J. Agric. Sci. Mansoura Univ., 30 (5): 2663 - 2683, 2005

COMPARATIVE STUDY ON DIFFERENT PLANTING MATERIALS OF JERUSALEM ARTICHOKE AND TECHNOLOGICAL AND BIOLOGICAL STUDIES OF THEIR INULIN

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ABSTRACT

Fuseau and Local Jerusalem artichoke cultivars were cultivated at the research station HRI using two planting materials (seedlings and tubers) and study their effect on the vegetative growth and tuber yield characteristics. The second part of this study depend on the tuber of Jerusalem artichoke produced from the control of the two cultivated cultivars (after 150 days of planting) as a source of inulin to study inulin effect on bread quality and its reflect on the bone health of the rats which gave good indicator for man health.

Jerusalem artichoke is an important source of inulin which useful for human bone health. This study tended to produce Jerusalem artichoke tubers easily and with high quality rich in their inulin content. Fuseau cultivar or/and its tubers or together gave the highest plant and tubers characteristics. Number of tuber/plant, total yield and dry matter increased with increasing the plant age till 180 days of planting date, especially with Fuseau cultivar. Local cultivar tuber powder was superior in protein, fructose and glucose contents, while Fuseau cultivar tuber powder contained the highest content of ash, crude fiber, inulin, fructose, calcium and phosphorus. Adding Jerusalem artichoke powder of the two cultivars at 5, 10 and 15% improved pan bread characteristics, Fuseau cultivar was the superior.

For the biological experiment, rats fed different diets contained Jerusalem artichoke powder (as inulin source) with or without calcium. Basal diet gave rats with the highest body and daily body weights followed by the rats fed on Jerusalem artichoke powders of the two cultivars. The thickness and length of femur and tibia and the thickness of joint are in the high levels in rats fed on diets contained Jerusalem artichoke powders plus calcium followed by those fed on diets contained Jerusalem artichoke only.

Rats fed on diets supplemented with Fuseau Jerusalem artichoke powder plus calcium, their serum and bone contained the highest levels of calcium and phosphorus contents. From the results, Jerusalem artichoke powder only (Fuseau and Local) or the Local + calcium have significant effect on these respects.

INTRODUCTION

Jerusalem artichoke tubers are one of the main rich sources of inulin, also is alternative sugar crops which accumulate linear fructose polymers (fructans) in its tubers. These tubers can be used in the food industry as dietary fibers and low calorie sweeteners or nonfood medical and industrial applications (Fuchs, 1993). Jerusalem artichoke is known as a crop with a high production potential (Kosaric *et al*, 1984).

Swanton and Cavers (1986) recommended that the number of emerged shoots from Jerusalem artichoke tubers was significantly higher than those arising from rhizomes. And they found also, that the percentage of tubers that regenerated was higher than that of rhizomes.

El-Sharkawy (1998) reported that the maximum plant growth parameters i.e. plant height, number of main stems, number of branches per stem, fresh weight of shoots and dry weight of leaves were recorded at 120 days after planting. McLaurin *et al* (1999) mentioned that the number of shoots peaked in week 10, the number of branches, stolon and tubers reached a maximum 24 weeks after planting. Number of leaves peaked between weeks 20 and 24 after planting. By the 16^{th} week after planting. 85% of the total dry matter was in the aboveground plant parts, then declined with increasing the plant age. On the other hand dry matter in the tubers peaked in week 22.

Hang and Gilliland (1982) mentioned that the top fresh weight of Jerusalem artichoke increased rapidly after emergence, reaching a maximum around 120 days, when tuber initiation was observed and found that tuber yield were similar plots harvested on 3December (1980) and 26 February (1981) [44.8-56.6 t/ha] and tubers could be harvested in any time after maturation. Perko (1990) reported that tuber yields of Jerusalem artichoke fluctuated between 3 and 4 Kg/m^2. Soja *et al* (1990) found that carbohydrate concentration (78-81% of D.M.) and molecular fructan distribution were influenced by mineral concentrations in the tubers. Genotypic differences were significant for yield, for concentrations of minerals and for fructan concentration in the tubers. Harvest time had the greatest influence on carbohydrate composition. Abd El-Lateef (2000) showed that inulin content of Jerusalem artichoke was 74.99%, also apparent absorption of Fe, Ca, Mg and P were increased and pH was decreased.

Inulin is a polysaccharide composed of a fructose disaccharide which additional fructo units attached by a b-2 linkage to give a general formula of GFn, where G= gluco and F= fructose. The human digestive system lacks the enzyme to break the β-2 linkage, thus the inulin has been shown to provide an energy of only 1.2 to 1.5 Kcal/g (Bishay, 1998). Silva (1996) found that inulin is neutral in odor and taste. Roberfroid (1993) stated that inulin can be used in baked goods and other cereal products. Inulin is not broken down by the human digestive system. Also, there is a low indirect caloric contribution due to this colonic fermentation. Serum calcium levels ranged in normal between 6-12 mg/100ml. This is probably because a very efficient homeostatic mechanism keeps the serum Ca levels within the normal range (Miller, 1989). Emerging evidence has shown that certain non-digestible oligosaccharides (NDOs) can improve Ca absorption (Coudray *et al*, 1997). Ohta *et al* (1997) found that inulin could improve the absorption of minerals. Scholz-Ahrens and Schrezenmier (2002) found that non-digestible oligosaccharides (NDO), such as inulin, stimulate mineral absorption, mainly calcium and magnesium. Long-term beneficial effects on bone health have been indicated by accumulation of bone mineral content in growing rats or prevention of bone loss in ovariectomized rats. Also, they showed that the effect of NDO on mineral metabolism may be based on the enhancement of passive and active mineral transport across the intestinal epithelium, mediated by an increase in certain metabolites of the intestinal flora and a reduction of pH. In rats oligofructose effectively prevented loss of bone mineral content. The addition of 5% oligofructose prevented bone loss significantly in the femur in the presence of high dietary calcium (1%) but not at 0.5%. At 0.5% Ca 10% oligofructose was needed to significantly increase bone mineralization, and this was only observed in the femur.

At fermentation of inulin and oligofructose by the microflora the reduction of pH occurs as the result of stimulated production of lactic acid and short-chain fatty acids. At lower pH more mineral is soluble in the gut lumen and thus is more readily absorbed from the gut mucosal cell (Ohta *et al* 1995a and Cummings *et al*, 2004).

Jerusalem artichoke is propagated by tubers but these tubers are difficult to store because of the thin skin which permits shrinkage and injury that leads to decay. So, the present investigation was designed to break the dormancy of these tubers to produce seedlings used as a planting material in comparison with using the tubers, to evaluate the characteristics of vegetative growth of two Jerusalem artichoke cultivars, produce the highest yield of tubers and superior constituents with the highest quality also the useful effect of inulin on human health, increase calcium absorption, increase calcium content of bone and helps reduce risk of osteoporosis. At last, use of inulin as supplementation material in industry of excellent bakery product.

MATERIALS AND METHODS

A-. First part:

Effect of cultivar and planting material on vegetative growth and tuber yield parameters:

Field experiment was carried out during summer seasons of 2003 and 2004 at Barage Horticultural Research Station, Kalubia governorate. Two planting materials of Jerusalem artichoke cultivars Local and Fuseau were prepared as follows:

1. Tuber seeds: unharvested tubers were stored in the soil until planting date.
2. Seedling: a. Under nursery condition seedlings were prepared by harvesting the tuber of the two cultivars at their maturity stage and stored in carton boxes (35 x 65 x 12 cm) filled with peat moss until complete sprouting. b. These tubers transferred in perforated black polyethylene bags contained a medium of peat moss: sand: clay (1:2:1).

The two planting materials of the Local and Fuseau cultivars were transplanted in the open field on the same date. Planting dates were the 13th and 20th of April for the two seasons, respectively. . The seeds of the two cultivars were planted on rows of one meter apart and on hills of 50 cm within the row.

The experimental design was a split plots with three replicates and the plot area was 25 m^2 (5 rows of 5m length and one meter width). Apart from plants of the two outside rows of each sub-plot were used for determination of different growth characters. Tuber yield was determined using the middle three rows.

Recorded data:

The following growth measurements were recorded during the two growing seasons for each treatment using three plants taken randomly at 120,150 and 180 days from planting: Stem length (m), stem number/plant, number of branches/plant, leaf dry matter (%), leaf area using the LI-3100 area meter (LI-COR Inc. Lincoln, Nebraska, USA) chlorophyll: using cholori meter (SPAD-501), fresh weight of tubers (kg/plant) was recorded at 120, 150 and 180 days after planting per treatment were used to determine the average total weight of tubers/plant and the total yield (kg/plot) and number of tubers/plant. Dry matter percentage was determined at each harvest time after 120, 150 and 180 days of planting. Tubers samples from each experimental sub-plot were weighed and oven dried at 105°c to constant weight.

B- Second part:

Technological and biological studies:

Preparation of samples:

Jerusalem artichoke tubers were cleaned with tap water to remove dusts and other undesirable materials, then cut into small pieces and 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 powder was kept in polyethylene bags and stored at 4±1°c in a refrigerator until using.

Commercial wheat flour, 72% extraction rate, yeast, salt, shortening and sugar was obtained from local market.

Chemical analysis:

Moisture, crude fiber, ash, crude protein and carbohydrates were determined as described in A.O.A.C. (2000). Phosphorus was determined according to the method described by Herbet *et al* (1971). Calcium was determined using Perkin-Elmer 23865 atomic absorption spectro-photometer Germany. Inulin; glucose and fructose contents were determined using HPLC according to the method described by Alistair and Van Niekerk (1983).

Preparation of pan bread:

A straight-dough formula was as follows:-

The formula consists of (based on flour weight) 100 gm wheat flour, J.A powder of the two cultivars at 5,10 and 15%, 3 gm compressed yeast, 1 gm salt, 5 gm sugar, 3 gm shortening and adequate amount of water. All the above mentioned ingredients were separately added and mixed. After 25 min., 140 gm from the fermented dough was placed in baking pans (5x9x8 cm), then proofed at 30°c till 55 min. and baked at 240°c for 15 min. (A.A.C.C., 1990).

Sensory evaluation:

Bread quality parameters were evaluated. Fifteen staff members of Food Technology Institute carried out the test after one hour of baking (A.A.C.C., 1990).

Biological experiment:

Using 5% of Jerusalem artichoke had the highest quality scores of bread followed by 10% with non-significant differences. Thus, we used 10% of Jerusalem artichoke in this study in feeding the rats due to its healthy effects.

Thirty weanling male albino rats (88-96g) were obtained from Food Technology Institute. These animals were housed individually in suspended mesh-bottom stainless steel cages at room temperature (25±2°c) and provided with redistilled deionized water and basal diet for seven days as adaptation period. The basal diet, minerals and vitamins mixtures were prepared as recommended by A.O.A.C. (2000). The ingredients of each diet were shown in Table (1). The adapted rats were weighted and divided by selective randomization into six groups of 5 rats each, everyone was assigned to one of the six diet groups as presented in Table (1). Fresh diets were fed to animals daily. After the end of experimental period (7 weeks), the blood was withdrawn by cardiac puncture into plastic tubes and centrifuged for 10 min. at 3000 r.p.m. to separate serum. Serum calcium and phosphorus were determined according to the method of Merja *et al* (2001).

The right femur, right tibia and joint were cleaned and freed of surrounding soft tissue. The length and thickness of each were measured with vernier caliper. The dried bones were ashed at 700°c for 12h, cooled to asses the percentage mineral content. Bone calcium was measured by the method described by Alistair and Van Niekerk (1983).

Statistical analysis:

Statistical analysis of data was done according to Snedecor and Cochran (1980).

Table (1); Diet composition as g/100g.

Diet / Component	Basal	Group1	Group2	Group3	Group 4	Group5
Casein	15.00	15.00	13.98	13.98	13.91	13.91
Corn oil	10.00	10.00	10.00	10.00	10.00	10.00
Salt mixture	4.00	4.00	4.00	4.00	4.00	4.00
Cellulose	5.00	5.00	4.34	4.34	4.37	4.37
Vitamin mixture	1.00	1.00	1.00	1.00	1.00	1.00
Starch	65.00	64.40	56.68	56.08	56.72	56.12
Calcium	-	0.60	-	0.60	-	0.60
Jerusalem artichoke powder	-	-	10.00	10.00	10.00	10.00

RESULTS AND DISCUSSION

Effect of cultivar and planting material on vegetative growth parameter:

The effect of cultivar, planting material (tuber and seedlings) and the interaction between them on vegetative growth of Jerusalem artichoke plants and their characteristics are presented in Table (2). It is evident that Fuseau cultivars gave significantly taller plants, the highest number of branches/plant and the largest leaf area/plant than Local cultivar (Soja *et al*, 1990). There was a difference between the two cultivars in the number of main stem/plant but in non significant order. These results are true in the two growing seasons. Data in the same table indicate that there were significant differences between the effect of the two planting materials (tuber or seedlings) on each of plant height, number of main stem/plant and leaf area/plant, but in non significant order for number of branches/plant. Using the tubers as planting materials enhancing plant height, number of main stem/plant, number of branches/plant and leaf area/plant more than seedlings ones (Swanton and Cavers, 1986 and Soja *et al*, 1990) , then tubers planting materials are superior in both seasons. Similar conclusion was obtained by Swanton and Cavers, (1986).

For chlorophyll and /or dry matter of vegetative growth the same trend was found, whereas Fueau cultivar and/or using tubers as planting material were significantly in higher rates as compared with other cultivar and planting material. These are true in the two growing seasons. Soja *et al* (1990) came to the same conclusion.

Concerning the interaction (cultivar x planting material), it is clear from data in Table (2) that the highest values of all plant vegetative growth parameters were recorded in plants growing from tuber of Fuseau cultivar followed by plants from the seedlings of the same cultivar. However, the lowest characteristic values were noticed for plants obtained of seedling planting material of the Local cultivar.

Effect of cultivar and planting material on tuber yield parameters:

Data on number of tubers/plant, total yield/plant; total yield/plot and DM of tubers are presented in Table (3). It should be noted that there were significant differences among cultivars in these respect except the second season of number of tuber/plant. The maximum values were obtained by Fuseau cultivar in the two seasons The data were in the line with these of Soja *et al* (1990).

Using the tubers of Jerusalem artichoke as planting materials exhibiting the highest value of number of tuber/plant, total yield/plant, and total yield/plot and tuber dry matter which in agreement with the data of (Perko, 1990). No significant differences between the two planting materials on these characteristics.

Seedlings of the Local cultivar gave the lowest level of the previous yield parameters as compared with the other treatments. Tuber seeds of Fuseau cultivar significantly gave the highest values of these respects.

Table (2): Effect of cultivar and plant material on vegetative growth characters of Jerusalem artichoke at 180 days after planting during the two seasons 2003 and 2004.

Character	Plant height		No. main of stem/plant		No. branches/plant		T. leaf area/plant		Total chlorophyll		Dry matter (%)	
Season	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Cultivars												
Fuseau	3.06^{A}	3.13^{A}	7.00^{A}	7.50^{A}	42.17^{A}	39.00^{A}	93.40^{A}	85.97^{A}	46.37^{A}	47.68^{A}	27.92^{A}	26.09^{A}
Local	2.45^{B}	2.85^{B}	5.67^{A}	5.17	27.67^{B}	25.00^{B}	71.38^{B}	62.04^{B}	39.20^{B}	41.92^{B}	25.25^{B}	25.02^{A}
L.S.D. at 5%	0.37	0.16	N.S.	N.S.	8.95	8.69	10.92	9.95	3.53	5.17	0.67	N.S.
Plant material												
Tubers	3.058^{A}	3.10^{A}	7.83^{A}	7.50^{A}	37.33^{A}	32.50^{A}	89.98^{A}	84.37^{A}	44.48^{A}	48.77^{A}	27.54^{A}	26.45^{A}
Seedling	2.45^{B}	2.88^{B}	4.83^{B}	5.17^{B}	32.50^{A}	31.50^{A}	74.79^{B}	63.64^{B}	40.83^{B}	40.83^{B}	25.63^{B}	24.67^{B}
L.S.D. at 5%	0.10	0.08	1.73	1.22	N.S.	N.S.	4.38	1.83	2.64	2.27	1.49	1.52
Interaction												
Fuseau												
Tuber	3.12^{A}	3.26^{A}	8.33^{A}	9.33^{A}	48.00^{A}	40.00^{A}	101.39^{A}	96.10^{A}	47.90^{A}	51.13^{A}	29.13^{A}	26.52^{A}
Seedling	3.00^{A}	3.00^{B}	7.33^{AB}	5.67^{B}	36.33^{B}	38.00^{A}	85.40^{B}	75.84^{B}	44.83^{AB}	46.40^{AB}	26.71^{B}	26.37^{A}
Local Tuber	3.00^{A}	2.95^{B}	5.67^{BC}	5.66^{B}	28.67^{B}	25.00^{B}	78.57^{B}	72.64^{B}	41.07^{B}	44.23^{B}	25.94	25.82^{AB}
Seedling	1.92^{B}	2.75^{C}	4.00^{C}	4.67^{B}	26.67^{B}	25.00^{B}	64.18^{C}	51.44^{C}	37.33^{C}	37.43^{C}	24.55	23.52^{B}
L.S.D. at 5%	0.15	0.11	2.45	1.73	8.73	8.48	6.19	2.59	3.73	3.13	2.12	2.22

Table (3): Effect of cultivar and plant material on number of tubers/plant, total yield/plant, total yield/plot and dry matter % of Jerusalem artichoke at 180 days after planting during the two seasons 2003 and 2004.

Character / Comparisons	No. of tuber/plant		Total yield/plant (Kg)		Total yield/plot (Kg)		Dry matter (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Cultivar								
Fuseau	72.47^{A}	71.47^{A}	5.28^{A}	5.40^{A}	162.27^{A}	163.25^{A}	28.87^{A}	27.85^{A}
Local	59.73^{B}	68.47^{A}	3.84^{B}	3.43^{B}	117.98^{B}	107.25^{B}	24.88^{A}	24.52^{B}
L.S.D. at 5%	11.86	N.S.	0.74	0.91	27.08	34.07	N.S.	1.97
Planting material								
Tubers	68.47^{A}	75.30^{A}	4.63^{A}	4.45^{A}	141.90^{A}	136.26^{A}	27.35^{A}	26.63^{A}
Seedlings	63.73^{A}	64.64^{A}	4.53^{A}	4.37^{A}	138.35^{A}	134.23^{A}	26.40^{A}	25.73^{A}
L.S.D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction								
Fuseau								
Tubers	74.63^{A}	76.67^{A}	5.73^{A}	5.97^{A}	170.40^{A}	187.34^{A}	29.27^{A}	28.13^{A}
Seedlings	70.30^{A}	73.93^{A}	4.82^{B}	4.48^{AB}	154.13^{AB}	139.15^{B}	28.47^{AB}	27.57^{A}
Local								
Tubers	62.30^{AB}	66.27^{A}	4.45^{B}	4.08^{B}	129.67^{B}	129.32^{B}	25.43^{AB}	25.13^{B}
Seedlings	57.17^{B}	63.01^{A}	3.33^{C}	2.78^{C}	106.30^{C}	85.18^{C}	24.33^{B}	23.90^{B}
L.S.D. at 5%	8.59	N.S.	0.42	1.18	20.80	40.52	1.69	1.92

Seedlings of Fuseau cultivar and tuber seeds of the Local one lay in between. These results were true in the two growing seasons.

From the same table using tubers as planting materials produced plants had tubers with the highest DM contents, but without significant differences. Swanton and cavers (1986) obtained similar results.

The interaction between cultivar x planting material show that there were significant differences between the used treatments, using tuber seeds of Fuseau cultivar was superior to the other while seedlings of the Local cultivar had the lowest values.

Effect of harvesting date on tuber characteristics:

It is evident from the data illustrated in Fig (1and 2) that the number of tubers/plant increased gradually as the growing season extend and this increment reached its maximum count at 180 days after planting in the two seasons. The increment in the tubers number/plant was superior when Fuseau cultivar and tuber seeds were in comparison with the Local cultivar and also when seedling was used as planting materials, these were found during the three harvesting dates (Soja *et al*, 1990 and El-Sharkawy, 1998).

Data illustrated in Fig (3) show that the highest fresh yield/plant was obtained after180 days from the planting date, while the lowest ones was produced when the tubers were harvested after 120 days only. Significantly Fuseau cultivar gave the highest fresh tuber yield/plant in both seasons at the three harvesting dates compared with Local ones (except harvesting after120 days in the first season). Hang and Gilliland (1982) and Soja *et al* (1990) came to a similar conclusion.

Concerning the effect of planting materials on the average fresh weight of tubers/plant Fig (4) indicate that using Jerusalem artichoke tubers as planting materials gave plants had minor nonsignificant differences than using seedlings in propagation at all harvesting dates in the two growing seasons.

From Fig (3 and 4) there were gradual increases in the tubers fresh weight/plant with delaying the harvesting date from 120 days to 150 days and to180 days, respectively.

The effect of harvesting date, cultivar and planting materials on total yield of fresh tubers per plot during the two growing seasons were shown in Fig (5 and 6). Data illustrated in Fig (5) show that Jerusalem artichoke total yield (kg/plot) increased with increasing the plant age till 180 days in both seasons (Soja *et al*, 1990 and McLaurin *et al*, 1999). The increment of photosynthesis and the transplantation of the reserves from stems and leaves to store in the tubers still continuously till the last harvesting date which result in more increment in the tubers yield gradually till the dryness of the plant tops at low temperature in December. In the same manner, Hang and Gilliland (1982) found that tuber yields were similar in plots harvested on 3 December (1980) and at 26 February (1981).

Data illustrated in Fig (5 and 6) clearly show that Fuseau cultivar and using tuber of Jerusalem artichoke as planting material were resulting in more increment during all harvesting dates than the other used cultivar and planting material (Soja *et al*, 1990).

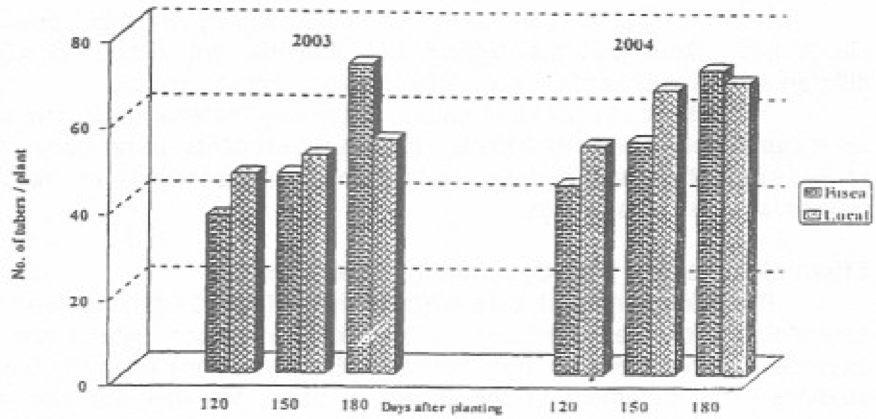

Fig. (1): Effect of cultivars on No. of tubers / plant harvested at 120, 150 and 180 days after planting during 2003 and 2004 seasons.

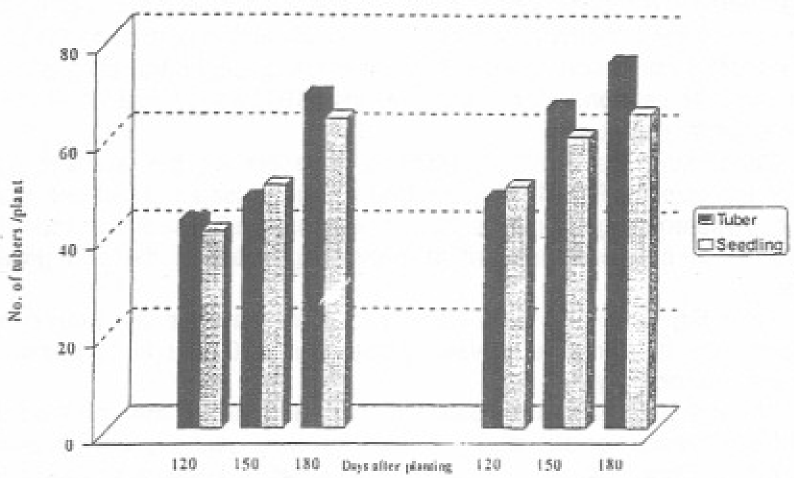

Fig. (2):Effect of planting materials on No. of tubers /plant harvested at 120, 150 and 180 days after planting during 2003 and 2004 seasons.

Differences in dry matter content of produced tubers are illustrated in Fig (7 and 8). Higher percentage of DM was significantly obtained from Fuseau cultivar comparing with the Local ones. No significant differences in the first season.

Fig (7 and 8) illustrated the data of Jerusalem artichoke tuber dry matter content which show gradual increase with increasing the age of the plants and reached its maximum level after 180 days of planting. The translocation of carbohydrates from the vegetative growth to the tubers resulting in more increment in dry matter content of the tubers specially in the period from 120 days to 180 days of the two growing seasons. These results coincided with the work of Hang and Gilliland (1982); Soja *et al* (1990) and McLaurin *et al* (1999).

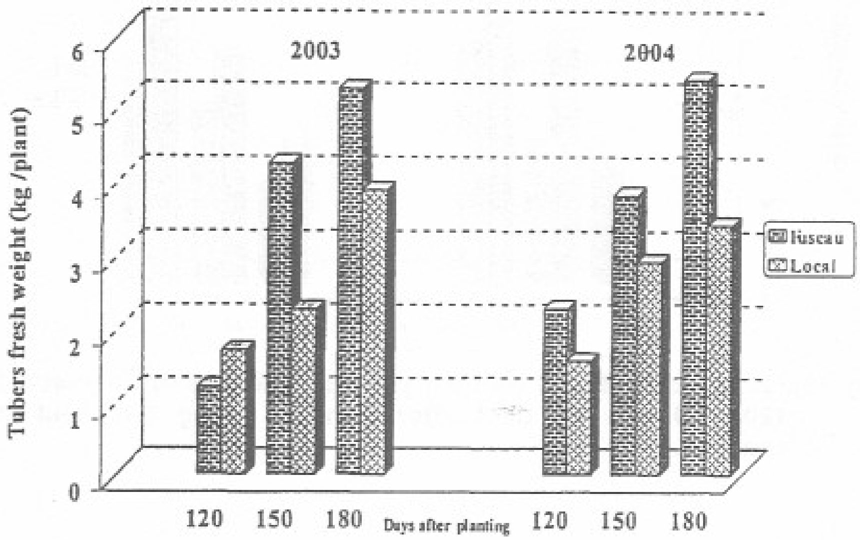

Fig. (3): Effect of cultivars on fresh weight of tubers per plant harvested at 120, 150 and 180 days after planting during 2003 and 2004 seasons.

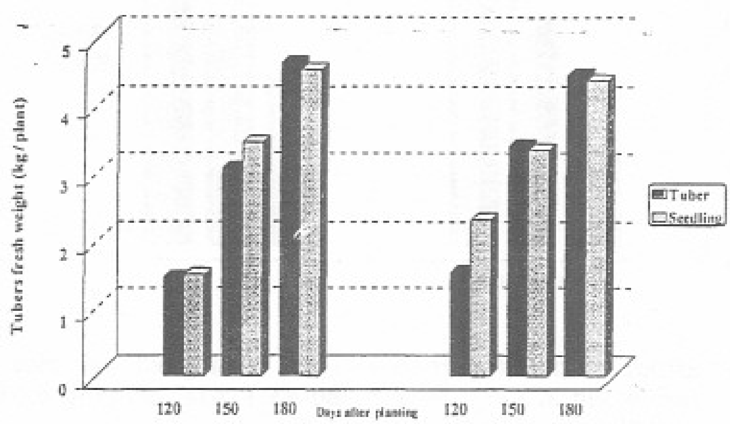

Fig. (4):Effect of planting materials on fresh weight of tubers per plant harvested at 120, 150 and 180 days after planting during 2003 and 2004 seasons.

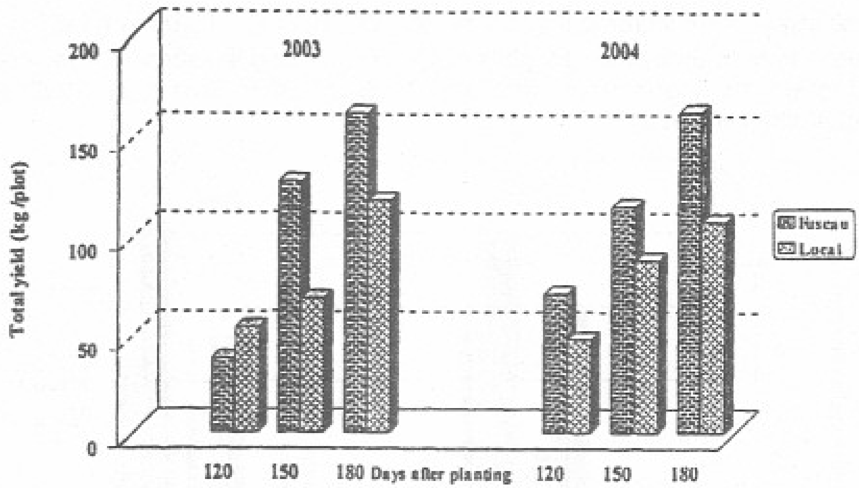

Fig. (5): Effect of cultivars on total yield per plot (25 m^2) harvested at 120, 150 and 180 days after planting during 2003 and 2004 seasons.

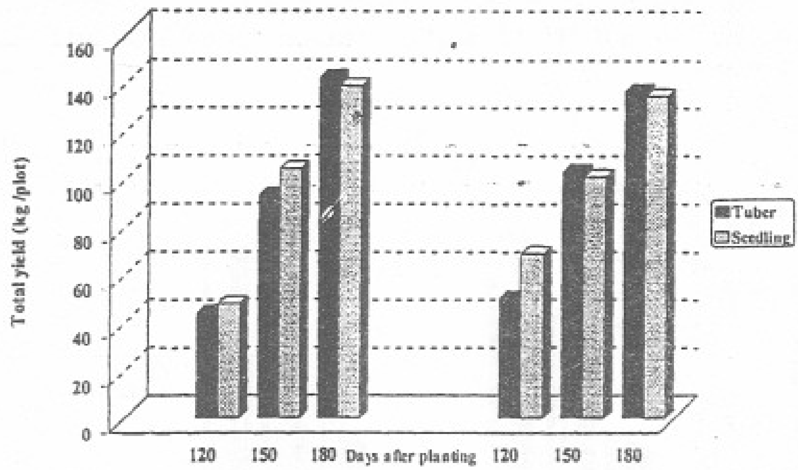

Fig. (6): Effect of planting materials on total yield per plot (25 m^2) harvested at 120, 150 and 180 days after planting during 2003 and 2004 seasons.

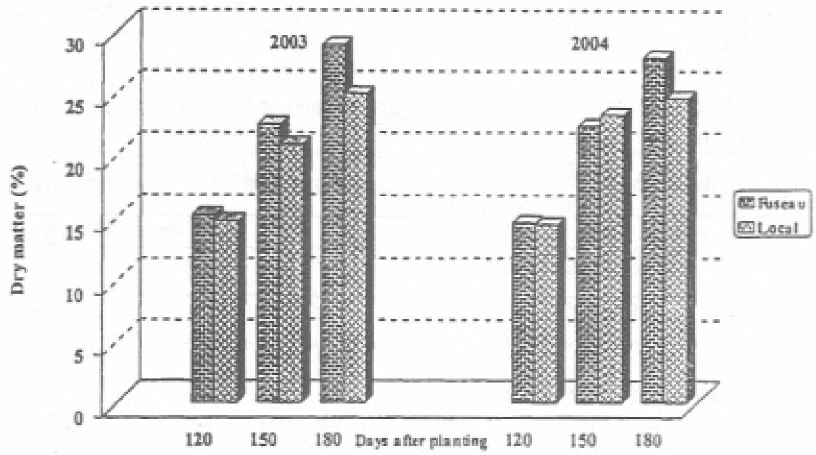

Fig. (7):Effect of cultivars on dry matter percentage harvested at 120, 150 and 180 days after planting during 2003 and 2004 seasons.

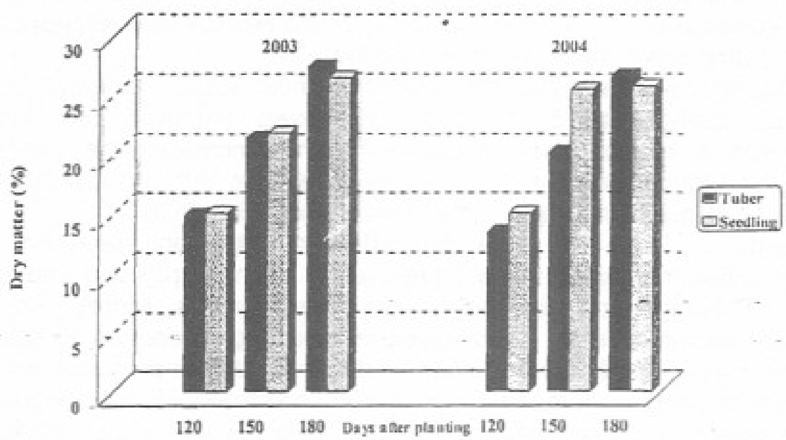

Fig. (8):Effect of planting materials on dry matter percentage harvested at 120, 150 and 180 days after planting during 2003 and 2004 seasons.

Using Fuseau cultivar and the tuber as seeds are consider the best as compared with Local cultivar and the seedlings as plant material as shown in Fig (7 and 8) after 120, 150 and 180 days of planting date.

Chemical analysis of Jerusalem artichoke:

Chemical composition of Jerusalem artichoke tuber powder as percentage on dry weight are shown in Table (4). Data shown that the Local cultivar was superior in both protein, fructose and glucose contents, while Fuseau cultivar contained the highest content of the rest components such as ash, crude fiber, inulin, calcium and phosphorous. These results are in harmony with those obtained by Kosaric *et al* (1984), Bishay (1998) and Abd El-Lateef (2000).

Table (4): Chemical composition of Jerusalem artichoke tuber powder (as % on dry basis).

Cultivar	Protein	Ash	Crude fiber	Inulin	Fructose	Glucose	Calcium	Phosphorus
	%						mg/100mg	
Fuseau	8.26	6.82	5.92	73.50	2.73	1.12	72.11	391.32
Local	9.91	6.61	5.23	68.24	3.51	1.61	68.21	370.55

Sensory evaluation of pan bread:

Sensory characteristics of pan bread supplemented with Fuseau and Local cultivars of Jerusalem artichoke powder at 5, 10 and 15% levels are presented in Table (5). The results of sensory characteristics (appearance, crust color, crumb color, brightness, crumb texture, softness, odor, eating quality and overall acceptability score), indicated that there were differences between loaves characteristics scores made of the two cultivars, except crust color and eating quality which significantly differ.

Adding Jerusalem artichoke powder (as inulin source) to bread, Local or Fuseau cultivars at 5, 10 and 15% levels improved pan bread characteristics to be more useful to human health by increasing the hardness of bone and reduced blood sugars. These acceptable with produced bread due to the presence of inulin (Silva, 1996 and Roberfroid, 1993).

Data in Table (6) show the effect of interaction between the supplementation material of the two (Jerusalem artichoke powder) and their addition percentages on pan bread with characteristics scores. Adding Fuseau cultivar with different levels gave pan bread high scores as compared with every level of Local cultivar. Bread made of wheat flour produced loaves with lowest scores as compared with loaves contained 5% of Jerusalem artichoke powder of the two cultivars. The highest bread scores were obtained from loaves their formulas contained 5% followed by 10% of Jerusalem artichoke powder. Data indicate the superiority of the characteristic scores of the pan bread were found when wheat flour supplemented with 5% and 10% of the two Jerusalem artichoke cultivars, while adding 15% of Fuseau and local Jerusalem artichoke powder had the lowest scores. This means that inulin and oligofructose that composed Jerusalem artichoke powder were important materials in improving pan bread characteristics. These results are in harmony with those obtained by O'Brien *et al* (2003) who found that wheat bread containing inulin at 2-5% resulted in the highest quality bread. Fuchs (1993) obtained similar results.

These results are in agreement with those obtained by Frank (2002) who found that inulin and oligofructose may significantly improve organoleptic characteristics. Their incorporation allows upgrading of both tastes and mouthfeel in a wide range of food applications. In general, in each parameter there were significant differences between the used supplementing materials.

Table (5): Effect of cultivar of Jerusalem artichoke on the characteristics of pan bread supplemented with their powders.

Character / Cultivar	Appear-ance (10)	Crust color (10)	Crust character (10)	Crumb color (10)	Brightness (10)	Crumb texture (10)	Softness (10)	Odor (15)	Eating quality (15)	Total scores (100)
Fuseau	9.34	9.22	9.50	9.31	9.13	9.38	9.31	14.13	14.09	93.41
Local	8.28	8.06	8.66	8.16	7.78	8.31	8.28	13.28	13.44	84.25
L.S.D. at 5%	0.88	0.44	0.92	0.47	0.91	0.47	0.38	0.70	0.97	3.61

Table (6); Sensory characteristics of pan bread supplemented with Jerusalem artichoke powder at different levels.

Cultivar	Character / Treatment (level)	Appear-ance (10)	Crust color (10)	Crust character (10)	Crumb color (10)	Brightness (10)	Crumb texture (10)	softness (10)	odor (15)	Eating quality (15)	Total scores (100)
Fuseau %	Zero	8.25	8.00	9.00	9.25	9.25	8.75	8.63	13.13	14.00	88.25
	5	10.00	9.88	10.00	10.00	9.63	10.00	9.88	14.63	14.38	98.38
	10	9.50	9.75	9.63	9.25	8.88	9.50	9.63	14.50	14.63	95.25
	15	8.63	8.25	8.63	8.00	8.00	8.25	8.25	13.75	13.38	85.13
Local %	Zero	8.25	8.00	9.00	9.25	9.25	8.75	8.63	13.13	14.00	88.25
	5	9.00	8.88	9.25	8.88	8.38	9.00	8.88	13.88	14.00	90.13
	10	8.63	8.50	8.50	7.88	7.38	8.38	8.38	13.88	13.50	85.00
	15	7.25	6.88	7.88	6.63	6.13	7.13	7.25	12.25	12.25	73.63
L.S.D. 5%		0.22	0.34	0.42	0.35	0.30	0.40	0.37	0.67	0.77	1.51

Biological application:

The effect of different used diets on rats initial and final body weight, body weight gain and daily body gain are presented in Table(7). It should be noted that there were no significance difference between initial weights. There were significant differences between the final body weight of the rats fed on the six used diets. All groups of diets significantly increased the final body weight of the tested rats, the highest increment was found in rats fed on basal diet followed with rats fed on 2 and 4 group of diets, while the rats fed on diets 3 and 5 followed by group1 (diet 1) obtained the lowest final body weight. Body weight gain and daily body weight gain followed the same trend.

Table (7): Body weight (initial and final), body weight gain and daily weight body gain of rats fed on the different tested diets. (Means ± SD)

Diet / Body weight	Control (Basal)	Group 1	Group 2	Group 3	Group 4	Group 5	L.S.D. at 5%
Initial body weight	89.8± 3.311	90.4± 9.851	89.4± 10.461	89.6± 10.707	91.4± 10.461	92.6± 10.707	N.S.
Final body weight	269.0± 30.053	195.0± 4.050	221.8± 32.307	210.0± 5.441	215.8± 20.760	207.2± 10.068	31.47
Body weight gain	179.2± 29.963	104.6± 12.800	132.8± 29.363	120.4± 7.736	124.4± 13.063	114.6± 9.478	30.12
Daily body weight gain	3.66± 0.611	2.13± 0.263	2.71± 0.597	2.47± 0.158	2.54± 0.267	2.34± 0.193	0.61

This may be due to that inulin like fiber and which also gave low calories and the absence of inulinase enzyme in the small intestine which enable to split the β(1-2). Similar conclusion was obtained by Roberfroid *et al* (2002) which found that the body weight gain of rats fed on diets containing 10% inulin was lower 5-7% than that of the control rats.

Data in Table (8) show the effect of feeding rats on Jerusalem artichoke powder only or plus Ca on bone length and thickness of the experimental animals as compared with rats fed on basal diet with or without Ca. The length of tibia and the thickness of tibia and joint were in the lowest levels in rats fed on basal (control) diets with or without Ca, while these parts were in the highest levels in rats fed on the two Jerusalem artichoke cultivars supplemented with Ca followed by feeding the rats on the two Jerusalem artichoke cultivars only. Fuseau cultivar was the superior ones. These differences in significant order (Coudray *et al*, 1997; Ohta *et al*, 1997 and Scholz-Ahrens and Schrezenmier, 2002). Using Fuseau and Local cultivars plus Ca as feeding diets increased the length and the thickness of femur of the experimental rats as compared with the other diets. The lowest levels were obtained in rats fed on Local Jerusalem artichoke cultivar followed by (control) basal.

Table (8): Physical dimensions of femur, tibia and joint of rats fed on the different tested diets. (Means ± SD)

Bone dimension \ Diet	Control (Basal)	Group 1	Group 2	Group 3	Group 4	Group 5	L.S.D. at 5%
Thickness of femur	0.324± 0.062	0.334± 0.034	0.282± 0.013	0.378± 0.012	0.344± 0.034	0.390± 0.011	0.042
Length of femur	2.886± 0.100	3.268± 0.048	3.244± 0.065	3.328± 0.054	3.268± 0.065	3.372± 0.033	0.078
Thickness of joint	6.118± 0.163	7.214± 0.323	7.098± 0.428	7.232± 0.074	7.194± 0.429	7.272± 0.079	0.284
Thickness of tibia	0.208± 0.008	0.246± 0.008	0.230± 0.019	0.268± 0.015	0.240± 0.014	0.272± 0.017	0.023
Length of tibia	3.422± 0.052	3.820± 0.046	3.800± 0.117	3.874± 0.047	3.816± 0.048	3.898± 0.046	0.086

Generally, it may be concluded that length and thickness of tibia, femur and joint of the experimental rats tended to increase with feeding Jerusalem artichoke powder (two cultivars) with or without Ca addition, then improved the rats health. All these results may be due to the presence of inulin and oligofructose in the form of useful material for human health. The stimulating effect of inulin diet leads acids and short-chain fatty acids to produce by luminal bacteria from inulin. Organic acids lowered the pH and raised the solubility of calcium, magnesium and phosphorus (Ohta *et al,* 1995a and Cummings *et al,* 2004).

The results of serum calcium and phosphorus contents of rats fed on the different studied diets are shown in Table (9). With respect to serum calcium, the data reveal that serum Ca levels on all used diets were in the normal range (10.23 to 11.62 mg/100ml). Miller (1989) mentioned that serum Ca levels ranged between 6-12mg/100ml, this is probably because a very efficient homeostatic mechanism keeps the serum Ca levels within the normal range. The highest Ca levels were in serum of rats fed on Jerusalem artichoke cultivar Fuseau only or with the addition of Ca (11.49 and 11.62mg/100ml, respectively), followed by the Local cultivar of Jerusalem artichoke without or with Ca addition as a diet. Fed on basal diet resulted in lowest level of serum Ca followed by rats fed on basal diet plus Ca. the presence of inulin and oligofructose of Jerusalem artichoke improve the components of rats' serum. There are significant differences between control (basal) diet and all used diets in this respect.

Regarding phosphorus level, the obtained data showed significant differences between rats fed on basal diet and all the used diets except when the rats fed on diet containing basal diet + Ca. Adding calcium to the diets of Local or Fuseau Jerusalem artichoke were the superior. Level of phosphorus increased from 4.13 and /or 3.70 mg/100dl to 4.17 and 4.21mg/dl of blood serum when rats fed on Local and Fuseau Jerusalem artichoke only and plus Ca, respectively. The increment of phosphorus was in high rate when feeding rats on Fuseau Jerusalem artichoke. The lowest level of phosphorus was in rats fed on basal diet followed by which fed on basal diet + calcium without significant differences. From the previous results, it could be suggested that the used Jerusalem artichoke powder only or with calcium appeared to have significant effect (improve) on the level of calcium and phosphorus in blood serum.

Table (9): Effect of different of diets of Jerusalem artichoke on calcium of (serum and bone), phosphorus and ash of used rats. (Means ± SD)

	Control (Basal)	Group 1	Group 2	Group 3	Group 4	Group 5	L.S.D. at 5%
Calcium in serum (mg/dl)	10.23± 0.02	10.83± 0.14	10.56± 0.25	10.89± 0.09	11.49± 0.33	11.62± 0.26	0.32
Phosphorus in serum (mg/dl)	3.57± 0.56	3.69± 0.34	4.13± 0.34	4.17± 0.18	3.70± 0.25	4.21± 0.19	0.47
Calcium in bone (%)	14.67± 0.43	19.49± 0.79	18.42± 0.73	20.96± 0.51	19.65± 0.48	21.35± 0.58	0.95
Ash of bone (%)	41.38± 2.72	46.72± 3.25	49.68± 2.95	51.30± 1.34	50.24± 2.23	52.40± 0.92	3.28

About 99% of total body calcium is present in bone and bone calcium content has variously been used as an index of the body's calcium status. In Table (9) calcium percentage of the bone of rats fed on basal diet was in the lower rats as compared with rats fed on diets had more calcium or that fed on Jerusalem artichoke (the two cultivars) with or without calcium this may be due to the presence of inulin and oligofructose which improve bone, serum and health of experimental animals as feeding on inulin significantly decreased Type I collagen cross-liked excretion. The reduction in cross-link excretion as well as increased retention of calcium in the bones lead to increased bone mineral content and bone density as measured using bone (Kruger *et al*, 2003). Fuseau cultivar only or plus calcium were the superior. The percentage of ash of bone follows the same trend, the bone of rats which fed on Fuseau cultivar with or without calcium were in the higher levels while that fed on basal diet was in the lower ones. The rats fed on Local cultivar only or with calcium were in between. These results are in agreement with those obtained by Ohta *et al* (1995a) and Cummings *et al* (2004)

Conclusion

The tuber as a planting material of the two cultivars gave the highest yield and best characters as compared with seedling ones, but in general these results did not reach the significant level. The tubers gave losses about 40% (decay, shrinkage and injury) during their storage until planting. Thus, the use of seedling of Jerusalem artichoke is the best because of their low production cost, easy propagation and early yielding.

The use of Jerusalem artichoke powder which contained more of inulin, minerals and fructose contents, has a useful effect on human health due to increase calcium absorption which reflected in healthy and increase calcium content of bone. Then the use of Jerusalem artichoke as supplemented material to bakery products is required for people in Egypt.

REFERENCES

A.A.C.C. (1990): American Association Of Cereal chemists. Approved methods 12th ed., Pup. Univ. of Farm. St, Minn, USA.

A.O.A.C. (2000): Association Of Official Agricultural Chemists. Official methods of analysis. 17th ed., A.O.A.C., Washington DC, USA.

Abd El-Lateef, Bothyna M. (2000): Production of bakery products using two sources of inulin. Annals of Agric. Sci., Moshtohor Vol. 38(1): 361-378.

Alistair, W. W. and P.J. Van Niekerk (1983): Determination of reducing sugars, sucrose and inulin in chicory roots by high performance liquid chromatography. J. Agric. Food Chem. 31;282-285.

Bishay, L.E. (1998): The rheology of inulin as it relates to food. IFT Annual Meeting Technical Program Abstracts.

Coudray, C.; J., Bellanger; C., Castiglia-Delavaud; V., Vermorel and Y. Rayssignuier (1997): Effect of soluble or partly soluble dietary fibers supplementation on absorption and balance of calcium, magnesium, iron and zinc in healthy young men. European Journal of Clinical Nutrition. 51, 375-380.

Cummings, J.H., L.M., Edmond and E.A. Magee (2004): Dietary carbohydrates and health: do we still need the fiber concept? Clinical Nutrition supplementations. 1:5-17.

El-Sharkawy, Z. A. (1998). Physiological studies on Jerusalem artichoke. Ph. D. Thesis, Faculty of Agric., Cairo Univ.

Frank, A. (2002): Technological functionality of inulin and oligofructose. British Journal of Nutrition 87, Suppl. 2, S287-S291.

Fuchs, A. (1993): Production and utilization of inulin: II. Utilization of inulin. P. 319-352. In S. Michio and N.J. Chatterton (ed) Science and technology of fructans. CRC Press, Boca Raton FL.

Hang, A.N. and G.C., Gilliland (1982): Growth and carbohydrate characteristics of Jerusalem artichoke in irrigated control Washington. Washington State University, Prosser, WA 99350, USA. No xt 0098, 10 pp, 2pl.

Herbet, Di; P.J. Phipps and R.E. strange (1971): Chemical analysis of microbial cells. In "Methods in microbial" Academic Press, London, New York.

Kosaric, N., G.P. Costentino and A. Wicczorek (1984): The Jerusalem artichoke as an agricultural crop. Biomass, 5:1-36.

Kruger, M.C.; K.E. Brown; G.Collett, L. Layton and L.M. schollum (2003):The effect of fructooligosaccharides with various degrees of polymerization on calcium bioavailability in the growing rat. Experimental Biology and Medicine 228:683-688.

McLaurin, W.J., Z.C. Somda and S.J., Kays (1999): Jerusalem artichoke growth, development, and field storage. I. numerical assessment of plant part development and dry matter acquisition and allocation. Journal of plant nutrition. 2:(8), 1303-1313.

Merja, U.M.; J.E. Christel and A. Suvi (2001): Does it make a difference how and when you take your calcium? The acute effect on calcium and bone metabolism. Am. J. Clin. Nutr., 74:335-342.

Miller, D.D. (1989): Calcium in the diet: Food sources, recommended intakes, and nutritional bioavailability. Adv. Food Nutr. Res. 33: 103-156.

O'Brien, C.M.; A., Mueller; A.G.M., Scannell and E.K., Arendt (2003): Evaluation of the effects of fat replacers on the qualiy of wheat bread. Journal of Food Engineering. 56(2,3): 265-267.

Ohta, A.; M., Ohlsuki; S., Baba; T., Adachi; T., Sakata and E., Sakaguchi (1995a): Calcium and magnesium absorption from the colon and rectum are increased in rats fed fructooligosaccharides. Journal of Nutrition. 125, 2417-2424.

Ohta,A; M., Ohlsuki; A., Hosono; T., Adachi and H., Hara (1997): Dietary fructooligosaccharides prevent osteopenia after gastrectomy in rats. J. Nutr. 128:485-490.

Perko, J. (1990): Experiment in the diversification of vegetable growing the Japanese artichoke observations and yields. Revue- Suisse-de-Viliculture, d'Arboriculture-et-d'Hortoi 22:5, 295-297. [C.f. Hort. Abst. 66-8088, 1991).

Roberfriod, M. (1993): Dietary fiber, inulin and oligofructose: a review comparing their physiological effects. CRC Critical Review in Food Science and Nutrition. 33: 103-148.

Roberfroid, M.B.; J. Cumps and J.P. Devogelaer (2002): Dietary chicory inulin increases whole-body bone mineral density in growing male rats. J. Nutr., 132:3599-3602.

Scholz-Ahrens, K. E. and J. Schrezenmier (2002): Inulin, oligofructose and mineral metabolism- experimental data and mechanism. British Journal of Nutrition. 87, Suppl. 2, S179-S186.

Silva, R.F. (1996): Use of inulin as a natural texture modifier. Cearal Foods World, 41, No. (10): 792-794.

Snedecor, G.W. and W.G., Cochran (1980): Statistical methods. 7$^{\underline{th}}$ ed., Iowa State University press. Amer. Iowa, USA.

Soja, G.; G. Dersch and W. Praznik (1990): Harvest dates, fertilizer and varietals effects on yield, concentration and molecular distribution of fructan in Jerusalem artichoke (Helianthus tuberosus L.). J. Agronomy and crop science, 165 (3): 181-192.

Swanton, C.J. and P.B. Cavers (1986): The regenerative capacity of rhizomes and tubers different populations of Jerusalem artichoke (Helianthus tuberosus L.). Proceedings, North Central Weed Control Conference Vol. 41,3.

دراســة مقارنة لطرق إكثار الطرطوفه و كذا دراسة الاثر التكنولوجى و البيولوجى للانيولين

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تـم زراعة صنفين من الطرطوفه من مزرعة القناطر البحثية التابعة لمعهد بحوث البساتين و ذلـك إما بالدرنة أو بالشتلات و دراسة تأثير ذلك على النمو الخضرى و محصول الدرنات.تم تبع ذلك أخذ درنات عمرها ١٥٠ يوم من الزراعه جففت و طحنت و إدخلت فى درسات تكنولوجية و البيولوجـية لمعـرفه تأثير محتواها من الأنيولين على جودة الخبز و إنعكاستها على عظام الفئران حتى يكون مؤشر لإستخدمها فى غذاء الإنسان.

تعتبـر الطرطوفة مصدرا مهما للأنيولين الذى يعتبر عنصر مهم لسلامة العظام و تعمل هذة الدراسة على إنتاج طرطوفة بطرق ميسرة ذات جودة عالية غنية فى محتواها من الأنيولين. إن إسـتخدام الصنف Fuseau أو الزراعة بالدرنات كل على حده او معا اعطى نباتات ذات صفات متفوقة كما اعطت محصول ذو صفات و جودة مميزة. إزدادت كمية الدرنات و المحصول الكلى و المـادة الجافه للدرنات تدريجيا مع زيادة عمر النبات حتى عمر ١٨٠ يوم من الزراعة كما يلاحظ ان الـصنف Fuseau هو المتفوق على الصنف المحلى. عند تحليل الصنفين وجد انه على اساس المـاده الجافـه (المسحوق) وجد ان الصنف المحلى يحتوى على زيادة فى محتواه من البروتين و سكر الجلوكوز وسكر الفركتوز. اما الصنف Fuseau فإنه يحتوى على كمية أكبر من المحلى فى كل من الرماد و الألياف الخام و الأنيولين و الفراكتوز و الكالسيوم و الفسفور. وجد انه عند إضافة مـسحوق كلا من صنفى الطرطوفه بنسب ٥، ١٠، ١٥ % إلى دقيق القمح اعطى خبز قوالب ذو مواصفات محسنه لكن صنف Fuseau يتفوق فى ذلك عن الصنف المحلى.

بالنـسبه لتجـربة البيولوجـى نجد أن الفئران تغذت على وجبات تحتوى على مسحوق الطـرطوفه (بنسبه ١٠ %) كمصدر للانيولين سواء مفردا أو بعد إضافة الكالسيوم له و من ذلك نلاحـظ أن الفئـران التى تغذت على الكنترول (الوجبه العاديه) أعطت أعلى معدل زياده فى وزن الفئـران الكلى و اليومى يليها الفئران التى تغذت على وجبة محتوية على مسحوق الطرطوفة لكلا الصنفين. يلاحظ أن سمك و طول كل من عظمة الفخذ و الساق و الركبه لفئران الدراسه كانت فى أعلـى معـدلاتها فى الفئران التى تغذت على وجبة محتويه على مسحوق الطرطوفه مضاف إليها الكالسيوم يليها عظام الفئران التى تغذت على وجبة محتويه على مسحوق الطرطوفه فقط. أيضا نجد أن الفئـران التى تغذت على مسحوق الطرطوفه مضاف له كالسيوم يحتوى دمها و كذلك عظامها علـى أعلـى معـدل من كل من الكلسيوم و الفسفور وأيضا كمية الرماد. من هذة النتائج نجد أن مـسحوق الطـرطوفه لكـلا الصنفين ثم مسحوقها مضافا إليه كالسيوم أعطى أعلى معدل من هذة المحتويات.