Influence of Some Chemical and Technological Treatments on Jerusalem Artichoke for Inulin Production

Zeitoun,* M. A.; H. M. Osman;* B. M. Abd-El-Lateef **, and A. A. El-Gindy **

*Food Science Department, Faculty of Agriculture (Saba-Bacha), Alexandria University, P.O. Box 21531- Bolkley, Alexandria, Egypt. **Food Tech. Res. Inst., Agric. Res. Cent. Giza, Egypt

ABSTRACT

Recently, inulin has become more current and vibrant than ever because of its industrial applications. In this study the main source of inulin was Jerusalem artichoke tubers. Proximate composition of Jerusalem artichoke tubers was determined and compared with chicory roots. The pretreatment of Jerusalem artichoke tubers was carried out by blanching for enzyme inhibition. Pressing and diffusion methods were used for inulin extraction. The extracted inulin was clarified and dried. Chemical and technological characteristics of inulin were studied. The best treatments for Jerusalem artichoke tubers was blanching to inactivate the enzymes with 0.5% citric acid at 95°C for 4 min. which resulted in a completely enzyme inhibition. The extraction method also revealed that the best ratio was 1:5 (sample Jerusalem artichoke tubers: water) at 95°C for 45 min to give the highest yield of inulin extract (93.17%). The best clarification for juice extracted by diffusion method was obtained by using a 0.3% of calcium hydroxide at 90°C and pH of 10.50, while it was of 0.4% at 80°C for 5 minutes and pH 10.49 for juice by pressing method. Clarified inulin obtained by pressing method contained 1.3% fiber, 0.61% protein, 0.67% ash and 96.4% inulin, compared with 0.76, 0.50, 0.51 and 97.45, respectively obtained by diffusion method. The technological properties showed that the extracted and clarified inulin has a melting point of 172°C. At the same time the solubility of produced inulin was increased by increasing the temperature which reached 24.9% at 95°C.

INTRODUCTION

Inulin-type carbohydrates obtained from fungal and bacterial sources have been reported, but the predominant source for commercial inulin is of plant origin. In such plants, it is the reserve polysaccharide carbohydrate. It is reported that over 30.000 plants contain inulin including such commonly known vegetable as artichoke, asparagus, leek, onion, garlic, wheat, dahlia, and chicory roots (Elyachiovi *et al*, 1992; Leclerq and Hageman, 1993 and Silva, 1996). Jerusalem artichoke is considered one of the most interesting potential source of high inulin content (14-18%) (De Leenheer, 1996) (Van den, 1985). Maximal concentrations are found in Jerusalem artichoke, chicory and dahlia, where it constitutes up to 72-80% of the dry weight. Inulin is recommended sometimes for diabetics; it has a mildly sweet taste, and is filling like starchy foods, but because it is not absorbed, it does not affect blood sugar levels (Bergner, 1998). Inulin is an ingredient commonly used in biscuit and cakes, cereal bars, ice creams and desserts, milk, yogurt and cheese as substitute of fat (Niness, 1999).

Vukov *et al.* (1991) prepared and clarified inulin containing Jerusalem artichoke. After the tubers are washed and during homogenization, an edible acid is added as citric acid to prevent enzymatic oxidation of polyphenols present in the mach. The tubers pressed by heat treatment and acidification to pH 4, followed by filtration. Heating up and cooling down should proceed rapidly in order to prevent hydrolytic cleavage of the inulin chains. Berghofer *et al.* (1993) reported that the solubility of inulin is considered one of the most important properties if used in foodstuffs. They added that, inulin could be dissolved in hot water between 40 and 60°C. Thermal treatments of solid mixtures of inulin and citric acid result in the formation of di-D fructose dianhydrides and oligomers. Izzo and Niness (2001) formulated nutrition bars with inulin and oligofructose. Nutrient bars that can be processed to contain inulin and oligofructose are used as breakfast bars, meal-replacement bars, sport/energy bars and health benefit bars. Inulin and oligofructose can increase the sensory quality and shelf life of bars, while adding significant nutritional benefits, they can offer the benefit of sugar reduction, glycerin replacement, additional fiber and enhanced calcium absorption to any bar formula. In recent time jerusalem artichoke has been cultivated in Egypt on commercial scale and data concerning inulin extraction, purification and characterization from Jerusalem artichoke are very few. Therefore this study aimed to choose the optimal conditions for extracting the highest yield of inulin from Jerusalem artichoke tubers; purification that gives the white powder inulin; and to study some physicochemical characteristics of the extracted inulin.

MATERIALS AND METHODS

Jerusalem artichoke tuber (*Helianthus tuberosus* L.) harvested in October 2001 were obtained from the Experimental Station of Agriculture Research Center, Kaliobia Governorate, Egypt. Chicory Roots (Cichorium intybus) were obtained from Horticultural Research Institute (Agriculture Research Center, Dokki, Giza, Egypt).

Preparation of sample

Jerusalem artichoke tubers and chicory roots were cleaned with tap water to remove dusts and other undesirable materials, then cut into sample pieces. Chicory roots were freeze dried, while Jerusalem artichoke pieces were air dried in an air oven at 60-70°C for 24 hours. The dried samples were milled to pass through 100 mesh screen sieve. The recovered powders were kept in ethylene bags and stored at 4 ± 1°C in a refrigerator until using for further analysis.

Analytical Methods

Moisture content: Moisture content of Jerusalem artichoke tubers and chicory roots was estimated by drying the samples at 105 ± 5°C until reaching a constant weight as described in A.O.A.C (1990) Method.
Crude fat content: Crude fat content of Jerusalem artichoke tubers and chicory roots were determined by using petroleum ether (40-60°C) in Soxhlet apparatus as described in A.O.A.C. (1990) Method.
Crude protein content: Total nitrogen was determined using the procedure of Kieldahl as described in A.O.A.C. (1990) for each Jerusalem artichoke tuber and chicory roots. Crude protein was calculated by multiplying the total nitrogen content by 6.25.
Crude fiber content: Crude fiber was performed using the method of Egan *et al.* (1985).
Ash content: Ash content was carried out using a muffle furnace at 525-550°C as described in A.O.A.C. (1990) method.
Total carbohydrates: Total carbohydrate was determined in Jerusalem artichoke tuber and chicory roots by difference.
Inulin content determination: Inulin content was determined by using the method of Strepkov (1936) with some modifications as the following: One gram of sample was used after removing the soluble sugars and glycosides by mixing the weighed sample with 25 ml of 80% ethanol and shaking for 60 minutes. Sample was extracted with 25 ml of water at 70°C for 20 minutes. The slurry was filtered and the residue was twice with equal amounts of water each time. The combined filtrates were treated with 5 ml of 1.0 N lead acetate and 5 ml of saturated sodium phosphate dibasic. The recovered extract was filtered and diluted to 100 ml with water, 2 ml of this solution was placed in a test tube and (2 ml) of folin reagent was added. The mixture was heated in water bath at 60°C for 90 minutes. After cooling, the solution was titrated with standard potassium permanganate solution 0.01 N until reaching the rose color. The inulin content was calculated using the following equation reported by Strepkov (1936):

1.82 ml of 0.01 N potassium permanganate solution = 1 mg inulin.

Pretreatments of Jerusalem artichoke tubers
Washing: Tubers were washed and cleaned to remove the soil.
Skin removing: Skin of tuber was removed by using 4-6% NaOH at 95°C 1-2 min, then washed with water until it reached pH 7 according to (Dong, 1996), and sliced to 2-4 mm thickness.
Blanching and polyphenol oxidase inhibition in Jerusalem artichoke tuber for quality improvement (color stability): Different blanching treatments were carried out according to the method described by Zeitoun and Zeitoun (1999). Washed, skin removed and sliced Jerusalem artichoke tubers were immersed immediately in a solution containing citric or lactic acid with different

concentrations (0.5, 0.75, 1.0 or 1.5%) then heated at 80, 90 or 95°C for 1, 2, 3 or 4 minutes to choose the best condition for polyphenol oxidase inhibition.

Measurement of enzyme activity: Enzyme activity was measured by method described by Halpin and Lee (1987). Enzyme activity was determined by measuring the rate of increase in absorbance at 420 nm at 25°C with a model SPEKOL 77 (Carlzeiss Jena) spectrophotometer using catechol solution, distilled water and phosphate buffer pH 6.8. Activity was calculated using the following equation:

$$\%\text{Residual activity} = \frac{\text{Read after treatment}}{\text{Read before treatment}}$$

% Inhibition activity = (100-% Residual activity).

The washed, skin removed and sliced Jerusalem artichoke tubers was blanched with 0.5% citric acid at 95°C for four minutes as the best condition choosed according to the previous experiment of enzyme inhibition.

Inulin Extraction

The extraction of inulin was performed using the two following methods:

A. Diffusion extraction: Washed, skin removed, sliced and blanched Jerusalem artichoke tubers were mixed with different volumes of hot water (samples to water ratios were (1:1, 1:2, 1:3, 1:4, 1:5 w/v) according to Yamazaki (1994). The effect of using different temperatures (80, 90 & 95°C) as will as different times (20, 30 & 45 minutes) were also tried to choose the best condition of extraction.

B. Press extraction: After blanching, tubers were pressed as described by Barta (1993).

Clarification, filtration, concentration and drying of the extract:

Purification of extract was carried out according to the method described by Barta (1993). Then the filtered extract was concentrated under vacuum using pressure kettle 4 liters. The kettle was modified to be used as low pressure kettle. The modification was complished by connecting it to the vacuum pump. This modification was done according to Amin (1997). This modification resulted in a vacuum of 14 inches Hg vacuum. The temperature was kept inside the kettle at 60°C using a thermostatic controller heater. The time of concentration was adjusted for many trials to obtain a juice of 75% of total solids as have been measured by using Bellingham Stanley LTD pocket refractometer. Finally, the concentrated extract was dried firstly by freezing for sidimention and water portion separation, them the concentrated portion was dried in vacuum often at 40°C to reach a complete dryness of 5 ± 0.5% moisture.

Physical and chemical characteristics of produced inulin:

Solubility of produced inulin: Studying the solubility of inulin in water was carried out according the method described by Phelps (1965). 2.5 grams of inulin were added to 5 ml of distilled water in tubes. The mixture was heated in water bath at various temperatures (10, 20, 30, 40, 50, 60, 70, 80, 90 and 100°C) for 30 min. The solution was cooled and centrifuged at 4000 rpm for 15 minutes. Inulin was determined in the supernatant.

Melting point of produced inulin: The melting point of produced inulin was determined on a kelfer hot stage apparatus according to Kohda *et al.* (1976).

Microstructure of inulin powder: Inulin powder that pass through sieve (80µm, 160 µm, 200 µm, 315 µm) was examined at room temperature under polarized light using Zeiss Me b3 photomicroscope.

Effect of acidity and heating on hydrolysis of extracted inulin: Concentration (5%) of inulin was subjected to hydrochloric acid with different pH values (1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5 and 6 pH) at different temperatures (80, 90 and 95°C) for 60 minutes (Pekic *et al.*, 1985). The obtained reducing sugar from inulin hydrolysis was determined according to the method (Lane-Eynon) as described in A.O.A.C. (1990).

RESULTS AND DISCUSSION

Proximate composition:

Proximate compositions of dried Jerusalem artichoke tubers and chicory roots are shown in Table (1). It was clear that dried jerusalem artichoke tubers contained 80.3% of total carbohydrate which was much higher than that in dried chicory roots (63.1%). On the other hand, chicory roots showed the higher amount protein content and ether extract. The present results were similar to that obtained by Abdel-Lateef (2000), who reported that Jerusalem artichoke tubers powder contained 8.31% protein, 7.53% ash, 83.67% total carbohydrate. The present results are quite similar to that obtained by Abdel-Lateef (2000), also she found that chicory roots powder contained 4.81 protein, and total carbohydrate of 84.6%. At the same year Shalaby (2000) found that Jerusalem artichoke tubers contained 85.78% of total carbohydrate.

Table 1. Proximate composition of dried Jerusalem artichoke tubers and chicory roots (on dry basis):

Constituents (%)	Jerusalem artichoke tubers	Chicory roots
Moisture*	4.50	4.09
Protein	5.90	8.07
Ether extract	1.78	2.98
Ash	4.32	7.95
Crude fiber	3.21	13.80
Total carbohydrate	80.30	63.11

* Moisture content was 80.02% in Jerusalem artichoke tubers and 81.73% in chicory roots before drying.

Inulin content:

Inulen content was measured in dried jerusalem artichoke tubers and chicory roots. The averages of inulin content were 72.3 and 64.18%, respectively. The present data is in agreement with that obtained by Felming and Groot-Wassink (1979); Abdel-Lateef (2000) and Shalaby (2000) reported that the amount of inulin in Jerusalem artichoke was about 74.99% compared with in chicory roots (64.11%). Although chicory roots contained 63.2% of inulin, the extracted inulin from chicory roots had bitter taste according to the primary trials which have been done in the present work (data are not shown). Beek *et al.* (1990) reported that one of the quality criteria was the bitter taste in chicory roots which caused by sesquiterpene lactones. Therefore, further analysis were carried out only on the Jerusalem artichoke tubers.

Inulin Extraction

According to the enzymes activity of the fresh Jerusalem artichoke tubers, colour of the product became dark during extraction. To avoid this problem the product should be blanched to inactivate the enzyme. Table (2) shows the effect of time and temperature of blanching on polyphenol oxidase activity as an indicator for blanching effect on Jerusalem artichoke tubers. Inhibition (%) increased with increasing both the time and the temperature. The inhibition (%) reached 92% after 2 min. at 95°C. But it was not enough for enzymes inactivation. Therefore, acids were added to the blanching solution to enhance the inactivation was tried.

Table 2. Effect of blanching time and temperature on inhibition percent of polyphenol oxidase in Jerusalem artichoke tubers:

Blanching time (min)	Inhibition (%) at different temperature (°C)		
	80	90	95
1	12.1	78.3	88.3
2	28.0	84.1	92.0
3	36.1	86.2	92.1
4	76.0	90.6	92.5

Table (3) shows the effect of using lactic acid with different concentration (0.5–1.5%) for different time and temperature on inhibition of polyphenol oxidase of Jerusalem artichoke tubers. Unfortunately lactic acid of 1.5% in the blanching solution (was the highest concentration) had a complete enzyme inactivation. This acidity might lead to increase hydrolysis of inulin during the further processing. Therefore, citric acid was also used in the blanching solution to enhance the inactivation of enzymes to prevent the browning in the product during process. Phenolic compounds, since, play an important role in the browning response of plant tissues on cutting or injury (Mayer and Harel, 1981; Siriphanic and Kader, 1985).

Table (4) shows the effect of addition citric acid in blanching solution with different time and temperature on inhibition (%) of polyphenol oxidase activity in Jerusalem artichoke tubers. Complete inhibition of polyphenol oxidase was obtained after 2 min at 95°C with 1.5% citric acid, 3 min at 95°C with 0.75% citric acid and 4 min at 95°C with 0.5% citric acid. The pH values of blanched solution were decreased by using citric or lactic acid. This finding was in favor of blanching efficiency. Likewise blanching time was reduced (Zeitoun and Zeitoun, 1999). Colour of blanched Jerusalem artichoke tubers was improved by citric acid or lactic acid in blanching solution. As the PKa of citric and lactic are similar, Doores (1990) reported that PKa of citric and lactic acid are 3.14 and 3.08 respectively. According to this results, blanching solution of 0.5% citric acid at 95°C after 4 min was chosen as the best blanching condition of Jerusalem artichoke tubers before inulin extraction.

Table 3. Effect of different % of lactic acid in blanching solution with different time and temperature on inhibition % of polyphenol oxidase in Jerusalem artichoke tubers:

Blanching time (min.)	Inhibition %											
	Lactic acid 0.5 %			Lactic acid 0.75 %			Lactic acid 1.0 %			Lactic acid 1.5 %		
	Temperature °C			Temperature °C			Temperature °C			Temperature °C		
	80	90	95	80	90	95	80	90	95	80	90	95
1	66.3	72.4	88.3	68.1	78.4	88.1	70.3	80.1	94.3	72.4	88.1	96.1
2	70.1	82.2	90.1	72.3	84.2	96.3	74.1	86.3	96.2	92.5	93.3	100
3	88.2	89.1	92.2	88.2	88.3	98.5	90.2	94.1	99.1	96.1	100	100
4	90.1	91.3	98.3	93.1	94.5	99.1	95.1	97.5	100	100	100	100

Table 4. Effect of different (%) of citric acid in blanching solution with different time and temperature on inhibition % of polyphenol oxidase in Jerusalem artichoke tubers:

Blanching time (min.)	Inhibition %											
	Citric acid 0.5 %			Citric acid 0.75 %			Citric acid 1.0 %			Citric acid 1.5 %		
	Temperature °C			Temperature °C			Temperature °C			Temperature °C		
	80	90	95	80	90	95	80	90	95	80	90	95
1	70.1	82.2	88.3	78.1	88.1	88.6	80.3	90.1	90.6	82.2	92.3	94.0
2	68.2	83.1	90.4	78.5	88.2	96.1	82.1	92.2	96.4	88.3	96.0	100
3	72.4	84.5	92.1	85.4	90.3	100	86.3	92.6	100	90.1	98.0	100
4	84.2	87.1	100	88.3	94.1	100	89.2	96.0	100	98.1	100	100

Effect of time, temperature and solvent ratio on extractable inulin by diffusion method

Inulin extracted from Jerusalem artichoke tubers using hot water by diffusion method are shown in Table (5). It could be observed that by increasing the ratio of water at the same degree of temperature, the yield of inulin increased. Also, by increasing the degree of temperature of water and the time of extraction, the extracted inulin from Jerusalem artichoke increased. These results are in agreement with that obtained by Margaritis and Bajpai (1982) who extracted inulin from artichoke chips with water at temperatures ranged from 70 to 100°C. Although the higher percent of extracted inulin was obtained by using a solvent ratio of 5 : 1 water : sample at 45°C. But the ratio of 3 : 1 was chosen to be the best condition for extraction to facilitate the evaporation process for obtaining concentrated inulin product.

Table 5. Effect of solvent ratio, time and temperature on extractable inulin (%) from Jerusalem artichoke tubers by diffusion method:

Time (min.)	Solvent ratio	Extractable inulin % at different temperature (°C)		
		80	90	95
20	1:1	46.11	76.66	77.13
	2:1	61.10	83.33	85.40
	3:1	71.03	85.00	86.12
	4:1	71.12	87.70	90.03
	5:1	80.55	88.33	91.11
30	1:1	58.80	77.01	78.40
	2:1	72.21	84.00	85.91
	3:1	72.70	86.15	87.05
	4:1	75.00	88.00	90.84
	5:1	80.55	89.02	92.54
45	1:1	75.11	81.89	82.30
	2:1	75.91	85.07	90.14
	3:1	77.01	86.81	91.98
	4:1	80.03	90.66	92.50
	5:1	83.49	92.70	93.17

Effect of extraction method on the extractable inulin percent (yield)

Table (6) shows the yield of inulin extracted by the two methods (diffusion or pressing). It could be seen from this table that the yield of extractable inulin extracted by diffusion of the inulin as determined of Jerusalem artichoke tuber was higher (68.83%) than of inulin extracted by pressing (53.86%). These results are similar with results obtained by (Barta *et al.*, 1989 and Barta, 1993), who found that extraction of juice from the cleaned and chopped raw material could be carried out by pressing or by diffusion, resulted in an extractable inulin of 69.1% by diffusion and 54.6 by pressing method.

Table 6. Effect of extraction methods on extractable inulin percent (yield):

Extraction method	Inulin %	Extractable inulin (%) (yield)	Extraction efficiency
Diffusion	72.30	68.83	95.2
Pressing	72.30	53.86	74.5

Effect of heating on clarification of Jerusalem artichoke juice

Table (7) shows the percentage of clarification process for extracted juice of Jerusalem artichoke tubers by the two methods (pressing or diffusion) at different temperatures (80, 90 and 95°C) for 5 minutes. It could be observed that

the maximum clarification was 49.7% at 80°C in case of juice extracted by pressing method. While, in case of juice extracted by diffusion method, the percentages of clarification were lower at the three temperatures tested. At the same time, Table (7) showed that diffusion efficiency was much higher than that of pressing method. These results are in agreement with those obtained by (Barta, 1993) who found that, the optimal temperature for clarification in process of pressed juice was between 85 and 90°C, while, in case of diffusion it was between 60 to 65°C.

Table 7. Effect of heating at different temperature on clarification percent of Jerusalem artichoke extracted juice by pressing or diffusion for 5 min:

Temperature (°C)	Clarification (%)	
	Pressing	Diffusion
80	49.7	12.2
90	39.0	4.3
95	33.0	1.5

Effect of heating and calcium hydroxide (%) in Jerusalem artichoke tubers juice on pH values

To purify the extracted juice of Jerusalem artichoke tubers contained inulin from protein, pectic substances and other foreign matters, different concentrations of calcium hydroxide at different temperatures (80, 90 and 95°C) for 5 min. were used to adjust pH of the juice (Table 8). It could be observed that by increasing the concentration of calcium hydroxide, the pH of juice obtained by the two methods (pressing or diffusion) increased. Similar results were obtained by Barta (1993) who found that the colloids and floating contaminants in the raw juice could be coagulated at pH 10 to 11.5 by means of heating and calcium hydroxide, amounting to 0.2% (for extracted juice) and to 0.4% (for press juice) calcium hydroxide equivalent of the juice (w/v). Therefore, in present investigation 0.4% calcium hydroxide at 80°C for juice extracted with pressing and 0.3% at 90 for juice extracted with diffusion were observed.

Chemical characteristics of the inulin extract obtained by pressing or diffusion

As shown in Table (9), it was clear that the content of inulin in the extract with diffusion method was higher (97.45%) than that obtained by pressing method (96.44%). On the other hand, moisture, ether extract, crude fiber, protein and ash contents of extract by pressing method were slightly higher than those obtained by diffusion method. Similar results were reported by Shalaby (2000), who found that gross chemical composition of inulin isolated from Jerusalem artichoke tubers by pressing contained 5.09 moisture, 96.25 inulin,

0.48 ether extract; 0.64 crude protein; 1.38 crude fiber and 0.56 ash on dry matter.

Table 8. Effect of heating and calcium hydroxide (%) of Jerusalem artichoke tubers juice extracted with pressing or diffusion on the pH values:

Calcium hydroxide (%)	Temperature (°C)					
	80		90		95	
	Extracted methods (pH)					
	Press	diffusion	press	diffusion	Press	diffusion
0.1	5.1	5.3	5.0	5.2	5.4	6.0
0.2	5.7	8.8	5.9	9.4	5.5	9.9
0.3	8.9	11.1	8.8	10.5	8.3	11.3
0.4	10.5	11.9	9.2	12.1	8.4	11.4
0.5	10.7	12.1	11.3	12.1	10.9	11.8
0.6	11.9	12.3	11.4	12.1	11.4	11.9
0.7	12.2	12.4	11.7	12.2	11.9	12.2
0.8	12.5	12.4	12.4	12.3	12.4	12.3
0.9	12.6	12.4	12.5	12.3	12.5	12.4
1.0	12.6	12.4	12.6	12.4	12.5	12.5
1.1	12.7	12.5	12.6	12.6	12.6	12.5
1.2	12.7	12.5	12.6	12.6	12.6	12.6

Table 9. Chemical composition of inulin extracted from Jerusalem artichoke tubers by pressing or diffusion:

Constituents (%)	Inulin extracted with Pressing	Inulin extract by diffusion
Moisture	4.90	4.50
Inulin	96.44	97.45
Ether extract	0.51	0.45
Crude fiber	1.30	0.76
Crude protein	0.61	0.50
Ash	0.67	0.51

Effect of acidity and heating on the hydrolysis of extracted inulin

Table (10) shows the effect of different pH (1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5 and 6.0 pH) and different temperatures (80, 90 and 95°C) for 60 minutes on inulin at solution of 5%. It was clear that the amount of inulin hydrolyzed with the highest degree of acidity (pH 1.5) and temperature of 95°C did not exceed 15.0%. This amount decreased gradually with decreasing the acidity to reach 2.7% at pH of 6.0 at of 80°C. This result indicated that inulin was

quite stable even at higher acidity and temperature. These results are in agreement of those results obtained by Gruhn (1994), who reported that inulin was stable even in acidic conditions or at high temperatures.

Table 10. Effect of acidity and heating on the hydrolysis % of extracted inulin:

Different degrees of pH	Temperature (°C)		
	80	90	95
	Hydrolysis (%)		
1.5	14.0	14.5	15.0
2.0	12.7	14.1	14.7
2.5	12.5	13.9	14.3
3.0	12.3	13.6	14.0
3.5	11.6	13.2	13.8
4.0	11.4	12.5	13.1
4.5	9.8	10.4	13.0
5.0	8.4	10.3	12.8
5.5	8.4	10.3	0.9
6.0	2.7	7.4	9.6

Physical characteristics of extracted inulin

The solubility

Solubility of inulin extracted from Jerusalem artichoke at different temperatures (expressed as gram/100 ml water) is shown in Table (11). It was clear that the solubility of inulin at constant time (30 min.) increased with increasing the temperature. The solubilities of inulin were 18.53, 22.81 and 24.81 at 80, 90 and 100°C, respectively. These results are in harmony with those obtained by Vandorpe (1991). Berghofer *et al.*(1993); Marchetti (1993) and Shalaby (2000); who reported that inulin was soluble in hot water, but the solubility decreased in cold water. The same authors added that the solubility of 4 to 6% inulin in water gave as lightly unclear solution, they attributed this phenomenon to the precipitation that occurred because of the presence of long chains compounds of inulin.

Melting point of purified inulin

Melting point of dried and purified inulin were determined on a Kelfer hot stage apparatus and the average of three determinations was 172°C. These results are in agreement with those results reported by (Anonymous, 2001).

Table 11. The solubility of inulin at different temperatures (expressed as g inulin/100 ml water)

Time (min.)	Temperature °C	Solubility of Inulin
30	10	0.51
	20	1.59
	30	4.70
	40	6.80
	50	10.50
	60	12.61
	70	13.98
	80	18.53
	90	22.02
	100	24.81

REFERENCES

Abd El-Lateef, M.B. (2000). Production of bakery products using two sources of inulin. Annuals of Agric. Sc., Moshtohor. 38 (1): 361-378.

Amin, A.A.W. (1997). Chemical and technological studies on treacle (Black Honey). Ph.D. Thesis presented to the Graduate School, Faculty of Agriculture, Alexandria University. Egypt.

Anonymous (2001). "Safety data for inulin ". Http://google.yahoo. com/bin/queryo 2 P=inulin & hq=site: www. http:physchem.ox. ac.uk/MSDS/IN/inulin.html.

AOAC, (1990). Official methods of analysis of the Association of Official Analytical Chemists, Kenneth Helrich (ed.) 15th ed. Arlington, Virginia. 22201 U.S.A.

Barta, J.; S. Torok, K. Vukov, P. Fodor, and Magyar-Pichler. (1989). Die technische Hydrolyse der Fructose Topinambur. Zucker industrie, 114:397-400.

Barta, J. (1993). Jerusalem artichoke as multipurpose raw material for food products of high fructose or inulin content. In: A. Fuchs (Ed.). Inulin and Inulin containing crops 1993, Elsevier Science Publishers B.V. pp 323-339.

Beek, T.A. Van, P. Maas, M.B. King, E. Leciercq, J.G.A. Voragen, and de. A.Groot. (1990). "Sesquiterpene lactones from chicory roots. J. Agric. Food Chem. 38, 1035-1038.

Berghofer, E., A. Cramer, U. Schmidt, and M. Veigi (1993). Pilot-scale production of inulin from chicory roots and its use in food stuffs. In: A Fuchs (Ed.), Inulin and Inulin containing Crops 1993, El-Sevier Science Publishers B.V. pp. 77-84.

Bergner, P. 1998. "Inulin" medical Herbalism: A Journal for the Herbal Practitioner. Uttp://medherb.com/92 Inulin. HTM.

De Leenheer, L. and H. Hoebregs (1994). Progress in the elucidation of the composition of chicory inulin. Starch/Starke 46 (5): 193-196.

Dong, Q. (1996). Pickling of *Helianthus tuberosus* L. tubers in soft packages Food Science, China. 17 (4): 36-39.

Doores, S. (1990). PH control agents and Acidulants. In: Food Additives, P. 477 479. Branen, A.L., Davidson, P.M. and Salminen, S. (Eds.,). Marcel Dekker INC, New York and Basel.

Egan, H., S.R. Kirk, and A. Sawyer. (1985). Pearson's chemical Analysis of Foods. Churchill Livingston; Edinburgh, London, Melbourne and New York.

Elyachioui, M., J.P. Hornez, and R. Tailliez (1992). General properties of extra cellular bacterial inulinase. J. Applied Bacteriology, 73: 514-519.

Fleming, S.E. and D.W.J. Grootwassink (1979). Preparation of high fructose syrup from Jerusalem artichoke tubers (*Helianthus tuberosus* L.). CRC Critical Reviews in Food Sci. Nutr., 12: 1-28.

Gruhn, E. (1994). "Inulin-dietary fiber from chicory and fructose syrups processed the reof". Food Process. 6: 7.

Halpin, B.E. and Y.C. Lee (1987). Effect of blanching on enzyme activity and quality changes in green peas. Journal Food Science, 52 (4): 1002-1005.

Izzo, M., K. Niness (2001). "Formulating nutrition bars with inulin and oligofructose". Cereal-Foods world, 46 (3): 102-106.

Kohda, H., Kassai, R., Yamassaki, K., Murataml, K., and Tanaka, O. (1976). New sweet diterpene glucosides from *Stevia rebaudiana* Bertoni. Phytochemistry. 15, 981-983.

Leclercq, E. and G.J. Hageman (1993). Valorization of an inulin rich by product of chicory. In: A. Fuchs (Ed), Inulin and Inulin Containing Crops, 1993, Elsevier Science Publishers B.V. pp: 367-372.

Marchetti, G. (1993). "Chicory (*Cichorium intybus*) and Jerusalem artichoke (*Helianthus tuberosus* L.) as sources of inulin". Industria Saccarifera Italiana 86 (2) 47-53.

Margaritis, A. and P. Bajpai. (1982). Ethanol production from Jerusalem artichoke tubers (*Helianthus tuberosus*) using *Kluyveromyces marxianus* and *Saccharomyces rosei*. Bioeng., 941-953.

Mayer, A.M. and E. Harel (1981). Polyphenol oxidase in fruits. Changes during ripening. In: Recent advances in the biochemistry of fruits and vegetables. Friend, J. and Rhodes, M.J.C. (eds), Academic press, London, 159-180.

Niness, K.R. (1999). Inulin and oligofructose: what are they". J. Nutr., Suppl. 7, 129, 1402S-1406S.

Pekic, B.; B. salvica, Z. Lepojevic, and S.M. Petrovic (1985). Effect of pH on acid hydrolysis of Jerusalem artichoke inulin food chemistry 17: 169-173.

Phelps, C.F. (1965). The physical properties of inulin solutions Biochem. J., 95 (1): 41-47.

Silva, F.R. (1996). Use of inulin as a natural texture modifier. Cereal Food World. 41 (10): 792-494.

Shalaby, M.A.M.S. (2000). Extraction of inulin from some plant sources and its utilization in preparing some diabetic foods. Ph.D. Thesis Food Technol. Dept., Fac. Agri. Kafr El-Sheikh Tanta University.

Siriphanic, J. and A.A. Kader (1985). Effects of CO_2 on total phenolics, phenylalanine ammonia lyase and polyphenol oxidase in lettuce tissues. J. Amer. Soc. Hort. Sci., 110: 249-253.

Strepkov, E. (1936). Determination of inulin. Biochem. J., 288: 301.

Van den, B. (1985). Inulin winning uit Landbouwgewassen'Raport Vakgroep Proceskkunde, Landbouwhogeschool, Wageningen, 6-8.

Vandorpe, J. (1991). Inulin: functional and physiological properties. Food ingredients Europe: Conference Proceedings, Netherlands. 1991 b: 154-156.

Vukov, K., M. Erdelyi, and E. Pichler-Magyar (1991). Preparation of pure inulin and various containing products from Jerusalem artichoke for Human consumption and for Diagnostic use". In: A. Fuchs (Ed). Inulin and Inulin-containing crops (1993) Elsevier Science publishers B.V. pp: 342.

Zeitoun, M.A.M. and Zeitoun, M.A.A. (1999). The influence of some treatments on keeping quality of artichoke." J. Agric. Res. Tanta Univ., 52 (3): 422-438.

Yamazaki, H. (1994). "Purification of Jerusalem artichoke fructans and their utilization by Bifidobacteria". J. Sci. Food Agri. 64: 461-465.

الملخص العربى

تأثير بعض المعاملات الكيميائية والتكنولوجية على نبات الطرطوفة لإنتاج الإنيولين

*محمد عبد الحميد زيتون ، *هاتم مصطفى عثمان ، **بثينة محمد عبد اللطيف و **آسمة عيسى الجندى

* قسم علوم الأغذية ، كلية الزراعة (سابا باشا) – جامعة الأسكندرية ، ص.ب. ٢١٥٣١ – بولكلى ، الأسكندرية، مصر. معهد بحوث تكنولوجيا الأغذية ، الجيزة ، مصر

أصبح الأنيولين فى الأونة الأخيرة ذو أهمية أكثر من ذى قبل نظراً لإستخداماته الصناعية. إستخدمت درنات نبات الطرطوفة كمصدر أساسى للأنيولين فى هذه الدراسة. أجريت عليها معاملات أولية بالغمر فى الماء الساخن لتثبيط الإنزيمات ، وتم إستخلاص الأنيولين بإستخدام طريقة العصر وطريقة الإنتشار. وقد تم بعد ذلك ترويق ، تركيز وتجفيف الأنيولين الناتج. تم تقدير الخصائص الكيميائية والتكنولوجية للأنيولين. أوضحت النتائج أن استخدام محلول يحتوى على ٠,٥% حامض ستريك على درجة حرارة ٩٥°م لمدة ٤ دقائق أعطى تثبيط إنزيمى تام. وأوضحت نتائج طرق الاستخلاص أن استخدام ١ : ٥ (عينة من درنات الطرطوفة : ماء) لمدة ٤٥ دقيقة على درجة ٩٥°م أعطي أعلى محصول من الأنيولين المستخلص . وتم الحصول على أفضل ترويق لعصير الإنيولين المستخلص بطريقة الإنتشار بإستخدام ٠,٣ % هيدروكسيد كالسيوم على درجة ٩٠°م ورقم حموضة ١٠,٥ ، بينما فى طريقة العصر كانت بإستخدام ٠,٤% هيدروكسيد كالسيوم ، ٨٠°م ، ٥ دقائق ورقم حموضة ١٠,٤. كما إتضح أن الأنيولين الذى تم الحصول عليه بطريقة العصر يحتوى على ١,٣ % ألياف ، ٠,٦ % بروتين ، ٠,٦٧ % رماد و ٩٦,٤ % انيولين ، بينما عندما إستخدمت طريقة الإنتشار فقد إحتوى الأنيولين الناتج على ٠,٦٧ % ، ٠,٥٠ % ، ٠,٥١ % و ٩٧,٤٥ % على التوالى. أوضحت نتائج دراسة الخصائص الطبيعية للأنيولين المستخلص أن له درجة إنصهار ١٧٢°م وأن ذائبيته تزداد بزيادة درجة الحرارة ووصلت إلى ٢٤,٩% على ٩٥°م.