparing. The study identified the Fuseau variety as the most suitable for its investigation. It aimed to evaluate the plant's potential in lowering blood sugar, triglycerides, cholesterol, and LDL cholesterol. The study was conducted on fortified shamy bread with Jerusalem artichoke at varying levels (10–40%) and fed to diabetic rats for five weeks. Results showed a significant reduction in serum glucose and improved lipid profiles, including triglycerides, the worse cholesterol profile, i.e., LDL, and VLDL cholesterol, while the healthy cholesterol, i.e., HDL cholesterol increased across all treated groups.
Keywords: Jerusalem Artichoke, tuber packaging, Diabetic-bakery.

1. Introduction

Therapeutic components found in medicinal plants aid in illness management, including diabetes, though no universal treatment exists. Strategies are required to mitigate the condition's effects. [1-3] Several plants have been identified with hypoglycemic activity and the ability to reduce oxidative stress, including the Jerusalem Artichoke. [1, 4] Jerusalem Artichoke, this flowering and perennial plant, native to North America and belonging to the sunflower family (Asteraceae), is now widely farmed all over the world for several purposes, including the food business, diabetes patients' diets, and the manufacturing of ethanol. Its plants resemble sunflowers (above ground) and potatoes (underground). But it also produces an enormous number of tubers that are smaller, crispier, and sweeter than potatoes and have a ginger-like appearance. Jerusalem Artichoke is a valuable vegetable crop with rich nutritional and medicinal properties. It contains bioactive compounds that may aid in Alzheimer's disease treatment. Additionally, its tubers are exceptionally rich in inulin, offering further health benefits. [1, 5-7] This crop is privileged of the carbohydrate inulin rather than starch. The Jerusalem Artichoke tubers are the main storage organ of this plant, which has a high content of inulin and fructo-oligosaccharide. [8] Inulin is widely used in several industries, particularly foods and pharmaceutics. For the food sector, inulin may be used as a fat replacer, sweetener thickener, and water-retaining agent. It could be applied in pharmaceutics as a drug carrier, stabilizer, and auxiliary therapeutic agent for certain diseases. [9, 10]

Planting dates significantly impact Jerusalem Artichoke tuber yield, with temperature playing a crucial role in its development. [11, 12] Night temperature and day length primarily influence tuber formation, while

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photosynthesis affects tuber yield and inulin content. Cultivation at elevated temperatures (10-16°C) reduces total dry biomass, whereas inulin concentration increases when grown in warmer conditions (21-31°C). [12-14] It can grow in Mediterranean regions under nearly zero applied fertilizers or organic matter or applied pesticides. [15] It could be cultivated under different climatic zones due to its tolerance to abiotic stresses, great ecological resiliency, and high photosynthetic efficiency. [16] The chemical composition of Jerusalem Artichoke tubers is an important issue, which may differ among cultivars depending on production conditions, harvest periods, postharvest storage, and processing methods. [9] The plant's fibrous root system forms tubers that store fructans, mainly inulin, supporting its roles in horticulture, fodder, bioethanol production, and inulin extraction. [11, 12, 17] Fructooligo-saccharides (FOS) and inulin act as prebiotics, resisting enzymatic hydrolysis and providing functional dietary fiber benefits. Additionally, Jerusalem Artichoke tuber powder is rich in essential minerals (K, Fe, Mg, Ca, and P), inulin, and bioactive compounds. [1, 5]

Ensuring optimal storage conditions are essential for preserving the quality and nutritional value of fresh produce. Cold storage has been recognized as the most suitable and effective method for maintaining the quality of globe artichokes during storage. Additionally, the use of perforated polypropylene lining boxes has proven to be highly effective in extending the shelf life of globe artichokes while preserving their highest nutritional content. Therefore, storing globe artichoke heads under cold storage conditions is the best approach to enhance their storability and maintain their freshness for an extended period. [18, 19]

Proper packaging materials are essential for maintaining product quality and marketability during cold storage. Storing globe artichoke heads at 4°C in polyethylene bags significantly reduces weight loss, minimizes unmarketable portions, and preserves visual appeal compared to unpackaged heads. [20] Similarly, using selective films like polyethylene bags for Jerusalem Artichoke tubers decreases weight loss and delays senescence, enhancing postharvest quality**.** Research further confirms that polyethylene bag packaging effectively extends tuber storability by reducing deterioration compared to unpackaged tubers. [21-23] These findings highlight the importance of suitable packaging in prolonging shelf life and maintaining product freshness. [24] Rashed *et al.* demonstrated that storing local cultivar Jerusalem Artichoke tubers treated with black cumin oil in polypropylene at cold storage significantly reduced weight loss and spoilage while maintaining aesthetic and physiochemical quality for ten months. Although conventional storage methods, such as overwintering in open fields, are cost-effective, they have technological limitations.

The characterization of Jerusalem Artichoke powders is determined by their total polyphenol content, which contributes to antioxidant properties beneficial for a healthful diet and disease prevention. [1, 5, 25] These powders contain high concentrations of inulin-type fructans, making them suitable for diabetic-friendly bakery and pastry products. Rao states that daily inulin intake significantly increases beneficial gut bacteria. Additionally, the consumption of FOS and inulin is linked to a hypoglycemic effect, making them suitable for diabetics. Since 1992, the FDA has classified these dietary fibers as Generally Recognized as Safe (GRAS) substances.[26]

Jerusalem Artichoke is rich in pectin, which supports microbiota function and helps reduce blood cholesterol levels. [1, 27] It also contains higher levels of B vitamins and vitamin C compared to other vegetables. [5, 28] Research has explored its use in various food products, including bread, wafers, baked goods, crackers, cookies, beverages, dairy products, and confections. [1, 29-32] Sarosi *et al.,* found that adding up to 5% Jerusalem Artichoke powder to dough enhances bread quality and extends shelf life. [33] Additionally, its incorporation in bakery products boosts probiotic levels and reduces pathogenic bacteria. [34]

This study examined the effects of various varieties and planting dates on growth, tuber yield, and constituent components, as well as the impact of two distinct packaging materials on the augmentation of storage capacity and preservation of Jerusalem artichoke tubers. The research also aimed to minimize adverse chemical transformations in the tubers under cold storage conditions. This manuscript aspires to explore the influence of inulin and other components present in the Jerusalem artichoke Fuseau variety on serum glucose, blood lipid profiles, and cholesterol concentrations.

2. Materials and Methods

2.1. The first part of the experiment

Two varieties of Jerusalem artichoke tubers, Local and Fuseau cv., were cultivated in a field experiment on clay soil at the Experimental Farm of Sakha Horticulture Research Station, located in Kafr El-Sheikh Governorate, Egypt (Latitude: 31°6'N/Longitude: 30°56'E). Furrow irrigation was employed for plants, with tubers planted at 15th April and 15th May during the summer seasons of 2021 and 2022. The 20 m² experimental unit consisted of two rows, each 1 m wide and 10 m long, with a spacing of 50 cm between tubers. This setup was utilized to investigate the impact of various varieties and planting dates on Jerusalem artichoke

production, quality, and chemical composition. **Table 1** presents the location's average air temperatures (°C) and relative humidity **(%)**.

Table 1: Location weather data for monthly average in Kafr El-Sheikh Governorate

Seasons	2021				2022			
Month	Average air temperature (°C)		Average Relative humidity (%)		Average air temperature(°C)		Average Relative humidity (%)	
	Min.	Max.	7:30	13:30	Min.	Max.	7:30	13:30
March	14.77	22.31	81.1	48.13	11.3	18.9	80.2	47.2
April	19.1	26.8	74.3	45.8	19.8	25.8	76.5	45.5
May	25.6	32.5	74.3	42.5	21.9	29.9	79.6	44.4
June	25.5	32.2	80.1	50.2	25.7	31.3	81.6	50.4
July	28	34.7	84.8	50.5	25.9	33.4	77.7	64.9
August	28.3	35.6	85.3	48.4	25.9	34.6	77.1	68.5
September	25.2	32.5	84.1	50.5	23.9	31.9	83.6	55.2
October	21.8	29.3	75.8	63.0	20.2	26.9	90.9	60.6
November	18.9	26.6	88.1	57.2	16.6	25.5	92.1	61.9
December	12.2	20.2	88.1	61.3	14.59	22.97	93.67	67.5

Source: Sakha Agriculture Research Center Meteorological Station

The soil chemical and physical properties were measured in the soil analysis laboratory according to Page [35] and Klute [36] the results are presented in **Table 2**.

Table 2: Some chemical and physical properties of the experiment soil (average two years)

Soil depth	EC dSm^{-1}	pH	Soluble cations (meq/L)				Soluble anions (meq/L)			Particle size distribution			
			Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	HCO_3^{-1}	Cl^{-1}	So_4^{-2}	Clay %	Silt %	Sand %	Soil texture
0-30	8.17	6.07	1.8	2.26	5.36	0.14	3.2	3.53	3.24	49.5	26.3	24.2	Clay

EC: soil electrical conductivity (dsm^{-1}= Deci siemens per meter)

The experimental design employed a split plot approach with three replicates. The two planting dates (15th April and 15th May) were randomly assigned within the subplot, whereas the two varieties (Local and Fuseau) were established in the main plot. Agricultural practices adhered to the guidelines set forth by the Agriculture Ministry.

The following characteristics of all treatments were recorded:

Five plants from each treatment were randomly selected to measure stem length (cm) and the number of stems per plant after 120 days from the planting date. At harvesting time (240 days post-planting), five plants were sampled to assess tuber fresh weight (gm), yield per plant (kg), and total yield per fed. (ton). Tuber samples were obtained from each treatment, washed with distilled water, weighed, and dried in an oven at 70 °C until a constant weight was achieved to ascertain the dry matter percentage. Total carbohydrates, total sugar, and inulin content (mg/100g D. W.) of tuber were analyzed following the methods of Dubois *et al.,* [37] AOAC., [38], and Saengkanuk *et al*. [39], respectively.

2.2. The second part: Storage experiment

Local and Fuseau varieties tubers from the first planting time were chosen to complete the experiment and conduct all physical and chemical analyses.

Local and Fuseau cv. tubers were promptly transported to Sakha Food Technology Research Laboratory. Tubers were sorted, and all defective specimens were discarded before packing. The tubers were meticulously chosen, ensuring they were devoid of visible damage or defects. They were then washed using a sodium hypochlorite solution (0.2g/L) for 5 minutes to remove the soil and minimize contamination, then rinsed with water again. Finally, excess water was eliminated at room temperature. Subsequently, air drying was conducted for 3 minutes, after which the samples were randomly divided into three groups. The three groups were immersed in a 3% Ascorbic Acid solution for 5 minutes to improve tuber quality. [40] The first group was packaged in perforated polypropylene (PP), the second in perforated high-density polyethylene (HDPE) bags,

and the last group consisted of unpacked tubers as the control. Eighteen samples were prepared for each wrapping film and the control. Each sample had an approximate weight of 300 grams and was packed in a perforated package comprising 10% of the packaging area, featuring 60 holes per package with a diameter of 0.5 mm. The sealed package dimensions were 20 x 30 cm.

All treatments were maintained at 4ºC with a 90-95% relative humidity. Three samples from each wrapping film and the control were randomly selected and assessed monthly at zero time, 1, 2, 3, 4, and 5 months to evaluate the following characteristics: weight loss, decay, inulin, total soluble solids (TSS), and microbial analysis.

2.3. Packaging sources

The packaging materials were sourced from two companies in Egypt: polypropylene (PP, 55 µm) from the Islamic Company for Packages in October 6th City, Giza, and high-density polyethylene (HDPE, 30 µm) from the Arabic Medical Packaging Company (Flexpack) in Cairo.

2.3.1. Physical and chemical analysis

All physical and chemical characteristics were recorded on the harvesting date (zero time) and after 1, 2, 3, 4, and 5 months.

2.3.2. The percentage of weight loss

Weight loss was determined as the percentage reduction from the initial weight of the tubers. [41]

2.3.3. Percentage of decay (Unmarketable portion)

The percentage of decay was determined by evaluating tuber defects. It was calculated using the formula: Percentage of decay = (decay weight / initial weight) × 100.

2.3.4. Inulin content (mg/100g D. W.)

The tubers containing inulin were longitudinally sliced into thin pieces at their midpoint. Fifty grams of the sliced tuber were immersed in absolute ethanol at 4°C for 24 hours and then stored at -20°C until further analysis. The samples were dried in an oven at 60°C for 10 hours. For inulin extraction, 2 g of the dried sample was mixed with distilled water and heated at 80°C for 20 minutes. After cooling to room temperature, the solution was filtered using a 0.45 µm membrane filter. A 500 µl portion of the extract was transferred into 25 ml volumetric flasks containing 3% HCl and diluted to 25 ml with water. The mixtures were heated in a water bath at 80°C for 45 minutes. After cooling, the solutions were stored in plastic bottles before analysis via spectrophotometry. The inulin content was determined using the method outlined by Saengkanuk *et al*. [39]

2.3.5. Total Soluble Solids (TSS) %

The fresh tubers' total soluble solid content was measured with a refractometer, following the method mentioned by AOAC. [41]

2.3.6. Microbial analysis

The total bacterial count (TBC) and yeast and mold (Y&M) counts were determined following the methods described by Elabd. [42] Results were reported as log CFU/g.

2.4. Part 3: chemical analyses and feeding experiments

Fuseau varieties tubers from the first planting date were chosen to complete the experiment. Fuseau CV. tubers were immediately transported to Sakha Food Technology Research Laboratory.

Wheat flour *Triticum aestivum* with a 72% extraction rate was sourced from the North Cairo Flour Mills Company in Egypt. Active dry yeast *Saccharomyces cerevisiae* was procured from the Egyptian Sugar and Integrated Industries Company (ESIIC) Chemicals Factory, located in El-Hawamdia City, Giza, Egypt. Salt (sodium chloride) was purchased from a local market in Egypt.

2.5. Technological Methods

2.5.1. Preparation of Jerusalem artichoke tuber Fuseau powder (JAFP)

Twenty kilograms of JAFP were thoroughly washed with tap water to remove dust and impurities. So, the tubers were steamed for 30 minutes, chopped into small pieces, and dried in an air oven (Fisher Scientific) at 60-70°C for 72 h. The dried pieces were ground in an electric Brabender Duisburg roller mill, Germany and passed through a fine mesh sieve (Mesh w=0.125mm, d=0.09mm). The resulting flour was stored in polyethylene bags at -18°C until needed.

2.5.2. Proximate composition of WF, JAFP, and its blends

The proximate composition was analyzed using AOAC methods. [41] Crude protein was determined by the Micro-Kjeldahl method (AOAC Method 960.52), [43] crude fat was measured using the Soxhlet extraction method (AOAC Method 963.15), [44] and ash content was assessed through the dry ashing method (AOAC Method 923.03). [45] Carbohydrate content (%) was calculated by subtracting crude ash, fat, crude fiber, and protein values from 100% of the dry matter. The energy value was calculated in calories using Atwater's conversion factors as follows:

Kcal/100 g = [(4.1 × carbohydrate) + (4.1 × protein) + (9.1 × fat)].

2.5.3. Determination of Minerals

Minerals were determined according to the procedures outlined by AOAC. [41]

2.5.4. Determination of Vitamins

The contents of thiamine (B1), riboflavin (B2), niacin (B3), Pyroidoxine, , Pantothenic acid and vitamin C were determined following the method outlined by Ekinci and Kadakal. [46] and Borodulina et al., [48]

2.5.5. Baking techniques

Shamy bread was made following the procedure outlined by **El-Dreny and El-Hadidy** [47] in **Table 3**. The standard bread-making recipe included 100% wheat flour (72% extraction) or a wheat flour blends, 1% fresh compressed baker's yeast, 1% salt, and an appropriate amount of water to achieve the desired dough consistency.

Table 3: Preparation of shamy bread

Constituents	Control	Blend1	Blend2	Blend3	Blend4
WF (g)	100	90	80	70	60
JAPF (g)	0	10	20	30	40
Salt (g)	1	1	1	1	1
Yeast (g)	1	1	1	1	1

WF= Wheat flour (72% ext.), JAFP= Jerusalem artichoke Fuseau tubers powder, g= gram

2.6. Sensory evaluation of shamy bread

Sensory possessions of shame bread were carried out by 10 trained panelists, following the procedure described by El-Dreny and El-Hadidy. [47] The evaluation criteria included general appearance (20), separation of layers (20), roundness (15), crumb distribution (15), crust color (10), taste (10), and odor (10). The panelists were selected from the staff at the Sakha Food Technology Research Laboratory, Agricultural Research Centre, Egypt.

2.6.1. Biological assay

The animal study was conducted at the Institute of Food Technology Research within the Agricultural Research Centre in Giza, Egypt. 36 adult male albino rats (Sprague Dawley strain), each weighing 160 ± 10 g, were obtained from the Animal House of Food Technology for Experimental Research in Giza. The rats were individually housed in wire cages under controlled laboratory conditions and fed a basal diet for an one-week acclimatization period. The composition of the basal diet followed the guidelines of Reeves et al, [48] consisting of 14% casein, 4% maize oil, 1% vitamin mixture, 4% mineral mixture, 0.25% choline chloride, 5% cellulose, and maize starch making up the remainder. The vitamin mixture was prepared according to Campbell,

[49] while the mineral mixture was formulated following the guidelines of Hegsted et al. [50] After acclimatization, the rats were randomly assigned to two main groups. Group 1, the negative control group G1(C-), included six rats fed the basal diet. Group 2, consisting of 30 rats, received a subcutaneous injection of alloxan (150 mg/kg BW) after an overnight fast to induce diabetes, following the method described by Buko et al. [51] The second group was divided into five subgroups, each comprising six rats fed on 100% basal diet before treatment to induce diabetic rats. After, rats induced diabetes. G1 fed on 50% basal diet and 50% shamy bread control. Subgroup 2 (positive control, G2 =C+) was fed with 50% control of shamy bread and 50% of the basal diet, while Subgroups G3, G4, and G5 received 50% of the basal diet supplemented with 50 %of shamy bread containing10%, 20%,30, and 40% JAPF, respectively. The rats were kept under standardized conditions (23±2°C temperature, 55±5% humidity, and a 12-hour light/dark cycle) with unrestricted access to food and water for six weeks. Diet intake and body weight were monitored biweekly. After the study, the rats underwent fasting for up to 12 hours before being euthanized. Blood samples were collected from the aorta, centrifuged, and stored at -20°C for biochemical analysis

2.6.2. Biochemical Analysis and Enzymes Assays

Serum glucose, cholesterol (CHL), low density lipoprotein (LDL), high density lipoprotein (HDL), triglyceride (TG), total lipids, Serum glutamic-oxaloacetic transaminase (GOT) and glutamic-pyruvic transaminase (GPT), and alkaline phosphatase (ALP) purchased from SPINREACT Co, SPAIN 2024.

2.6.2.1. Determination of serum glucose

The measurement of blood glucose levels in serum samples was conducted using a commercially available kit from Spain React Company (Spain), following the methodology proposed by Trinder. [52]

2.6.2.2. Determination of serum lipids

Serum total lipids were estimated by Knight et al. [53]Triglycerides were determined according to Fassati and Prencipe. [54] Total cholesterol and HDL were determined according to the methods described by Allain. [55] VLDL and LDL were determined according to description of Lee and Nieman [56] and calculated using the following equations:

- LDL (mg/dl) = Total cholesterol - (HDL + VLDL).
- VLDL (mg/dl) = Triglycerides ÷ 5.

2.6.2.3. Determination of liver function

Aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP) were determined according to the method of Henry, [57] Varley et al. [58] and Rosalki and Foo, [59] respectively.

2.7. Statistical Analysis

Statistical analysis was performed using SPSS software (version 26), and Duncan's multiple range tests were employed to compare the means. The comparisons were made at a significance level of ($P \leq 0.05$).

3. Results and Discussion

3.1. Effect of two varieties and planting dates on growth, tuber yield, and components of Jerusalem artichoke

Growth parameters and tuber yield are expressed as plant height (cm), no. of stems/plant, tuber fresh weight (g), total yield/ plant (kg), and total yield/fed (ton) of Jerusalem artichoke were illustrated in **Table 4**.

There was a significant ($P \geq 0.05$) effect of varieties Local and Fusaeu of all traits under study throughout the two seasons. The Fuseau cv. exceeded the Local cv. in all traits during the two growing seasons. There was a significant effect of planting dates on 15th April and 15th May in all traits under study in the two seasons. The data mentioned that the first planting date on 15th April recorded the best plant height, no. of stems /plant, average fresh weight, total yield per plant, and total yield in both seasons. The data in **Figure 1** shows the interaction between varieties and planting dates, Fuseau cv. planted on 15th April had a higher plant height, number of stems/plants, tuber fresh weight, total yield per plant, and total yield per fed than the other treatments throughout the two growing seasons.

Table 4: Effect of cultivars and planting dates on growth, tuber yield, and components of Jerusalem artichoke during two seasons

characters	Plant height (cm)		No. of stems/plant		Tuber fresh weight (g)		Total yield/ plant (kg)		Total yield/fed (ton)	
Season	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
	Cultivars									
Local	192^{b}	197^{b}	4.9^{b}	5.1^{b}	82.2^{b}	83.7^{b}	2.2^{b}	2.4^{b}	16.8^{b}	18.5^{b}
Fuseau	218^{a}	224^{a}	5.9^{a}	6.5^{a}	97.5^{a}	101.7^{a}	2.6^{a}	2.8^{a}	19.6^{a}	21.5^{a}
	Planting date									
15thApril	212^{a}	218^{a}	5.8^{a}	6.2^{a}	96.9^{a}	100.1^{a}	2.5^{a}	2.7^{a}	19.0^{a}	20.7^{a}
15th May	208^{b}	213^{b}	5.4^{b}	6.1^{b}	82.8^{b}	85.3^{b}	2.3^{b}	2.5^{b}	17.4^{b}	19.3^{b}

Means within the same column, individually for cultivars or planting date, followed by the same letters are not significantly different at 5% according to Duncan's Multiple Range Test.

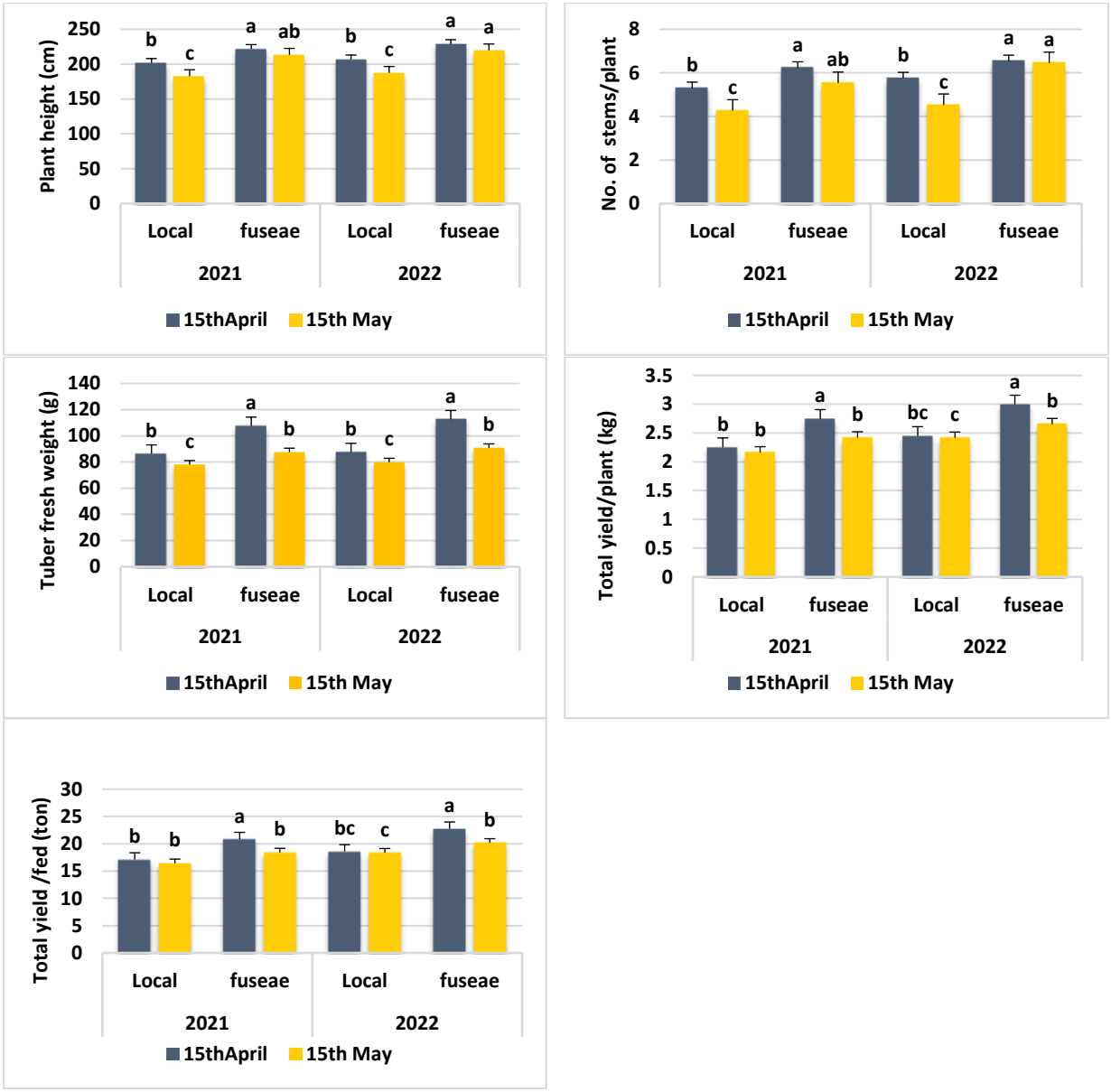

Figure 1: Interaction effect of cultivars and planting dates on growth, tuber yield, and components of Jerusalem artichoke during two seasons

The genetic composition of the two varieties used in this study may cause this outcome discrepancy. Also, the increments in the plant growth, tuber yield, and components on 15th April could be due to climatic conditions during the plant growth period more suitable, such as long days & high temperatures, according to Table A, which positively affected plant growth characteristics. The late planting of Jerusalem artichoke delays canopy development and reduces the time for tuber bulking. The interaction between the Fuseau cv. and the planting date of 15th April significantly affected total tuber yield per plant and tuber fresh weight in two seasons. This could be due to the relationship between the vegetative growth, especially plant height and stem number of plant and yield parameters. Similar results were reported by other researchers. [6, 11, 60, 61] **Table 5** shows tubers' dry matter, total carbohydrates, total sugar, and inulin percentage.

Table 5: Influence of cultivars and planting dates on some chemical traits of Jerusalem artichoke tubers during two seasons

characters	Tuber dry matter %		Total carbohydrates (%)		Total sugars (%)		Inulin (mg/100g D W.)	
Season	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
	Cultivars							
Local	26.1^{b}	26.8^{b}	28.4^{b}	28.9^{b}	31.3^{b}	31.9^{b}	12.1^{b}	12.2^{b}
Fuseau	27.4^{a}	28.6^{a}	29.9^{a}	30.5^{a}	32.6^{a}	33.6^{a}	13.3^{a}	13.5^{a}
	Planting date							
15thApril	27.3^{a}	28.2^{a}	30.6^{a}	31.2^{a}	32.3^{a}	33.1^{a}	13.2^{a}	13.4^{a}
15th May	26.2^{b}	27.3^{b}	27.6^{b}	28.1^{b}	31.5^{b}	32.5^{b}	12.2^{b}	12.3^{b}

Means within the same column, individually for cultivars or planting date, followed by the same letters are not significantly different at 5% according to Duncan's Multiple Range Test

The Fuseau cv. produced tubers with significantly higher dry matter, total carbohydrates, total sugar, and inulin content (27.42 and 28.63%, 29.88 and 30.49, 32.55 and 33.64, 13.28 and 13.54%) than the Local cv. (26.11 and 26.80, 28.38 and 28.85, 31.25 and 31.93, 12.11 and 12.22%) during two seasons, respectively.

For planting dates, the 15th of April during both seasons recorded the highest dry matter, total carbohydrates, total sugar, and inulin percentage of tubers. Meanwhile, the second planting date, the 15th of May, had the lowest percentages of the same traits. The data presented in **Figure 2** explained the interactions between varieties and planting dates. There were significant increases in tuber dry matter, total carbohydrates, total sugar, and inulin contents. Fuseau cv. tubers planted on 15th April showed higher dry matter, total carbohydrates, total sugar, and inulin than the other treatments.

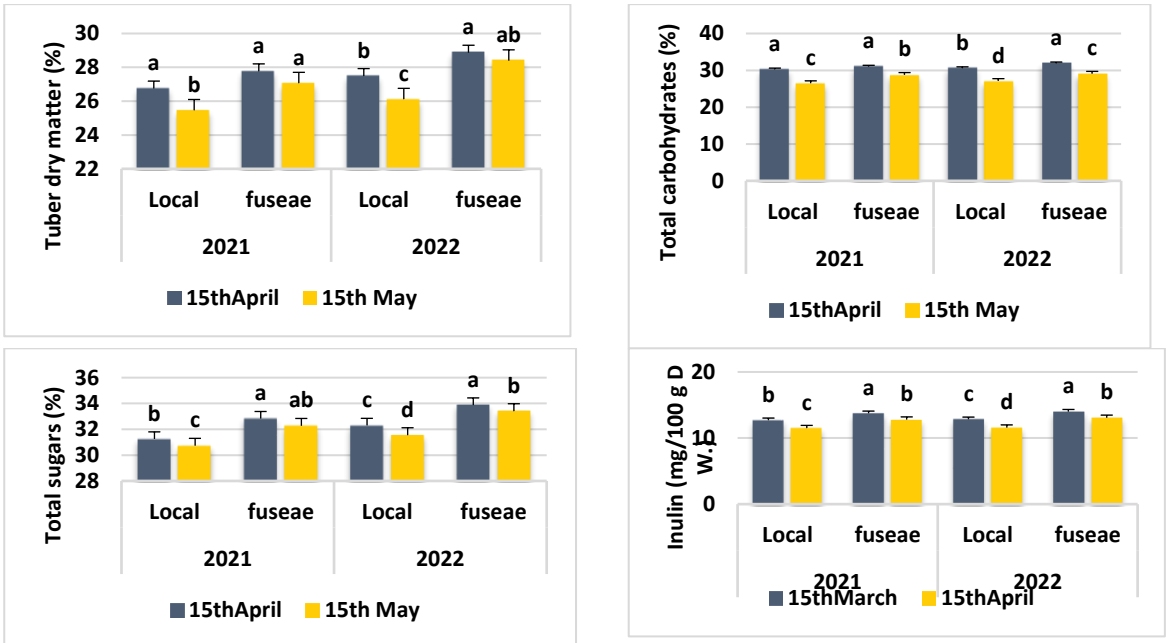

Figure 2: Interaction effect of cultivars and planting dates on dry weight, total carbohydrate, total sugar, and inulin traits of Jerusalem artichoke during two seasons

As for the chemical constituents of two Jerusalem artichoke varieties (Local and Fuseau) at two planting dates and the effect of both variety and plant dates on the chemical constituents of tubers. The results showed differences between Jerusalem artichoke varieties at two plant dates and the effect of both variety and planting dates on the chemical constituents. These differences in the concentrations of the previous chemical constituents may be due to genetic differences among both Jerusalem artichoke varieties, according to other researchers. [6, 11, 60-62] These results agreed with those obtained by Abdullah et al., [63] and Taleb [64] noted that the Fuseau cv. is superior to the Local cv. in protein content and ash. The higher contents of dry matter, total carbohydrates, total sugar, and inulin of tubers were recorded at the planting date of 15th April. This superiority might be due to the favorable effects of high temperatures and long days during the periods, which simulate the plant metabolism and increase vegetative growth. Consequently, more metabolites are stored in tubers. Similar conclusions were obtained by El-Banna and Haggag, and Titei. [11, 65] Also, our findings revealed that an increase in all treatments of Jerusalem artichoke through the second season may be caused by the suitable temperatures, and relative humidity (Table A) during the growth and formation period of tubers. In multi-location trials, the contribution of environmental effect was significant for tuber yield and shoot dry weight. [66, 67]

3.2. Storage experiment

3.2.1. Impact of packaging materials and storage time on storability of Jerusalem artichoke

3.2.1.1. Physiochemical changes

3.2.1.1.1. Weight Loss

Figure 4 presents that weight loss significantly ($P \leq 0.05$) increases with storage duration in both seasons and for both varieties. This is expected as tubers lose moisture and undergo physiological changes over time. The reduction in the fresh weight of Jerusalem artichoke tubers may be attributed to moisture loss through transpiration and the reduction in dry matter content due to respiration. [21, 68] These findings are consistent with the results reported by ElSharkawy et al. [69] Weight loss is highest for all packaging materials and varieties by the fifth month, indicating that prolonged storage significantly impacts tuber quality. For the effect of Packaging Materials, perforated PP and HDPE packaging significantly ($P \leq 0.05$) reduce weight loss compared to the control, with PP being more effective than HDPE. The control group showed the highest weight loss in both seasons and for both varieties. Jerusalem artichoke tubers have thin and fragile skin, making them prone to water loss after harvest. [21, 22] PP packaging significantly reduces weight loss compared to the control. For example, in Season 1, the Local variety showed 30.53% weight loss in the control group but only 11.05% in PP packaging after five months. HDPE also reduces weight loss compared to the control but is generally less effective than PP. Polypropylene bags may help reduce the respiration rate of the tubers by lowering oxygen (O_2) levels, increasing carbon dioxide (CO_2), and preventing moisture loss within the package. This, in turn, inhibits specific ripening processes, reducing weight loss during storage. [70] Haggag et al. [18] and Danilcenko et al, [22] observed that tubers or heads stored in plastic boxes, either lined with perforated polypropylene (PP) or unlined, at temperatures of 0 or 5°C and 95% relative humidity (RH), showed that lined plastic boxes resulted in lower weight loss and decay percentages. The Fuseau variety generally experiences higher weight loss than the Local variety across all packaging materials and storage periods. For example, in Season 1, after five months, the Fueasa control group loses 32.78% of weight, while the Local control group loses 30.53%. These differences may be attributed to the distinct branching structure of the two cultivars, which also tend to leak more readily than others. Fuseau tubers exhibit significantly higher transpiration rates. [71]

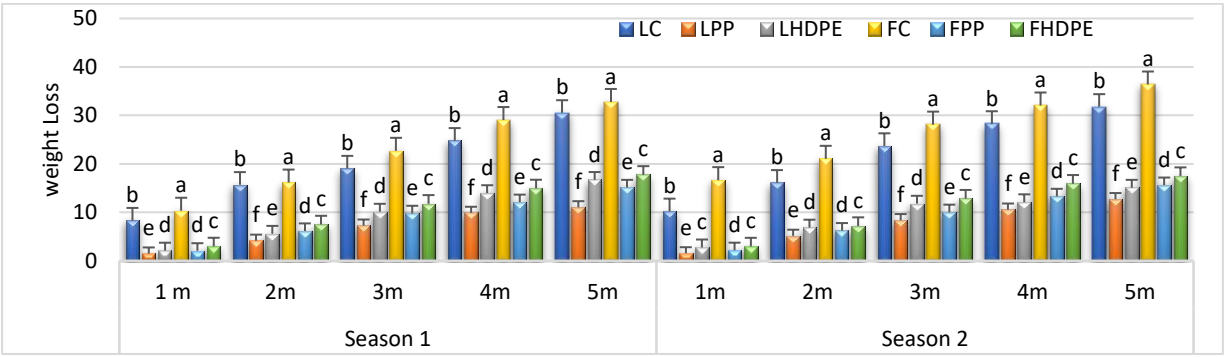

Figure 3: Influence of storage periods and packaging materials on the percentage of weight loss of two cultivars Jerusalem artichoke fresh tubers storage during two seasons

m: months- L: Local variety – F: Fuseau variety- PP: perforated polypropylene -HDPE: perforated highdensity polyethylene.

Season 2 generally experiences higher weight loss compared to Season 1. This could be attributed to environmental factors such as temperature, humidity, or differences in storage conditions impacting weight retention over time.

Decay Percentage

Figure 4 presents data on the effect of storage duration and packaging materials on the decay percentage of two varieties of Jerusalem artichoke tubers (Local and Fuseau) over two storage seasons.

Decay significantly ($P \leq 0.05$) increased with storage duration in both seasons and for both varieties. This is expected, as tubers are more susceptible to microbial activity and physiological deterioration over time. By the fifth month, decay is highest for all packaging materials and varieties, indicating that prolonged storage significantly impacts tuber quality.

For the effect of Packaging Materials, PP and HDPE packaging significantly ($P \leq 0.05$) reduced decay compared to the control, with PP being more effective than HDPE. The control group showed the highest decay percentage in both seasons and for both varieties. This highlights the importance of packaging in reducing decay during storage. PP packaging significantly reduced decay compared to the control. For example, in Season 1, the Local variety showed 25.11% decay in the control group but only 9.58% in PP packaging after five months. HDPE also reduced decay compared to the control but is generally less effective than PP. For instance, in Season 2, the Fueasa variety showed 28.12% decay in the control group but 16.17% in HDPE packaging after five months. These findings may be attributed to variations in the films' properties, such as their permeability and thickness. [72]

The Local variety exhibits better resistance to decay than Fuseau, consistently showing lower decay percentages across both seasons. This suggests that the Local variety may have better resistance to decay or lower susceptibility to microbial activity compared to Fuseau.

Decay is generally higher in Season 2 compared to Season 1 for both varieties and packaging materials. This could be due to differences in environmental conditions (e.g., temperature, humidity) between the two seasons, which may have influenced microbial growth and physiological deterioration.

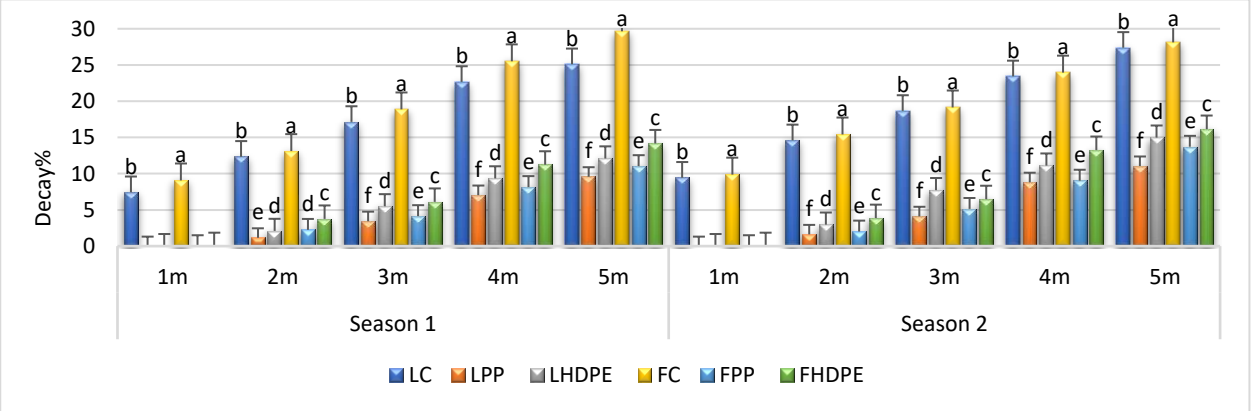

Figure 4: Influence of storage periods and packaging materials on decay% of two cultivars Jerusalem artichoke fresh tubers storage during two seasons

m: months- L: Local variety – F: Fuseau variety- PP: perforated polypropylene -HDPE: perforated highdensity polyethylene.

3.2.1.1.2. Inulin content (mg/100g)

Figure 5 examines inulin content declines over time for both varieties and all packaging materials. This is consistent with the natural degradation of inulin during storage due to enzymatic activity, respiration, and other biochemical processes. These results can be attributed to the depolymerization of fructan-by-fructan exohydrolase (FEH), which may also be linked to the increased levels of free fructose, indicating higher activity of inulinase as the tuber aged. This, in turn, reduced inulin content. [73] The rate of decline varies depending on the packaging material and the variety, with some combinations showing better preservation of inulin than others.

For the effect of Packaging Materials, HDPE consistently outperforms PP and controls the preservation of inulin content for both varieties and across seasons. This is likely due to its superior barrier properties against moisture, oxygen, and other factors contributing to inulin degradation. The control samples (L and F)

showed the most significant ($P \leq 0.05$) decline in inulin content over time; this highlights the importance of packaging in preserving inulin. PP packaging provides better inulin retention than the control but is less effective than HDPE. For example, In Season 1, after 5 months, LPP retained 8.98 g/100g inulin content, while Lcontrol droped to 6.23 g/100g. HDPE is the most effective packaging material for preserving inulin content in both varieties. For example, In Season 2, after 5 months, FHDPE retains 13.06 g/100g inulin content, while Fcontrol drops to 8.19 g/100g. Similarly, **Haggag et al., [18] and Danilcenko et al., [22]** reported that plastic boxes, whether lined with perforated polypropylene or unlined, stored at 0 or 5°C and 95% RH, demonstrated that lined boxes were more effective in maintaining TSS concentrations, total sugars, and inulin, while also exhibiting lower respiration rates compared to heads or tubers stored in unlined boxes. These outcomes may be linked to the rise in free fructose levels. This suggests an increase in inulinase activity as the tuber matures, leading to a reduction in inulin content. [73]

The Fuseau variety retains more inulin than the Local variety, making it a better candidate for storage if inulin preservation is a priority.

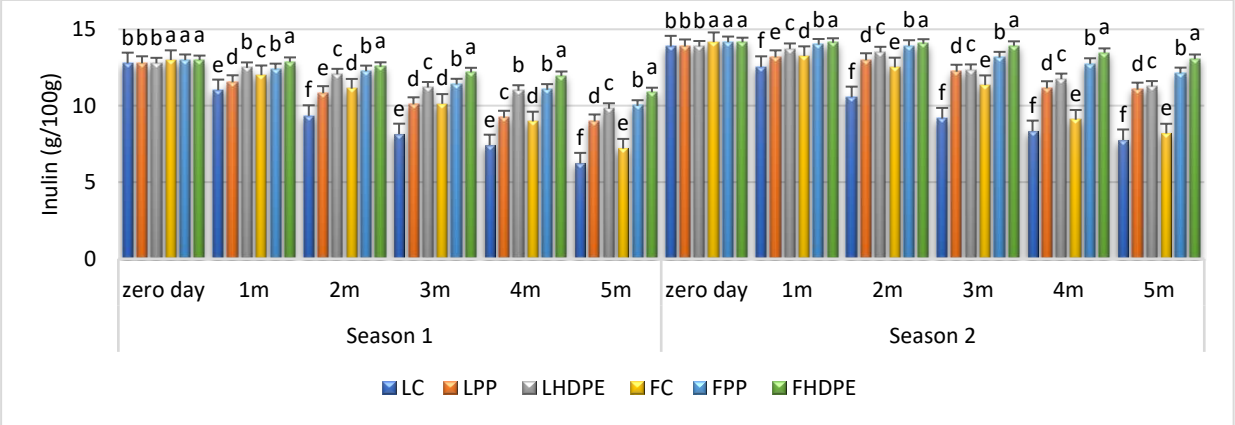

Figure 5: Influence of storage periods and packaging materials on inulin (g/100g) of two cultivars of Jerusalem artichoke fresh tubers storage during two seasons

m: months- L: Local variety – F: Fuseau variety- PP: perforated polypropylene -HDPE: perforated high-density polyethylene.

3.2.1.1.3. Total Soluble Solids (TSS)

Figure 6 examines the effect of storage periods and packaging materials on the Total Soluble Solids (TSS) of Jerusalem artichoke fresh tubers during two seasons. TSS is a critical quality parameter that reflects the concentration of soluble solids in the tubers, including sugars, organic acids, and other dissolved substances. Fig. 6 compared the effectiveness of different packaging materials in preserving TSS over a five-month storage period for two varieties (Local and Fuaesu).

TSS declined over time for both varieties and all packaging materials. This is consistent with the natural degradation of soluble solids during storage due to metabolic processes such as respiration and enzymatic activity. During storage, physiological processes continued, leading to a decrease in the respiration rate. As a result, under these conditions, reducing and total sugar degradation occurred irregularly. The carbohydrate structure is affected by various factors, such as the plant source, maturity, climate, growing conditions, and the length of storage. [24]

For the effect of Packaging Materials, HDPE consistently outperforms PP and control in preserving TSS for both varieties and across both seasons. This is likely due to its superior barrier properties against moisture, oxygen, and other factors contributing to TSS degradation. The control samples (L and F) showed the most significant decline in TSS over time. This highlights the importance of packaging in preserving TSS. PP packaging provided better TSS retention than the control but was less effective than HDPE. For example: In Season 1, after 5 months, LPP retained 22.21°Brix TSS, while L control dropped to 17.12 Brix. HDPE is the most effective packaging material for preserving TSS in both varieties. For example, In Season 2, after 5 months, FHDPE retained 22.95 TSS Brix, while F control dropped to 17.02 Brix.

The local variety showed better TSS retention than the Fuseau variety, suggesting it may be more suitable for long-term storage or have a higher initial TSS. Plangklang and Tangwongchai have made a similar observation, observing that TSS in the HEL65 variety showed a slight increase. In contrast, in the JA89 variety, it rapidly decreased after two weeks of storage. [74]

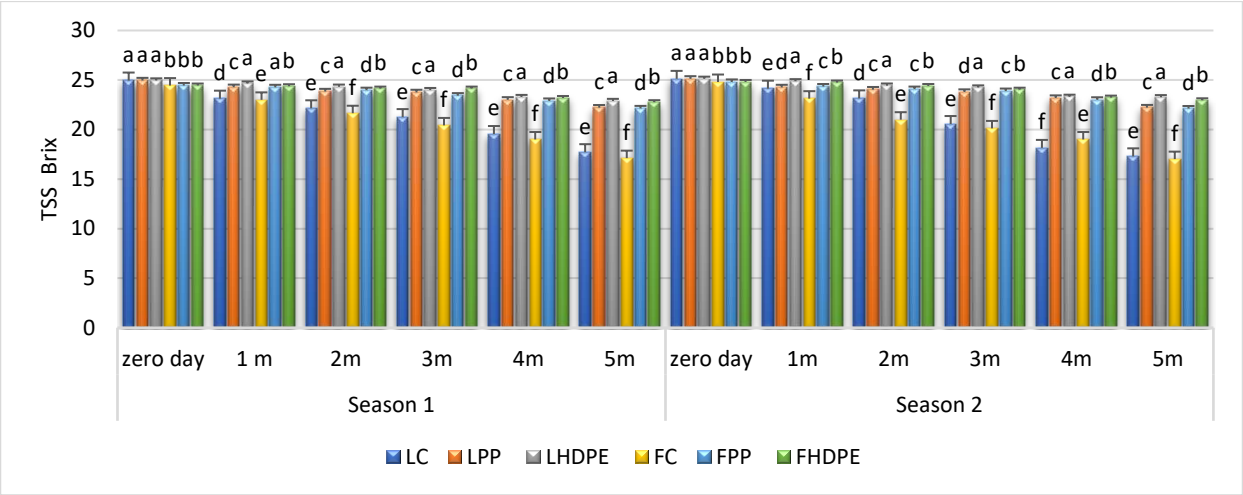

Figure 6: Influence of storage periods and packaging materials TSS of two cultivars Jerusalem artichoke fresh tubers storage during two seasons

m: months- L: Local variety – F: Fuseau variety- PP: perforated polypropylene -HDPE: perforated highdensity polyethylene

3.2.1.2. Microbiological analysis

3.2.1.2.1. Total count and Yeast & Molds

Figure 7 and **Figure 8** presents data on the effect of storage periods and packaging materials on the microbial load (Total count and Yeast & molds CFU/g) of two varieties of Jerusalem artichoke tubers (Local and Fuseau) during two storage seasons. In both seasons and for both varieties, microbial load significantly ($P \leq 0.05$) increased with storage duration. By the end of storage, microbial load is highest for all packaging materials and varieties, indicating that extended storage significantly impacts tuber quality.

For the effect of Packaging Materials: PP and HDPE packaging significantly ($P \leq 0.05$) reduced microbial load compared to the control, with HDPE being more effective than PP. The control group showed the highest microbial load in both seasons and for both varieties. PP packaging significantly reduced microbial load compared to the control. PP also reduced microbial load compared to the control but is generally less effective than HDPE. For instance, in Season 2, the Fuseau variety showed 23.92 and 14.56 CFU/g in the control group TC and Y&M, respectively, but in HDPE packaging, 11.50 and 7.93 CFU/g TC and Y&M respectively, after five months.

PP also reduced microbial load compared to the control but is generally less effective than HDPE. For instance, in Season 1, the Fuseau variety showed 21.90 and 14.06 CFU/g in the control group TC and Y&M, respectively, but in PP 13.11 and 7.50 CFU/g TC and Y&M respectively, after five months. Xiao et al. likely observed that storage temperature significantly impacted the packaging atmosphere, which plays a crucial role in maintaining the quality and shelf life of radish microgre. [75] These results can be attributed to a more significant reduction in respiration rate and decreased ethylene production, which improved marketability and General Appearance. [76] Additionally, the findings Compatible with Rashed et al. [24]

The Fuseau variety generally experiences a higher microbial load than the Local variety across all packaging materials and storage periods. For example, in TC Season 1, after five months, the Fuseau control group showed 21.90 CFU/g, while the Local control group showed 19.82 CFU/g. This suggests that the Local variety may have better resistance to microbial load or lower susceptibility to microbial growth than Fuseau.

Microbial load is generally higher in Season 2 compared to Season 1 for both varieties and packaging materials. For example, in the control group of the Local variety, TC after five months is 19.82 CFU/g in Season 1 and 21.94 CFU/g in Season 2. This could be due to differences in environmental conditions (e.g., temperature, humidity) between the two seasons, which may have influenced microbial growth rates.

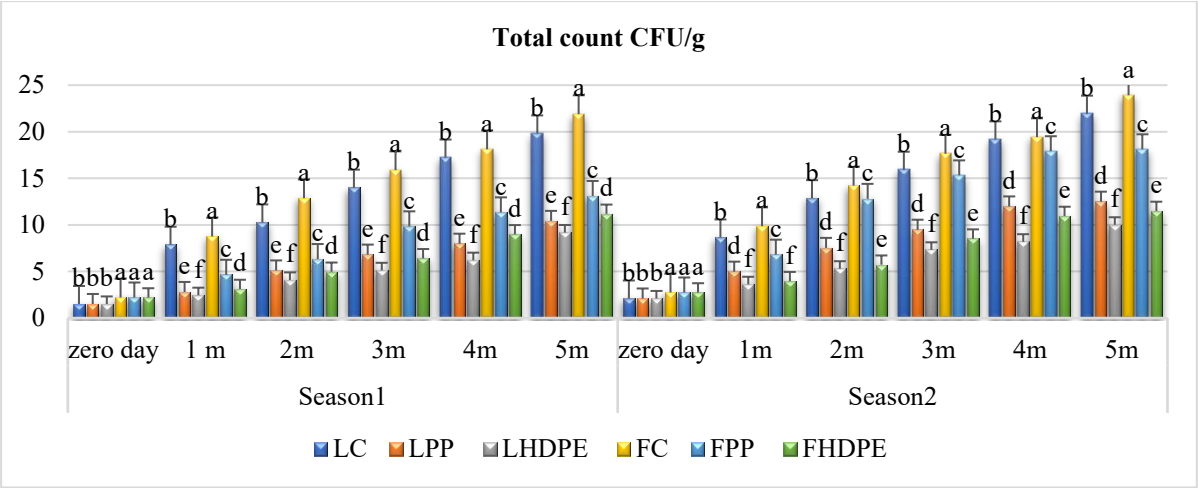

Figure 7: Influence of storage periods and packaging materials on Microbial load (Total count CFU/g) of two cultivars Jerusalem artichoke fresh tubers storage during two seasons

m: months- L: Local variety – F: Fuseau variety- PP: perforated polypropylene -HDPE: perforated high-density polyethylene.

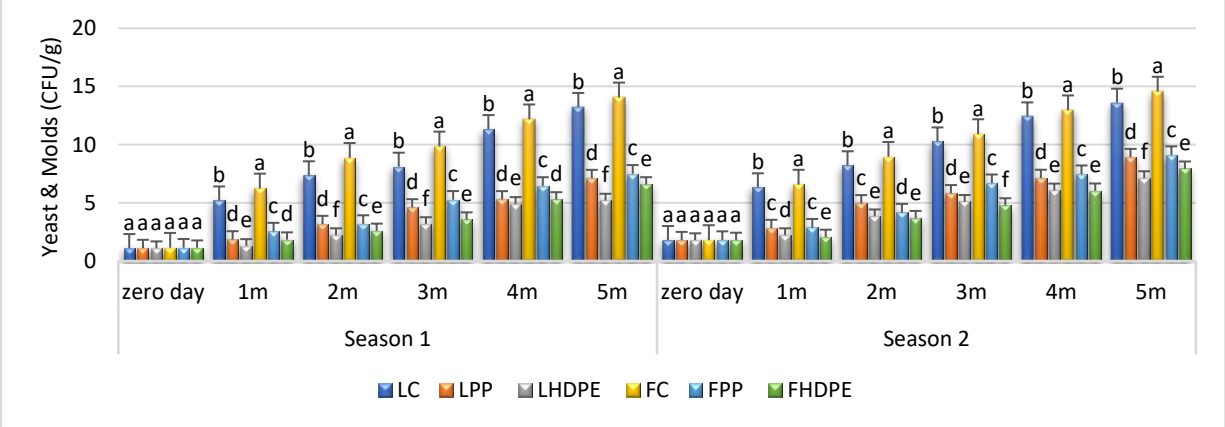

Figure 8: Impact of storage periods and packaging materials on Microbial load (Yeast &Molds CFU/ g) of two cultivars Jerusalem artichoke fresh tubers storage during two seasons

m: months- L: Local variety – F: Fuseau variety- PP: perforated polypropylene -HDPE: perforated high-density polyethylene.

3.3. Chemical analyses and Feeding experiments

3.3.1. Chemical analyses of JAFP and WF

Table 6 shows the chemical composition of WF (72 %) and JAFP. WF contained 11.90 % protein, 0.50 % ash, 1.75 % fat, 0.75 % crude fiber, and 85.10 % available carbohydrates. These findings were aligned with El-Hadidy, [77] El-Hadidy et al., [78] Mospah, et al. [79] and Mospah, et al. [80] who presented that the chemical composition of WF (72 % extraction) was 1.75 % lipid, 0.45 % ash, 0.84 % fiber, and 11.81 % protein (on dry weight basis). Nonetheless, the JAFP result, which comprised 8.50% crude fiber and 1.50% fat, can be said to be a high source of fiber. In addition, it contained 6.30 % protein, 4.50 % ash, and 79.20 % available carbohydrates. These findings were aligned with Mostafa [1].

The mineral content of JAFP and WF is also presented in Table 3. The mineral content of JAP had the highest content compared to WF. JAP was characterized by higher contents of Ca, K, P, Zn, Mn, and Fe than WF. The vitamin content of JAB is also presented in Table 2. The vitamins ascorbic acid and riboflavin content of JAP had the highest content compared to WF. Wheat flour had higher vitamin Pyridoxine, thiamine B1, and niacin B3 content than WF. These findings were aligned with (Mospah, et al. [80] and Mostafa [1].

Table 6: Chemical analyses of TNTF and WF

Raw materials	JAFP	WF
Crude protein%	6.30^{a} ±0.07	11.90^{b} ±0.06
Fat%	1.50^{b} ±0.02	1.75^{a} ±0.02
Ash%	4.50^{a} ±0.05	0.50^{b} ±0.01
Crude fiber%	8.50^{a} ±0.07	0.75^{b} ±0.02
Available carbohydrates%	79.20^{b} ±0.05	85.10^{a} ± 0.02
Energy (kcal/100g)	364.20^{b} ±0.15	413.63^{a} ±0.02
Ca	60.11^{b} ±0.05	18.50^{c} ±1.03
P	350^{a} ±2.03	140.00^{d} ±1.55
K	2300 ±2.53	1250.50^{d} ±1.03
Mg	90.50^{c}±1.07	103.00^{d} ±1.00
Zn	5.00^{c} ±0.03	4.20^{c} ±0.01
Mn	3.60^{c} ±0.02	0.80^{d} ±0.01
Fe	24.50^{a} ±0.08	2.00^{d} ±0.01
Vitamin (C) (mg / 100g)	24.70^{a} ±0.08	ND
Thiamine (B1) (mg / 100g)	0.20^{b} ±0.01	0.90^{a} ±0.01
Riboflavin	3.80^{a}±0.02	0.15^{b}±0.01
Pyroidoxine (mg / 100g)	0.095^{b} ±0.00	0.50^{a} ±0.01
Niacin (B3) (mg / 100g)	1.50^{b} ±0.03	7.90^{a} ±0.05
Pantothenic acid (mg / 100g)	0.25^{b} ±0.01	1.50^{a} ±0.02

Each value was an average of three determination ± standard deviation

Different letters indicate to significant differences between raw materials in the same column($p \leq 0.05$).

Sensory attributes of shamy bread

Table 7 provides the sensory attributes of shamy bread prepared from JAFP and wheat flour blends. The sensory attributes of mixed shamy bread were affected significantly by blending with different levels of JAFP. Shamy bread appeared significantly lower when blended with various JAFB concentrations compared to the control 19.50. Adding JAFP to wheat flour decreased the appearance of shamy bread to 18 and 15 respectively. Blending with different proportions of JAFP significantly decreased the separation of layers of shamy bread in comparison to the control 20.00. Enrichment of wheat flour with JAFP decreased the layer separation to 19 and 18 respectively. Fortification of wheat flour with JAFP significantly decreased the roundness of shamy bread to 14 and 13 respectively, compared to control 15. Blending with different Proportions of JAFP significantly ($P \leq 0.05$) decreased the distribution of crumbs of shamy bread in comparison to the control 14. Blending wheat flour with JAFP decreased the crumb distribution to 14 and 13 respectively. Blending with different proportions of JAFP significantly ($P \leq 0.05$) decreased the crust color of shamy bread in comparison to the control 9.5. Blending wheat flour with JAFP decreases the crust color to 9 and 7.50 respectively. The taste of shamy bread was significantly lower when blended with various JAFP concentrations than the control 9.70. Adding JAFP to wheat flour decreased the taste of shamy bread to 9 and 7, respectively. Blending with different proportions of JAP significantly decreased the odor of shamy bread in comparison to the control 10. Enrichment of wheat flour with JAFP decreased the odor to 9.5 and 7.5, respectively. The total scores of shamy bread were significantly lower when blended with various JAFP concentrations compared to the control 97.7. Adding JAFP to wheat flour decreased the taste of shamy bread to 93 and 81.5, respectively. Another report suggests that adding 5% *Jerusalem Artichoke* powder results in bread with good organoleptic qualities, long shelf life, and high nutrient contents. [81]

Table 7: Organoleptic evaluation of shamy bread made from wheat flour (72% extraction) and different levels of JAFP

Blends	Appearance 20	Separation of layer 20	Roundness 15	Distribution of crumb 15	Crust color 10	Taste 10	Odor 10
Control	19.50^{a} ±0.03	20.00^{a} ±0.00	15.00^{a}±0.00	14.00^{a} ±0.15	9.50^{a}± 0.30	9.70^{a} ±0.20	10.0^{a}±0.00
Blend 1	18.00^{b} ±0.20	19.00^{b} ±0.15	14.50^{b} ±0.20	14.00^{a} ±0.20	9.00^{b} ±0.15	9.00^{b} ±0.20	9.50^{b} ±0.15
Blend 2	17.00^{c} ±0.30	18.50^{c} ±0.20	14.00^{c} ±0.14	13.50^{b} ±0.10	8.50^{c} ±0.22	8.70^{c} ±0.30	9.00^{c} ±0.06
Blend 3	16.00^{d} ±0.25	18.00^{d} ±0.15	13.50^{d} ±0.13	13.00^{c} ±0.14	8.00^{d} ±0.10	8.00^{d} ±0.25	9.00^{c} ±0.05
Blend 4	15.00^{e} ±0.40	18.00^{d} ±0.10	13.00^{e} ±0.20	13.00^{c} ±0.20	7.50^{e} ±0.09	7.00^{e} ±0.30	8.00^{d} ±0.20

Control: WF 100%- Blend 1: WF: JAFP 90:10- Blend 2: WF: JAFP 80:20- Blend 3: WF: JAFP 70:30- Blend 4: WF: JAFP 60:40

Each value was an average of ten determination ± standard deviation

Different letters indicate to significant differences between blends in the same column($p \leq 0.05$)

3.3.2. Proximate composition of shamy bread

Table 8 presents the proximate composition of shamy bread prepared from blends of JAFP and wheat flour. The composition of the mixed shamy bread was significantly affected by varying levels of JAFP. The protein content of shamy bread was notably lower in the blends containing different concentrations of JAFP compared to the control, which had a protein content of 11.83%. Specifically, the addition of JAFP reduced the protein content to between 11.34% and 9.66%

Conversely, incorporating JAFP into the wheat flour significantly increased the fat content of the shamy bread compared to the control, which had a fat content of 1.75%. The fat content in the JAFP blends was observed to decrease to between 1.73% and 1.65%

Moreover, fortifying the wheat flour with JAFP led to a significant increase in the ash content of shamy bread, rising to between 0.90% and 2.10%, compared to the control value of 0.50% .

The carbohydrate content of shamy bread was significantly decreased ($P \leq 0.05$) when blended with different proportions of JAFP, compared to the control, which had a carbohydrate content of 85.17%. The carbohydrate levels in the blends with JAFP ranged from 84.89% to 82.74%.

Additionally, blending with varying proportions of JAFP significantly reduced the energy content of the shamy bread compared to the control value of 413.63 kcal per 100 g. The energy content in the JAFP blends ranged from 410.29 kcal to 393.86 kcal per 100 g. As the proportion of JAFP increased, the energy content of the blends decreased significantly. These findings align with Chirsanova et al. [81] and Mostafa [1].

Table 8: Chemical composition of shamy bread samples

Blends	Protein%	Fat%	Ash%	Fiber%	Carbohydrate%	Caloric value (kcal/100g)
Control	11.83^{a} ±0.01	1.75^{a} ±0.01	0.50^{e} ±0.01	0.75^{e} ±0.01	85.17^{a} ±0.07	413.63^{e} ±0.10
Blend 1	11.34^{b} ±0.03	1.73^{b} ±0.00	0.90^{d} ±0.03	1.50^{d} ±0.02	84.89^{b} ±0.04	410.29^{d} ±0.20
Blend 2	10.78^{c} ±0.05	1.70^{c} ±0.01	1.30^{c} ±0.02	2.30^{c} ±0.01	83.92^{c} ±0.20	403.74^{c} ±0.30
Blend 3	10.22^{d} ±0.04	1.68^{d} ±0.01	1.70^{b} ±0.03	3.08^{b} ±0.04	83.32^{d} ±0.09	398.80^{b} ±0.15
Blend 4	9.66^{e} ±0.05	1.65^{e} ±0.01	2.10^{a} ±0.02	3.85^{a} ±0.05	82.74^{e} ±0.04	393.86^{a}±0.20

Control: WF 100%- Blend 1: WF: JAFP 90:10- Blend 2: WF: JAFP 80:20- Blend 3: WF: JAFP 70:30- Blend 4: WF: JAFP 60:40
Each value was an average of ten determination ± standard deviation
Different letters indicate to significant differences between blends in the same column($p \leq 0.05$)

3.4. Influence of JAFP on blood glucose level of normal and diabetics diets rats

Table 9 demonstrates the influence of JAFP on blood glucose levels in standard and diabetic rats over different time intervals. Initially, before the intervention, all groups exhibited similar blood glucose levels, ranging between 102 and 108 mg/dl, with no significant differences. However, after 72 hours, the diabetic control group (G2) showed a sharp increase in blood glucose levels (305 mg/dl), which continued to rise to 311 mg/dl after six weeks, indicating sustained hyperglycemia.

In contrast, diabetic rats that consumed Shamy bread containing JAFP exhibited a dose-dependent reduction in blood glucose levels over the six weeks. The group consuming 10% JAFP (G3) showed a modest reduction in glucose levels (250 mg/dl), while those on 20% JAFP (G4) and 30% JAFP (G5) demonstrated more significant declines to 200 mg/dl and 185 mg/dl, respectively. The most notable improvement was observed in the group consuming 40% JAFP (G6), where blood glucose levels were reduced to 150 mg/dl, suggesting a strong hypoglycemic effect.

JAFP supplementation helps regulate blood glucose levels in diabetic rats, with higher doses showing greater improvements. Its hypoglycemic effects may be linked to enhanced insulin sensitivity, increased glucose uptake, or slowed carbohydrate absorption, making it a potential natural intervention for diabetes management. Studies have shown that inulin, found in Jerusalem artichoke, improves glucose tolerance and lipid profiles by slowing gastric emptying and modulating intestinal hormones. [4, 82] Research by Roberfroid and Delzenne [83] and Giacco et al. [84] supports the role of fibers in blood glucose regulation, while Cani et al. [85] found that inulin supplementation improves glucose tolerance and insulin secretion in diabetic patients.

Table 9: Influence of JAFP on blood glucose level of normal and diabetic rats

Treatment	Groups	After adaptation (mg/dl)	After 72h (mg/dl)	After 6 weeks (mg/dl)
Normal control (-)	G_1	108^{a} ±9.00	98^{b} ±2.00	100^{f} ±8.00
Diabetic control (+)	G_2	105^{a} ±5.84	305^{a} ±6.00	311^{a} ±10.00
Blend 1	G_3	103^{a} ±7.00	295^{a} ±8.00	250^{b} ±9.00
Blend 2	G_4	102^{a}±12.00	310^{a} ±10.00	200^{c} ±7.00
Blend 3	G_5	107^{a} ±5.84	302^{a} ±7.00	185^{d} ±8.00
Blend 4	G_6	105^{a} ±10.84	315^{a} ±12.00	150^{e} ±6.00

Normal control (-): 50%shamy bread 100% WF (72% extract) + 50% Basal diet - Diabetic control (+): 50%shamy bread 100% WF (72% extract) + 50% Basal diet - Blend 1: WF: JAFP 90:10- Blend 2: WF:JAFP 80:20- Blend 3: WF:JAFP 70:30- Blend 4: WF:JAFP 60:40. Each value was an average of six determination ± standard deviation. Different letters indicate to significant differences between groups in the same column($p \leq 0.05$)

3.5. Impact of feeding with JAFP on TC, TG, HDL, LDL and VLDL of normal and diabetic rats

Table 10 illustrates the influence of JAFP on various lipid parameters in both standard and diabetic rats consuming a basal diet. The diabetic control group exhibited significantly elevated levels of total cholesterol (190 mg/dl), triglycerides (220 mg/dl), LDL (106 mg/dl), VLDL (44 mg/dl), and total lipids (3.60 g/dl) compared to the standard control group, which had substantially lower values. Additionally, HDL levels were significantly reduced in diabetic rats (40 mg/dl) compared to normal controls (65 mg/dl), indicating an adverse impact of diabetes on lipid metabolism. Incorporating JAFP into Shamy bread demonstrated a dose-dependent improvement in lipid parameters. A 10% JAFP supplementation led to a slight reduction in total cholesterol (180 mg/dl), triglycerides (190 mg/dl), and LDL (97 mg/dl), alongside an increase in HDL (45 mg/dl). Further increasing JAFP to 20%, 30%, and 40% resulted in progressive improvements, with 40% JAFP supplementation showing the most favorable lipid profile. At this level, total cholesterol was reduced to 140 mg/dl, triglycerides to 150 mg/dl, LDL to 51 mg/dl, and VLDL to 30 mg/dl. In comparison, HDL increased to 59 mg/dl, indicating a significant amelioration of dyslipidemia. These findings suggest that dietary JAFP supplementation could be beneficial in regulating lipid metabolism, particularly in diabetic conditions. The progressive improvement in lipid parameters with increasing JAFP concentrations highlights its potential hypolipidemic effects. This may be attributed to the bioactive compounds in JAFP, which could enhance lipid metabolism and reduce the risk of cardiovascular complications associated with diabetes.

The hypolipidemic influence of Jerusalem artichoke may result from enhanced fecal lipid excretion and reduced lipid absorption, as suggested by Zaky [86]. Additionally, research by Beylot [87] and Tapera et al., [4] indicated that the lipid-lowering properties of inulin are linked to its fermentation in the large intestine by bifidobacteria, which produce short-chain fatty acids. Among these, propionate plays a key role in inhibiting hepatic lipid synthesis, including producing fatty acids and cholesterol.

Table 10: Influence of JAFP on some lipid parameters of normal and diabetic rats fed on a basal diet

Groups	Total cholesterol (mg/dl)	Triglyceride (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	VLDL (mg/dl)	Total lipids (g/dl)
Normal control (-)	120^{f} ±1.50	120^{f} ±1.20	65^{a} ±0.90	31^{f} ±0.20	24^{f} ±0.60	١.20^{f} ±0.01
Diabetic control (+)	190^{a} ±2.00	220^{a} ±5.00	40^{f} ±0.40	106^{a} ±0.30	44^{a} ±1.00	3.60^{a} ±0.02
Blend 1	180^{b} ±1.90	190^{b} ±4.00	45^{e} ±0.30	97^{b} ±0.50	38^{b} ±2.00	3.20^{b} ±0.04
Blend 2	160^{c} ±2.00	170^{c} ±3.00	50^{d} ±0.60	76^{c} ±0.50	34^{c} ±1.00	2.90^{c} ±0.05
Blend 3	150^{d} ±3.00	160^{d} ±2.00	55^{c} ±0.30	63^{d} ±1.00	32^{d} ±0.90	2.50^{d} ±0.08
Blend 4	140^{e} ±4.00	150^{e} ±2.50	59^{b} ±1.00	51^{e} ±2.00	30^{e} ±0.90	2.00^{e} ±0.01

Normal control (-): 50%shamy bread 100% WF (72% extract) + 50% Basal diet - Diabetic control (+): 50%shamy bread 100% WF (72% extract) + 50% Basal diet - Blend 1: WF: JAFP 90:10- Blend 2: WF:JAFP 80:20- Blend 3: WF:JAFP 70:30- Blend 4: WF:JAFP 60:40. Each value was an average of six determination ± standard deviation. Different letters indicate to significant differences between groups in the same column($p \leq 0.05$)

3.6. Effects of feeding with JAFP on GPT, GOT, and ALP of normal and diabetic rats fed on a basal diet

Table 11 presents the impact of JAFP supplementation on liver function parameters, including ALT (GPT), AST (GOT), and ALP levels in normal and diabetic rats. The diabetic control group (G2) exhibited significantly elevated liver enzyme levels, with ALT at 67.45 U/L, AST at 86.11 U/L, and ALP at 120.53 U/L, indicating liver dysfunction commonly associated with diabetes. In contrast, the normal control group (G1) had considerably lower enzyme levels, suggesting normal liver function.

The introduction of JAFP in the diet led to a dose-dependent improvement in liver function. Rats fed with 10% JAFP (G3) showed a slight reduction in ALT (60.78 U/L), AST (76.45 U/L), and ALP (110.44 U/L) compared to the diabetic control. As the JAFP concentration increased, liver enzyme levels progressively declined. Notably, the group consuming 40% JAFP (G6) exhibited the most substantial improvement, with ALT decreasing to 45.30 U/L, AST to 50.54 U/L, and ALP to 80.70 U/L, approaching levels observed in normal rats.

These results suggest that JAFP supplementation plays a protective role in liver function, likely by reducing diabetes-induced liver damage. The improvement may be attributed to the bioactive compounds in JAFP, such as inulin and antioxidants, which could mitigate oxidative stress and inflammation in the liver. Consequently, incorporating JAFP into the diet may serve as a beneficial dietary intervention for improving liver health in diabetic conditions.

Studies have shown that dietary interventions with Jerusalem artichoke and inulin can improve metabolic and renal health in diabetic and hyperglycemic rats. Madinov et al., [88]It was reported that diabetes-related metabolic disturbances could elevate renal function, while Zaky [86] and Tapera et al., [4] found that feeding hyperglycemic rats Jerusalem artichoke tubers reduced serum glucose, triglycerides, total cholesterol, and LDL cholesterol while improving liver and kidney functions. Additionally, research by Delzenne et al., [89] and Younes et al., [90] demonstrated that inulin and oligofructose-enriched diets lowered uremia in normal and nephrectomized rats, likely due to increased fecal nitrogen excretion and reduced renal nitrogen excretion. [91]

Table 11: Influence of feeding JAFP on liver functions in rats

Treatments	Groups	**ALT** (GPT) (U/L)	**AST** (GOT) (U/L)	**ALP** (U/L)
Normal control (-)	**G1**	$35.11^{f} \pm 1.50$	$38.78^{f} \pm 1.24$	$74.87^{f} \pm 2.08$
Diabetic control (+)	**G2**	$67.45^{a} \pm 1.40$	$86.11^{a} \pm 2.23$	$120.53^{a} \pm 0.54$
Blend 1	**G3**	$60.78^{b} \pm 2.20$	$76.45^{b} \pm 1.43$	$110.44^{b} \pm 1.15$
Blend 2	**G4**	$57.11^{c} \pm 0.45$	$70.79^{c} \pm 1.65$	$99.79^{c} \pm 1.53$
Blend 3	**G5**	$50.22^{d} \pm 1.45$	$60.33^{d} \pm 0.45$	$90.89^{d} \pm 0.45$
Blend 4	**G6**	$45.30^{d} \pm 2.45$	$50.54^{e} \pm 0.45$	$80.70^{e} \pm 0.45$

Normal control (-): 50%shamy bread 100% WF (72% extract) + 50% Basal diet - Diabetic control (+): 50%shamy bread 100% WF (72% extract) + 50% Basal diet - Blend 1: WF: JAFP 90:10- Blend 2: WF:JAFP 80:20- Blend 3: WF:JAFP 70:30- Blend 4: WF:JAFP 60:40. Each value was an average of six determination ± standard deviation. Different letters indicate to significant differences between groups in the same column($p \leq 0.05$)

4. Conclusion

The study highlights the importance of selecting Jerusalem artichoke cultivars adapted to optimal planting dates based on temperature variations. Higher temperatures promote better growth and increased inulin accumulation, making April 15th the ideal planting date for the Fuseau variety. Additionally, the study emphasizes the role of proper packaging in maintaining tuber quality and storability. Perforated polypropylene (PP) packaging reduces weight loss and decay, while perforated high-density polyethylene (HDPE) packaging at 4°C minimizes microbial load and preserves inulin and total soluble solids (TSS). The Fuseau variety is rich in vitamin C, iron, calcium, phosphorus, and inulin, making it beneficial for reducing blood glucose levels in diabetic rats and enhancing its value as a food and feed ingredient.

5. References

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