PRODUCTION OF CHIPS AND CRISP FROM JERUSALEM ARTICHOKE

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ABSTRACT

PRODUCTION OF CHIPS AND CRISP FROM JERUSALEM ARTICHOKE

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Jerusalem artichoke has been cultivated in various regions without any special breeding technique. On the other hand, in food industry it does not have a wide usage area. Hence, in food industry its use as a potato substitute in some products is believed to be increasing its economical value. As a first attempt chips and crisps produced from Jerusalem artichoke was analyzed for texture, sensory, color, oil and moisture content.

Jerusalem artichoke chips were fried in a bench top deep fat fryer for 120s, 180s and 240s at 160°C, 170°C, 180°C and 190°C. When microwave oven was used samples were cooked for 60s, 75s, 90s, 105s, 120s, 135s and 150s at 600 Watt, 900 Watt.

Rheological properties of Jerusalem artichoke puree was invesgitated and Xanthan gum (2%wb) and sodium metabisulphite (1%wb) added for the desired puree consistence and color. After the production of puree Jerusalem artichoke flour was produced and water added to this flour then dough obtained again. Rheological behaviour of the original puree and these prepared from the containing 1- 4.5 and 1 - 5.0 part water were quite similar.

In the light of the experimental results obtained as frying temperature and treatment time increased, moisture content and lightness of the Jerusalem artichoke products have decreased but a^* and b^* values, hardness, fracture and oil content increased.

The best results for frying of Jerusalem artichoke seem to be 180°C with about 240s treatment time for the chips and the same temperature for 180s for the crisps.

As microwave power level and duration of treatment increased, moisture content and lightness of the microwave cooked Jerusalem artichoke products have decreased, but a^* and b^* values increased. Hardness and fracturability values of the products first increased with time and then decreased.

When microwave oven was used, the best results were obtained for about 105s treatment time at 600W for the Jerusalem artichoke chips and about 60s processing time at 900W for the crisp.

Since treatment time for cooking was significantly reduced when microwave cooking was used, this method could be recommended as an alternative to conventional deep fat frying, as oil is not used as well.

Keywords: Jerusalem artichoke, frying, microwave cooking, chips, crisp, Jerusalem artichoke puree.

ÖZ

YER ELMASINDAN CİPS VE GEVREK ÜRETİLMESİ

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Yer elması özel yetiştirme teknikleri olmadan bir çok bölgede yetiştirilmektedir. Ancak gıda sanayiinde yaygın bir kullanım alanı yoktur. Yer elması patatese benzer özellikleri bulunan bir sebzedir. Bu nedenle gıda sanayiinde patates yerine kullanımı bu ürünün ekonomik değerini arttıracaktır. Bu amaçla bu çalışma ilk olarak yer elmasından üretilen cips ve gevreğin nem ve yağ içeriği, renk, yapı ve duyusal özellikler açısından incelenmiştir.

Yer elması cipsleri tezgah üstü derin yağ kızartıcısında 160°C, 170°C, 180°C, 190°C sıcaklığında 120sn, 180sn ve 240sn süreyle kızartılmışlardır. Mikrodalga fırın kullanımında ise numuneler 600W ve 900W güç seviyelerinde 60sn, 75sn, 90sn, 105sn, 120sn, 135sn ve 150sn süresiyle pişirilmişlerdir.

Yer elması hamurunun reolojik özellikleri incelenmiştir ve istenilen kıvam ve rengi elde etmek amacıyla ksantan gam (%2 yaş ağırlık) ve sodyum metabisülfit (%1 yaş ağırlık) eklenmiştir. Püre elde edildikten sonra yer elması unu üretilmiştir ve bu una su eklenerek yeniden hamur elde edilmiştir. Orjinal pürenin ve 1 – 4,5 ve 1 – 5,0 su eklenerek elde edilen hamurun reolojik özellikleri benzerlik göstermiştir.

Yapılan deneylerin sonuçlarına göre kızartma sıcaklığı ve işlem süresi arttırıldığında yer elması ürünlerinin nem içeriği ve beyazlık değerlerinin azaldığı fakat a^*, b^*, sertlik, kırılganlık ve yağ içeriği değerlerinde artış olduğu gözlenmektedir.

Yer elması kızartma işleminde en iyi sonuç cips şeklinde 180°C sıcaklığında 240sn işlem süresi, gevrekte ise aynı sıcaklıkta 180sn ile elde edilmiştir.

Mikrodalga fırın kullanıldığında ise en iyi sonuç cips şeklinde 105sn işlem süresi ile 600W gücünde, gevrekte ise 60sn sürede 900W gücünde elde edilmiştir.

Mikrodalga gücü ve işlem zamanı arttırıldığında, mikrodalgada pişirilmiş yer elması ürünlerinin nem içeriği ve beyazlık değerlerinin azaldığı, fakat a* ve b^* değerleri azalmıştır. Ürünlerin sertlik ve kırılganlık değerleri zamanla artmış sonrada azalmıştır.

İşlem süresinin mikrodalga fırın kullanıldığında önemli düşüş göstermesi, bu metodun geleneksel kızartma yöntemine göre daha az yağ içermesi de göz önüne alındığında tercih edilebilmesini sağlamaktadır.

Anahtar kelimeler: Yer elması, kızartma, mikrodalga pişirme, cips, gervrek, yer elması püresi.

“To my family”

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1.1.1 History

Jerusalem artichoke, also called sunroot or sunchoke or earth apple or topinambur, is cultivated widely across temperate world for its tuber, which is used as a root vegetable (Germplasm Resources Information Network).

Despite its name, Jerusalem artichoke has no relation to Jerusalem, and it is not a type of artichoke, though they are in the same family. The name Jerusalem is due to folk etymology; when Jerusalem artichoke was first discovered by Europeans it was called *Girasole*, an Italian word for sunflower. The Jerusalem artichoke is a type of sunflower, in the same genus as the garden sunflower *Helianthus annuus*. Over time the name Girasole was transformed into Jerusalem, and to avoid confusion some people have recently started to refer to it as sunchoke or sunroot (Purdue University Center for New Crops & Plants Products).

1.1.2 Classification

The sunflower genus, *Helianthus*, comprises around 50 species native to the Americas and found growing within the U.S. Their distribution varies from restricted to widespread. Two species are important as agricultural crops, the Jerusalem artichoke (*Helianthus tuberosus* L.) and the sunflower (*Helianthus annuus* L.). The Jerusalem artichoke is cultivated as a vegetable, fodder crop, and

as a source of inulin for food and industrial purposes, while the sunflower is grown as an oilseed crop (Heiser, 1978).

1.1.3 Chemical Composition

The tubers of Jerusalem artichoke typically comprise about 80% water, 15% carbohydrate, and 1 to 2% protein. Data on the composition of Jerusalem artichoke are relatively sparse in comparison to other vegetables and significant variation has been recorded for certain parameters. Differences in cultivar, time of harvest, production conditions, postharvest treatment, and preparation methods most likely account for this variation. Jerusalem artichoke tubers contain little or no starch, virtually no fat, and have a relatively low calorific value. Of the small amount of fat present, trace amounts of monounsaturated and polyunsaturated fatty acids have been reported, but no saturated fatty acids (Whitney and Rolfes, 1999). The polyunsaturated fatty acids linoleic (18:2 cis, cis n-6) and α -linoleic acid (18:3 n-3) have been recorded as present at 24 mg and 36 mg·100 $g^{-1}$of raw tuber, respectively (Fineli, 2004).

The tubers are a good source of dietary fiber, because of the presence of inulin. The principal storage carbohydrate of Jerusalem artichoke is inulin, and therefore carbon in the tubers (93.26 mg·g^{-1}; Somda et al., 1999) is predominantly in the form of inulin. The inulin content of tubers ranges from 7 to 30% of fresh weight (around 50% of dry weight); an inulin content of between 8 and 21% of fresh weight is considered typical (Van Loo et al., 1995). The protein in Jerusalem artichoke tubers comprises around 1.6 to 2.4 g·100 g^{-1} of fresh weight. Protein and nitrogen levels remain relatively constant in the tubers during development (Kosaric et al., 1984). Tuber protein contains all the essential amino acids in favorable proportions. It is rich in lysine and methionine, in comparison to proteins of other root and tuber crops, and is considered of high quality for food and feed applications (Cie´slik, 1998a; Rakhimov et al., 2003; Stauffer et al., 1981).

Jerusalem artichoke tubers have a high mineral content. The tubers are especially rich in iron (0.4 to 3.7 mg·100 g $^{-1}$), calcium (14 to 37 mg·100 g^{-1}), and potassium (420 to 657mg·100 g^{-1}), although they have relatively little sodium (1.8 to 4.0 mg·100 g^{-1}). Iron concentrations, for instance, are around three times higher than in potatoes (Cie´slik, 1998b). Relatively high levels of selenium have also been noted, up to 50 μ g·100 g $^{-1}$(Antanaitis et al., 2004; Bärwald, 1999). By the time of the final harvest, high levels of potassium, phosphorus, and calcium were found in the mature tubers.

The tubers are a good source of vitamins, especially vitamins in the vitamin B complex, vitamin C (ascorbic acid), and β -carotene (Van Loo et al., 1995). They have relatively high levels of folates or folic acid (13 to 22 μg·100 g^{-1}), while other vitamins in the B complex are present (thiamin, riboflavin, niacin, B6, pantothenic acid, biotin, and cobalamin). Vitamin C concentrations (2 to 6 mg·100 g $^{-1}$) are lower than in the aboveground plant parts, but are superior to other root and tuber crops, for example, around four times higher than in potatoes (Eihe, 1976). Carotenoids have also been noted at relatively high concentrations (9 to 29μg·100 g^{-1}), β-carotene being a precursor of vitamin A (0.6 to 1.0 mg·100 g^{-1}). A correlation has been noted between vitamin C and levels of nitrates in the tubers (Cie´slik et al., 1999). In fact, considerable variation has been reported for vitamin content in the literature, because vitamin concentrations are highly dependent on development stage, climatic conditions, agronomic practices, and other factors.

1.1.4 Inulin

Inulin molecules are much smaller than starch molecules, with the degree of polymerization (i.e.,the number of individual monosaccharide subunits) ranging from 2 to only about 70. The average number of fructose subunits varies with species, production conditions, and temporally (DeLeenheer, 1996). Molecules

with a degree of polymerization below 10 are called fructooligosaccharides (FOSs) or oligofructose. Short-chain fructooligosaccharides have two to four subunits. Inulin is predominantly a mixture of linear β-(1-2)-linked fructose chains with a terminal glycopyranose unit at the reducing end (Figure 1.1). There can be a small percentage of inulin chains that exhibit a very limited degree of branching (De Leenheer and Hoebregs, 1994) via β-(2-6)-linkages (Figure 1.1). The extent of branching varies among and within species (e.g., dahlia has 1 to 2% and chicory 4 to 5). The term inulin first appeared in the literature in 1818 (Thomson, 1818), predating the discovery of fructose by about 30 years. It was ascribed to a substance, first isolated from elecampagne (*Inulahelenium* L.) in 1804 (Rose, 1804). Jerusalem artichoke was first recorded as a source of inulin in around 1870. The actual linear structure of the molecule was not elucidated until the 1950s, and the small degree of branching that can occur only in the mid-1990s (De Leenheer and Hoebregs, 1994). As a polymer of fructose, inulin is classified as a fructan of which there are several types (inulins, levans, and branched fructans). However, on a quantitative basis, Jerusalem artichoke and chicory (*Cichoriumintybus* L.) are the most important inulin-storing plant species. Fructans are also synthesized by a number of microorganisms (Hendry, 1987; Yun et al., 1999).

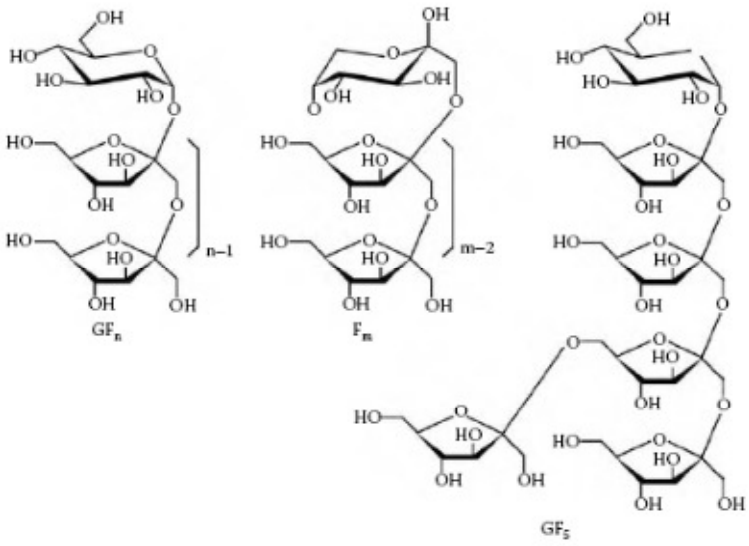

Figure 1. 1 Structure of inulin containing a terminal glucopyranose unit (GFn) inulin with a terminal fructoside unit (GFm), and a branched inulin (GFs).

Degree of polymerization can have a pronounced impact on the potential use of the inulin and fructooligosaccharides. Short-chain fructooligosaccharides (i.e., GF5) are of interest because of their health benefits, sweetness (~30% of sucrose), and as a substrate for the synthesis of certain chemicals (e.g., fermentation products). Inulins with higher degrees of polymerization can be used for fat replacement and high-fructose syrups (longer chain lengths decrease the percentage of glucose in the syrup). Likewise, longer chain lengths can be systematically reduced in size by partial hydrolysis using an endo-inulinase, while lengthening is not a commercially viable option.

Currently the primary commercial plant-derived sources for inulin are Jerusalem artichoke and chicory. The former is grown more so in Eastern Europe and the latter in Northwestern Europe. There is increasing interest in the commercial production of Jerusalem artichoke in China and several other countries. At present, neither crop is grown to any extent in the U.S., although there is some fresh-market production of Jerusalem artichoke. Instead of establishing breeding programs to further develop the Jerusalem artichoke as a crop, several groups have approached commercialization of

an inulin source by creating transgenic plants of other well-established crops (e.g., sugar beet, potato, corn, and soybean). (Engels et al., 2002; Hellwege et al., 2000).

An alternative to transgenic plants is expression of either β-fructofuranosidases (EC 3.2.1.26) or β-fructosyltransferases (EC 2.4.1.100) in a microorganism such as *Escherichia coli* for the synthesis of inulin or short-chain fructooligosaccharides from sucrose. In this case, sucrose acts as both the fructose donor and initial acceptor (Fishbein et al., 1988).

1.1.4.1 Uses of Inulin

1.1.4.1.1 Bulking Agents

Considerable interest was focused in the 1990s on inulin as a bulking agent in low-calorie foods, due to its limited utilization by humans. A bulking agent increases the weight or volume of a food without altering its functionality or utility. If an artificial sweetener is used to replace the sugar in a cake mix, the differential in sweetness (e.g., 600×) results in potentially a tremendous loss in volume. The addition of an acceptable bulking agent, especially one that confers few calories, restores the necessary bulk and functional properties of the sugar.

1.1.4.1.2 Bakery and Dairy Products

The addition of inulin or Jerusalem artichoke flour to bread generally confers several positive attributes (e.g., improved softness of the crumb, prolonged preservation, and improved bread volume) (De Man and Weegels, 2005; Miura and Juki, 1995). White and wheat/rye breads can be made with Jerusalem artichoke flour or inulin; as the inulin content increases, the crumb hardness decreases (Filipiak-Florkiewicz, 2003). Typically, the upper limit is around 8% inulin (Meyer, 2003). In wheat/rye breads, Jerusalem artichoke flour gave the highest quality. The addition of fructooligosaccharides decreases the calorie content and increases the fiber content

of the bread, making it a healthier food. Inulin is also used as thickener in ice cream, sandwich spreads, mayonnaise, chocolate products, and pastries (Berghofer et al., 1993a; Frippiat and Smits, 1993).

1.1.4.1.3 Fructose and Short-Chain Fructans

The characteristic inulin biochemistry of Jerusalem artichoke makes it an excellent source of fructose. Fructose is the sweetest of the natural sugars; its sweetness is around 16% greater than sucrose (Shallenberger, 1993). Fructose syrups are widely used by the food industry. They have a high solubility in water, fewer calories less than sucrose, and are less viscous. With these properties, fructose has gained in importance within the food processing industry as a sweetener. It is an ideal sugar for use in reduced-calorie foods, foods for diabetics, and products to combat obesity. A range of fructose-containing products can be obtained from Jerusalem artichoke, including sugar solutions, pure fructose syrup, and crystalline fructose.
Inulin, fructooligosaccharides, fructose, and other useful compounds can all be purified from the juice extracted from Jerusalem artichoke tubers. Fleming and GrootWassink (1979) describe a process for obtaining high-fructose syrup (75% yield) using enzyme hydrolysis. Fermentation using yeasts converts inulins and fructooligosaccharides to fructose, although the larger inulin polymers are difficult to convert (Fontana et al., 1993; Schorr-Galindo et al., 1995).

Jerusalem artichoke yields more fructose than sugar beet or maize. The fructose in Jerusalem artichoke derives from inulin, whereas it derives from sucrose in sugar beet and starch in maize. Barta (1993) reported total fructose yields ($t \cdot ha^{-1}$) for Jerusalem artichoke, sugar beet, and maize of 4.5, 2.9, and 2.1, respectively. Jerusalem artichoke cultivars with higher inulin content are preferred for fructose production.

1.1.4.1.4 Nutraceutical Supplements

Nutraceutical is any substance that is a food or a part of a food and provides medical or health benefits. Nutraceutical products are also known as functional foods. Inulin-containing foods have long been known to be beneficial for health. Inulin is fermented in the colon, selectively altering the microflora present (Gibson et al., 1995a). Bifidobacteria, a genus considered to have healthpromoting properties, displaces a number of undesirable microbes..

Fructooligosaccharides have been used as food supplements in Japan since 1983. A wide range of inulin-containing functional foods are marketed as beneficial for gastrointestinal conditions and for the promotion of mineral absorption (Hidaka et al., 2001). Over 700 products in Europe included inulin as a nutraceutical ingredient by 2000, including yogurts.

1.1.4.1.5 Medical Applications

Pure inulin powder is sold for nutritional and medicinal purposes. For nutritional purposes, it is sufficient that any toxic components and pathogenic organisms are removed from the inulin. However, for medical and diagnostic uses, inulin must be extremely pure and have a high degree of polymerization (>20). Inulin from Jerusalem artichoke typically has only half of its inulin above a degree of polymerization of 10, with 12 the most frequently occurring chain length in raw tubers (Vukov et al., 1993).

1.1.4.1.6 Fat Substitutes

The use of low-calorie fat replacers in foods facilitates reductions in the energy density of the diet. However, since fat confers a number of important quality attributes, it is critical that such foods be highly palatable. When all or part of the fat

is replaced, the foods must have comparable rheological and sensory-quality attributes to the original high-fat food. Textural properties are particularly important since fat has a pronounced impact on texture, mouthfeel, and hence eating quality. Therefore, in addition to lowering the calorie density, an acceptable fat substitute must have the appropriate functional properties, such as heat stability, emulsification, aeration, lubricity, spreadability, texture, and mouthfeel (Lukacova and Karovicova, 2003; Silva, 1996).

Inulin can be used to replace a significant portion of the fat in certain meats (Archer et al., 2004) and traditional squeezable and spreadable food products. As the fat is reduced, the amount of water increases to the detriment of the product's structure. The water binding capacity and melting and rheological properties of inulin in such products, however, allow reducing the fat content from around 80% to 20–40% (Silva, 1996).

The higher molecular weight fractions of inulin function more like fats than lower-dp fractions. Therefore, when inulin is used as a fat substitute, generally the low molecular weight fraction is removed, leaving a product with an average degree of polymerization of 25 or higher. The higher molecular weight inulin can form a gel that has excellent spreadability (Kasapis, 2000). Unless very high levels of inulin are used (25%), gel-forming proteins and hydrocolloids may need to be added to alter the structural properties of the product.

Inulin is soluble in water, though its solubility is strongly modulated by temperature (e.g., ~6% at 10°C and 35% at 90°C) (Silva, 1996). It has a water binding capacity of approximately 2:1 and, when in solution, reduces the freezing point of the water. It is dispersible in water but tends to clump due to its hydroscopic characteristics, a problem that can be partially circumvented by mixing it with sugar or starch. Commercially available inulin has a slightly sweet taste due to the presence of glucose, fructose, and sucrose. The odor is neutral.

1.1.4.2 Values in Human Diet

Jerusalem artichokes are often cooked in their skins, especially when baked. If peeled, they should be placed in cold water prior to cooking to reduce discoloration. Discoloration also occurs after cooking, with the exposed flesh turning from cream to dull gray. Discoloration is due to iron, a beneficial mineral that is abundant in the tubers at levels 3 $mg \cdot g^{-1}$ (USDA data in McGee, 1992) five times higher than in potatoes. Iron reacts with phenolic compounds, particularly chlorogenic acid, in damaged tissue to form a dark-colored complex.

1.1.4.2.1 Inulin and Obesity

Obesity represents a major global health crisis. Figures produced by the World Health Organization (WHO) in 2002 revealed that worldwide more than a billion adults were overweight and 300 million were clinically obese. In 2003, the International Association for the Study of Obesity calculated that up to 1.7 billion people in the world were overweight or obese. Organization for Economic Cooperation and Development (OECD) data published in 2002 showed that over 26% of the population of the U.S. was clinically obese, while over 20% of the populations of the U.K. and Australia were obese. Until recently, obesity was thought to be a problem only for rich countries. However, obesity is now prevalent in both developed and developing world nations; undernutrition and overnutrition coexist in many countries (Gardner and Halweil, 2000; Lang and Heasman, 2004).

Overnutrition is the root cause of the obesity epidemic. The consumption of excessive amounts of high-energy fatty and sugary foods leads to the accumulation of body fat. Obesity is defined as an excessively high amount of body fat in relation to lean body mass. Extreme degrees of obesity are rising at alarming rates. By 2003, over 6% of the U.S. population was morbidly obese, with a body mass index over 40. A body mass index above 25 increases the risk of premature death due to a range of degenerative diseases and health conditions, including cardiovascular disease,

hypertension, stroke, osteoporosis, some cancers (endometrial, breast, and colon), and diabetes mellitus (type 2 diabetes) (CDC, 2006; Lang and Heasman, 2004).

The World Health Organization estimates that over 3 million deaths a year can be attributed to overweight and obesity, a figure that is predicted to increase (WHO, 2002). The health care costs are already enormous. In 1998, it was estimated that medical expenses arising from overweight and obesity accounted for 9.1% of the total U.S. medical expenditure. The health care costs of overweight and obesity in the U.S. probably exceeded $78.5 billion in 2005 (CDC, 2006; Lang and Heasman, 2004).

Jerusalem artichoke is a bulky low-energy food that fits this profile. It has a low energy (calorie) value because enzymes in the digestive system do not degrade inulin and fructooligosaccharides, a prerequisite for absorption by the body. For this reason, inulin and fructooligosaccharides are often referred to as nondigestible oligosaccharides.

The utilization of inulin as a fermentable substrate by microflora in the colon, however, means they are broken down and absorbed to a limited extent. Inulin therefore has a small caloric value. Molis et al. (1996) calculated an energy value of 2.3 $kcal \cdot g^{-1}$(9.5 $kJ \cdot g^{-1}$) for fructooligosaccharides, while Livesey et al. (2000) proposed a value of 2.0 $kcal \cdot g^{-1}$(8.4 $kJ \cdot g^{-1}$) for all carbohydrates that undergo microbial fermentation. However, most energy values calculated for inulin and fructooligosaccharides in the literature have been lower than this. A calorific value of 1.5 $kcal \cdot g^{-1}$(6.3 $kJ \cdot g^{-1}$)was reported by Hosoya et al. (1988) and Ranhotra et al. (1993), for instance, while Roberfroid et al. (1993) gave a range between 1.0 and 1.5 kcal·g–1 (4.2 and 6.3 $kJ \cdot g^{-1}$). The differences reported for the caloric value of inulin are effectively insignificant in nutritional terms (Roberfroid, 2005). Although there is at present no universally accepted figure, the energy value for inulin is usually given as 1.5 kcal·g–1(6.3 $kJ \cdot g^{-1}$) on food labels and in nutritional advice (Roberfroid, 1999). Therefore, the caloric value of Jerusalem artichoke is much less than for most other root vegetables. While 100 g of boiled potato, for example, has a caloric value

of 76 kcal, the same amount of boiled Jerusalem artichoke tuber has 41 kcal (Vaughan and Geissler, 1997). Jerusalem artichoke is therefore an ideal vegetable to include in a weight-losing diet. As an ingredient (e.g., flour), Jersualem artichoke inulin can replace fat and sugar in low-calorie foods.

1.1.4.2.2 Inulin and Diabetes Mellitus

Diabetes mellitus is a disease in which blood sugar is not properly taken up into cells. Thus, the level of glucose in the blood remains high. The uptake of glucose into the body's cells is controlled by the hormone insulin, which is produced by the pancreas. Type 1 diabetes is due to the pancreas failing to produce sufficient insulin. It is often caused by genetic factors. Non-insulin-dependent diabetes, or type 2 diabetes, occurs when the body's cells are unable to respond very efficiently to the insulin produced. It is associated with obesity, overnutrition, excess dietary fat and sugar, and other factors. Type 2 diabetes accounts for around 90% of all diabetes. Both types of diabetes are treated by the injection of insulin, which acts to reduce the blood glucose concentration by facilitating the uptake of glucose by the cells in Type 1 diabetes, and by supplementing the body's insulin in Type 2 diabetes.

Over 18 million adults in the U.S. have diabetes (CDC, 2006), and over 170 million people worldwide have the condition, while its incidence is rising dramatically. The World Health Organization estimates that there may be 300 million people with diabetes by 2025 (WHO and FAO, 2002). There is a pressing need to develop a range of approaches to tackle type 2 diabetes and also address the root causes of its increased incidence, such as obesity and poor diet. Improvements in diet are therefore an important strategy in combating Type 2 diabetes.

Foods containing inulin are beneficial in the diet of people with diabetes mellitus. Inulins and fructooligosaccharides are not absorbed in the intestines (Rumessen et al., 1990), and therefore do not affect insulin levels, because the body does not sense a need to produce insulin. The ingestion of sucrose or glucose prompts blood sugar

and insulin changes, but no corresponding effects are noted when equivalent amounts of inulin or fructooligosaccharides are ingested (Roch-Norlund et al., 1972). Therefore, consuming inulin-rich foods helps to restore normal levels of blood sugar, whereas foods containing starch and sucrose further raise blood sugar levels. Experiments during the 1980s and 1990s confirmed the beneficial role of inulin-rich foods in diabetic diets. Daily intake of fructooligosaccharides has been shown to reduce blood sugar levels in both diabetic and healthy subjects (Luo et al., 1996; Yamashita et al., 1984). Inulin reduced insulin peaks compared to diets containing other carbohydrates (Rumessen et al., 1990) and an intake of around 16 to 23 g of inulin per meal has been recommended in diabetic diets (Van Loo et al., 1995).

Jerusalem artichoke was fed to diabetic patients in the 1920s with promising results (e.g., Carpenter and Root, 1928). It proved beneficial when substituted for other carbohydrate foods, such as potatoes, over periods ranging from 6 days to several months. The increase in blood sugar after eating Jerusalem artichokes (0.02 to 0.07% in 3 h) was significantly lower than when consuming an equivalent amount of fructose or other carbohydrates (Root and Baker, 1925).

Today, a moderate quantity of Jerusalem artichoke is recommended in diets aimed at countering diabetes and obesity. Eating Jerusalem artichoke daily, however, could become monotonous. Fortunately, foods incorporating tuber extracts also provide the health benefits of Jerusalem artichoke. Flour from Jerusalem artichoke, for instance, replaces wheat flour in a range of food products aimed at the weight-loss, health food, and diabetic food markets (Roberfroid and Delzenne, 1998).

1.1.4.2.3 Probiotics, Prebiotics and Bifidobacteria

A number of health benefits attributed to Jerusalem artichoke tubers in human and animal diets are related to its role as a promoter of probiotic activity in the large intestine. Probiotics have been a dietary element for thousands of years. However, the term *probiotic* only gained its current usage in the early 1970s, as an organism or

substance that has a beneficial effect on the balance of microorganisms in the colon. This definition coincided with work revealing the essential role of intestinal microflora in the digestion of food and in promoting general well-being. Today, a probiotic is generally defined as a live microbial feed supplement that beneficially affects the host animal by improving its intestinal microbial balance (Fuller, 1992).

The large intestine is the most heavily colonized region of the digestive system, with up to 10^{12} bacteria per gram of intestinal content. Around 50 genera are represented, with hundreds of different species and strains occurring. The vast majority of these bacteria are anaerobes, and they range from the beneficial to the pathogenic. The balance of the intestinal microflora greatly influences digestive processes. Beneficial bacteria naturally present in the large intestines include species of *Bifidobacterium a*nd *Lactobacillus*. Probiotics and substrates that promote their activity help shift the balance toward the optimum for these beneficial bacteria, so they constitute at least one third of the total bacterial population (Gibson et al., 1995b).

A number of bacteria and yeasts have probiotic activity. However, in commercial applications, bacteria associated with four genera have predominated: *Bifidobacterium*, *Lactobacillus*, and, to a lesser extent, *Enterococcus* and *Streptococcus* (Lee et al., 1999). A number of claims are made for these products, including improvement of the colon microflora balance, stimulation of the immune system, enhanced resistance to bacterial infection, and general health benefits.

Many factors contribute to the effectiveness of probiotic organisms, including their ability to adhere to the lining of the intestine (Crociani et al., 1995). A crucial factor in the survival and proliferation of both native and introduced beneficial bacteria (i.e., bifidobacteria, lactobacilli) in the lower intestines is the availability of a carbohydrate source that has not been digested by the human digestive system and that can be used as a substrate for growth. A range of nondigestible oligosaccharides have been shown to stimulate the activity of bifidobacteria and lactobacilli in the colon (Fuller, 1997). Nondigestible substances that stimulate the growth or activity of beneficial bacteria in the colon are called prebiotics; they have become an

important component in probiotic supplements (Gibson and Roberfroid, 1995; Gibson et al., 2005; Tuohy et al., 2005). Jerusalem artichoke tuber extracts are rich in inulins and fructooligosaccharides, and are therefore a potential source of prebiotics.

Probiotic supplements can take the form of powders, dried tablets, pellets or cubes, and pastes or sprays, depending on their use. They usually contain an active bacterial ingredient (probiotic) plus a carbohydrate source that can be selectively fermented by the bacteria(prebiotic). A combination of an active bacterial ingredient and carbohydrate source is also called a synbiotic (Gibson and McCartley, 1998; Roberfroid et al., 2002a). *Synbiotic* has been slowly accepted as a term, however, and *Probiotic* is still commonly used for mixtures of probiotics and prebiotics (Heasman and Mellentin, 2001). A typical synbiotic (probiotic) supplement may therefore contain a culture of bifidobacteria together with inulins or fructooligosaccharides. Inulin prebiotic supplements are also added to food without a probiotic component to promote the activity of indigenous bifidobacteria. Some probiotic products (e.g., yogurt drinks) have come under critical scrutiny because the probiotic bacteria added, including bifidobacteria, do not survive beyond the stomach to contribute to the colon microflora (e.g., Graham-Rowe, 2006). However, there is no doubt that prebiotic inulin and fructooligosaccharide do reach the colon.

Inulin and fructooligosaccharides are excellent prebiotics because they are not digested or absorbed in the small intestine. The characteristic (1-2)-bonds, which link the fructose units, cannot be degraded by mammalian digestive enzymes (Oku et al., 1984), and therefore reach the colon as intact molecules. Around 85% of ingested inulin survives to the colon, where it acts as a fermentable substrate for the colonic microflora. Inulin and fructooligosaccharides selectively stimulate the growth of bifidobacteria and lactobacilli, an effect not achieved with other types of carbohydrate such as starch or pectin (Gibson et al., 2005; Mitsuoka et al., 1987; Wang and Gibson, 1993). They therefore influence species composition in the colon in favor of beneficial bacteria (Gibson et al., 1995; Gibson and Wang, 1994). A daily intake of around 8 to 10 g of fructooligosaccharides significantly increases bifidobacteria in the large intestine (e.g., Bouhnik et al., 1997; Hidaka et al., 1991;

Tuohy et al., 2001). As little as 5 g of inulin a day in the diet can produce an observable bifidogenic effect (Bouhnik et al., 1999; Williams et al., 1994).

By promoting bifidobacteria and other beneficial microorganisms, prebiotics help to suppress harmful microorganisms through competitive inhibition. Thriving populations of beneficial bacteria can outcompete other bacteria for nutritional resources and adhesion sites on epithelial cells lining the intestinal wall. Good adhesion is important to prevent bacteria being removed by host secretions and intestinal flow; the attachment ability of different *Bifidobacterium* species is correlated with their ability to colonize the large intestine (Crociani et al., 1995). Bifidobacteria also release antibacterial agents, as a result of fermenting inulins (Gibson and Wang, 1994). Lactobacilli secrete bacteriocins — peptides with specific antibacterial action (Dodd and Gasson, 1994). Numbers of pathogenic bacteria in fecal samples are often reduced when inulin and fructooligosaccharide supplements are included in the diet (e.g., Gibson and Wang, 1994). Among the potentially harmful bacteria that have been reported to be suppressed are *Clostridium perfingens* and *C. difficile* and pathogenic strains of *Escherichia coli*, *Staphylococcus aureus*, *Campylobacteria jejuni*, *Salmonella enteritidis*, and *Candida albicans*(Araya-Kojima et al., 1995; Buddington et al., 2002; Fooks and Gibson, 2002; Gibson et al., 1995; Gilliland and Speck, 1977; Harmsen et al., 2002; Kleessen et al., 1997; Rao, 2001; Wang and Gibson, 1993; Yamazaki et al., 1982). However, not all dietary trials with inulin and fructooligosaccharide supplements resulted in significantly reduced counts of pathogenic bacteria (Roberfroid, 2005).

Prebiotic and synbiotic supplements containing inulins and fructooligosaccharides can be particularly effective after illness and antibiotic treatments, to help bifidobacteria recolonize the large intestine, as bifidobacteria can be eradicated by certain antibiotics (Colombel et al., 1987). They are also particularly helpful for other at-risk groups, such as the elderly, babies and infants, and people traveling or on holiday abroad, as a preventative measure against illness. In addition to their bifidogenic effect, inulin-type fructan prebiotics have been reported to have a range of other beneficial health effects. These claims are supported by data from studies

with animal models and from clinical trials, although it should be noted that large variability often occurs between different studies. The main health claims relate to mineral absorption and bone health, decreased blood lipids and heart disease, stimulation of the immune system and disease prevention, and improved bowel function (Boeckner et al., 2001; Roberfroid, 1995; Tungland, 2003).

1.1.4.2.4 Inulin and Bone Health

Prebiotics and synbiotics containing fructooligosaccharides enhance mineral bioavailability by improving the absorption of minerals in the colon, especially calcium, iron, and magnesium (Caers, 2004; Coudray, 2004; Hidaka et al., 2001; Ohta et al., 1994; Roberfroid, 2005). The mechanism for this is probably enhanced passive and active mineral transport across the intestinal epithelium, mediated by increased levels of butyrate and other short-chain fatty acids and decreased pH (Scholz-Ahrens and Schrezenmeir, 2002). Improvements in calcium and iron absorption may help prevent osteoporosis and anemia, respectively (Ohta et al., 1998; Weaver and Liebman, 2002). Fructooligosaccharide ingestion enabled rats, for instance, to recover from experimentally induced anemia and to increase levels of minerals in their bones (Ohta et al., 1998; Oda et al., 1994).

Calcium is a key factor in bone strength. By optimizing peak bone mass in early adulthood and by minimizing bone loss during the postmenopausal period, the risk, for example, of hip fracture can be significantly reduced. Improved calcium nutrition during development is critical and can reduce hip fracture rates later in life by around 50% (Coxam, 2005).

Prebiotic inulin and fructooligosaccharides added to the daily diet of animals significantly increase calcium absorption in animals (e.g., Coudray et al., 2003; Mineo et al., 2001; Ohta et al., 1994; Rémésy et al., 1993). This can increase mineralization and bone mineral density (Roberfroid et al., 2002b). In humans, a beneficial effect on calcium absorption is found in both adolescents (Griffin et al.,

2002, 2003; van den Heuvel et al., 1999) and postmenopausal women (van den Heuvel et al., 2000). In both groups, a mixture of inulins having low and high degrees of polymerization (DP) were the most effective treatment for enhancing mineral absorption (Coudray et al., 2003; Griffin et al., 2002, 2003). Such a mixture (e.g., a 1:1 ratio of fructooligosaccharides (average DP of 4) and longchain inulin (average of DP 25)) increased the calcium accretion to the skeleton by ~30 mg $Ca \cdot day^{-1}$(Abrams et al., 2005). Polymorphisms in the vitamin D receptor gene (Fok1), however, appear to strongly modulate calcium absorption and the magnitude of the response to supplementation.

In Japan, where mineral deficiency can be a nutritional problem, the beneficial effects of fructooligosaccharides on calcium absorption have been recognized in the labeling on dietary supplements since 1999 (Hidaka et al., 2001).

1.1.4.2.5 Blood Lipids and Heart Disease

Inulins and fructooligosaccharides help maintain the health of the cardiovascular system and may reduce the risk of heart disease. A key factor in this is the maintenance or improvement of blood lipid composition, through decreases in triglycerides(triacylglycerols), and the lowering of cholesterol and homocysteine levels(Hidaka et al., 2001; Luo et al., 1996; Tungland, 2003). Convincing lipid-lowering effects have been demonstrated in animals (e.g., Delzenne et al., 1993; Fiordaliso et al., 1995; Kok et al., 1998; Trautwein et al., 1998). Rats on inulin-rich diets, for example, had lower blood cholesterol and total lipid levels than control animals, while reductions in serum triglycerides were reported for rats on diets containing 5 to 20% fructooligosaccharides(Roberfroid, 1993). However, the situation is less clear-cut for humans, where higher inulin doses (over 30 $g \cdot day^{-1}$) can produce adverse gastrointestinal symptoms (Williams, 1999). Some human studies have found no effects, while a number of others have shown decreases in triacylglycerol or cholesterol levels for groups taking inulin and fructooligosaccharide supplements (Williams and Jackson, 2002). Roberfroid (2005)

reviewed 12 studies, finding 8 to have positive and 4 negative outcomes. Positive outcomes were more likely for subjects with moderate hyperlipidemia (Causey et al., 2000; Davidson et al., 1998; Hidaka et al., 1991; Jackson et al., 1999; Letexier et al., 2003) than for normal lipidemic volunteers (Brighenti et al., 1999; Luo et al., 1996; Pedersen et al., 1997; van Dokkum et al., 1999) or non-insulin-dependent diabetics (Alles et al., 1999; Luo et al., 2000; Yamashita et al., 1984). Inulin-type fructan supplements act to reduce lipogenesis in the liver, and this lowers lipid concentrations in the blood (Letexier et al., 2003).

Inulin and fructooligosaccharides are more effective at lowering serum levels of lipids (triglycerides) than cholesterol, with inulin more effective than short-chain fructooligosaccharides in both cases (Roberfroid, 2005). The moderate cholesterol-lowering action observed in several studies may arise as a result of the metabolism of inulin and fructooligosaccharides to short-chain fatty acids, which inhibit hepatic cholesterol biosynthesis, although the mechanism involved is not yet fully understood. Prebiotics may also help redistribute cholesterol from the blood plasma to the liver, while beneficial bacteria stimulated by prebiotics may interfere with cholesterol absorption from the colon, or directly assimilate cholesterol (Pereira and Gibson, 2002). High homocysteine levels can damage artery tissue, and interfere with the constriction and dilation of blood vessels and blood clotting processes. By lowering levels of homocysteine and undesirable lipids, inulin and fructooligosaccharide supplements may help to reduce the long-term risks of heart disease. The risk of atherosclerosis (thickening of the arteries), for example, may be reduced through a lowering of triglycerides and fatty acid levels in the blood serum.

1.1.4.2.6 The Immune System and Cancer Prevenetion

Inulin and fructooligosaccharides modulate the response of the immune system to illness, through the stimulation of bifidobacteria and lactobacilli, and the improvement of the general microfloral balance in the colon (Watzl et al., 2005; Yasui et al., 1992). In this role, prebiotics have been shown to promote the

production of macrophages, lymphocytes, and antibodies, in particular the local production of immunoglobulin A (IgA)-positive cells in the intestines and cecal mucosa (Bornet, 2001; Hosono et al., 2003; Kadooka et al., 1991; Roberfroid, 2005; Yasui et al., 1992). Fructooligosaccharides may therefore help to prevent a wide range of illness and disease conditions, including ulcerative colitis, symptoms of inflammatory bowel diseases, and E. coli O157 infection (Hidaka et al., 2001; Kanauchi et al., 2003; Oike et al., 1999; Wolf et al., 2003). The ability of inulins to stimulate the immune system has also led to interest in their use as vaccine adjuvants (Cooper, 1995; Silva et al., 2004). Newborn babies and infants have underdeveloped immune systems. Breast milk contains natural prebiotic oligosaccharides that stimulate bifidobacteria and lactobacilli, which tend to be more prevalent in the gastrointestinal flora of breast-fed babies. Infant formula and cow's milk are deficient in oligosaccharides, a factor holding back the development of an infant's immune system. The addition of fructooligosaccharide prebiotics to infant formula can increase gastrointestinal bifidobacteria and lactobacilli counts (Boehm et al., 2002; Knol et al., 2000; Moro et al., 2002), while daily fructooligosaccharide supplements (e.g., 2 $g \cdot day^{-1}$) can lower the prevalence of sickness (e.g., vomiting, diarrhea) in infants (Saavedra et al., 1999; Vandenplas, 2002; Waligora-Dupriet et al., 2005). By boosting the immune system, it has been claimed that fructooligosaccharide supplements reduce the risk of colorectal cancer developing (Kowhi et al., 1978, 1982; Pool-Zobel et al., 2002). In mice and rats, for example, fructooligosaccharides reduced colon carcinogens and the occurrence of colon tumors (Pierre et al., 1997), while dietary inulin and fructooligosaccharides suppressed chemically induced tumors (Taper and Roberfroid, 2002) and reduced genotoxic damage to the colonic epithelium in rats (Rowland, 1998). The release of the short-chain fatty acid butyrate, from fermenting inulin and fructooligosaccharides, may play a role in suppressing colon cancer. Butyrate has been shown to have a direct antiproliferation effect on tumor cells in vitro (Kruh, 1982), while the release of butyrate has been correlated with a protective effect against colon cancer in experimental studies with rats (Bornet, 2001; McIntyre et al., 1993). Moreover, inulin injections can prolong the survival of melanoma-bearing mice (Cooper and Carter, 1986).

1.1.4.2.7 Bowel Function

Inulins and fructooligosaccharides in the diet promote gastrointestinal health and improve bowel function. They do this primarily by contributing to dietary fiber a heterogeneous group of plantderived carbohydrates that are not digested by human enzymes and are not absorbed in the small intestine (Flamm et al., 2001). Dietary fiber plays an important role in nutrient absorption, digestive transit time, and stool composition and quantity, while providing the main nutrient source for colonic microflora (Trepel, 2004). Through its effect on the colonic microflora, dietary fiber has a bulking effect. In general, for every additional 1 g of dietary fiber consumed, stool weight increases by up to 5 g (Roberfroid et al., 2002a).

Fermentation products arising from the metabolism of prebiotics by colonic microflora, such as bifidobacteria and lactobacilli, include vitamins and short-chain fatty acids. These are largely absorbed in the colon and are metabolized to provide energy for the body. Probiotics containing strains of bifidobacteria have been shown to raise levels of water-soluble vitamins (e.g., thiamine, nicotinic acid, folic acid, and vitamin B12) in the large intestine (Deguchi et al., 1985; Lee et al., 1999). Short-chain fatty acids comprise acetates (e.g., acetic acid), propionates (e.g., propionic acid), butyrates (e.g., butyric acid), and lactates (e.g., lactic acid). They exert systematic effects on the metabolism of carbohydrates, fats, and cholesterol, and are vital for normal colonic function (Hidaka et al., 2001). The types of fermentation products arising from digestion depend on the make up of the intestinal microflora and the amount and structure of the inulin and fructooligosaccharides present. The fermentation and digestion of prebiotics increase the amount of bacterial biomass and raise intestinal levels of carbon dioxide, hydrogen, and methane, in addition to shortchain fatty acids (Andrieux et al., 1993; Roberfroid et al., 2002a).

Fructooligosaccharide supplements (e.g., 3 $g \cdot day^{-1}$) improve bowel function by relieving moderate constipation and increasing stool frequency (Kameoka et al., 1986; Tokunaga et al., 1993; Tominaga et al., 1999; Wolf et al., 2003). Inulin and fructooligosaccharides lower intestinal pH and increase the weight of the stools,

while also raising the levels of butyrate and other gaseous fermentation products (Campbell et al., 1997). Stool weight in humans can be increased by about 20% and breath hydrogen by around three-fold (Alles et al., 1997). The production of short-chain fatty acids reduces pH, while the increase in stool weight is mainly attributable to increased microbial biomass in the colon. As the water content is high, stools are softer and easier to expulse — thereby increasing stool frequency (Churbet, 2002).

Gastrointestinal disturbances can lead to several types of diarrhea, such as pseudomembranous colitis (caused by overgrowth of Clostridium difficile), rotavirus diarrhea, antibiotic-associated diarrhea, and travelers' diarrhea. Prebiotics and synbiotic supplements containing bifidobacteria with inulin or fructooligosaccharides have the potential to treat these conditions (Gibson et al.,1997). Travelers are prone to gastrointestinal disorders, through exposure to unfamiliar strains of microorganisms in food and drink. A trend toward fewer attacks of diarrhea and a better sense of well-being were reported for a group of travelers taking fructooligosaccharide supplements (10 g·day–1) compared to a control group (Cummings et al., 2001). Patients just recovered from the diarrhea symptoms of C. difficile infection receiving fructooligosaccharides (12 g·day–1) had higher levels of bifidobacteria than controls after 12 days and were less likely to suffer relapses of diarrhea (Lewis et al., 2005).

1.1.4.2.8 Digestive Downsides

Jerusalem artichoke has beneficial effects on digestion. It is a good source of dietary fiber, for instance, which helps to bulk food and reduce constipation. However, there can be digestive downsides too.

Human digestive enzymes do not target inulin. Around 89% (and up to 97%) of the inulin and fructooligosaccharides that we consume, on average, remain intact in the small intestine (Andersson et al., 1999; Molis et al., 1996). As it is not digested, there tends to be a lot of inulin in the large intestine or colon after eating a meal rich in inulin. However, none reaches the stools, and only a small fraction occurs in the

urine (Molis et al., 1996). This is because inulin is completely fermented by the general microbial fauna in the large intestine, especially by bifidobacteria and lactobacilli (Nilsson and Björck, 1988; Nilsson et al., 1988). The digestion of inulin and fructooligosaccharide is accompanied by the production of hydrogen, carbon dioxide, and other gaseous products (Stone-Dorshow and Levitt, 1987). This leads to an undesirable side effect of eating Jerusalem artichoke and other inulin-rich foods: flatulence.

1.2 Frying

Frying is a fast and convenient technique for the production of foods with unique sensory properties of colour, flavour, texture, and palatability. Deep-fat frying can be defined as the process of drying and cooking through contact with hot oil (Sahin et al., 1999).

Deep fat frying is a process of simultaneous heat and mass transfer. Heat is transferred from the oil to the food and oil penetrates the crust through the pores created by the evaporation of water from the food. So, fat uptake is largely determined by the moisture content of the food (Gamble et al., 1987; Saguy and Pinthus, 1995; Southern et al., 2000).

Especially at high moisture contents, vapor protects the food from oil absorption by creating an overpressure inside the pores. This barrier property of vapor probably continues until a few seconds after removal of the food from the oil. After taking the food out of the fryer, the temperature drops and the vapor in the pores condenses (Mellema, 2003). This condensation mechanism creates vacuum effect, which causes the adhering oil being pulled into the product. Mechanism of oil absorbtion were explained by the Gamble et al. (1987). They suggested that most of the oil enters the surface at damaged areas after frying, from the adhering surface oil being pulled into the slice when it is removed from the fryer due to the condensation of steam.

Heat is transferred by convection from the oil to the surface of the product and by conduction within the food. When the food is immersed in oil, surface temperature of the food rapidly reaches the boiling point of water and steam bubbles start to leave the surface. Due to the evaporation, surface drying is seen. The evaporation also leads to shrinkage and crust formation (Mellema, 2003). Pravisani and Calvelo (1986) proposed the existence of an evaporating moving boundary towards the center that separates crust and the internal region. It was shown by many researchers that while the temperature in the internal region increases rapidly and stays constant around the boiling point of water (Farkas et al., 1996; Vitrac et al., 2000; Velez-Ruiz et al., 2002); the crust temperature continues to rise above the boiling point of water (Farkas et al., 1996; Hubbard and Farkas, 2000). The formation of crust is a significant quality index for fried foods. Crust characteristics such as color, surface roughness, depth and texture are functions of several factors, such as the food constituents, the frying temperature and duration, and the quality of frying oil. There is sufficient evidence that crust structural characteristic is the main factor influencing mass transfer during frying (Aguilera and Gloria, 1997; Pinthus et al., 1995).

Vapor bubbling is related to water loss rate and decreases after reaching a maximum value with increasing frying time (Costa et al., 1997; Hubbard and Farkas, 2000). Drying rate affects the value of the heat transfer coefficient. The oil agitation caused by the increased rate of vapor loss promotes higher heat transfer rates (Costa et al., 1999; Hubbard and Farkas, 2000). However, there is some evidence that water vapor bubbles form a very poorly conductive gas layer around the sample and may result in an additional resistance to heat transfer (Fellows, 1996; Costa et al., 1999). Sahin et al. (1999) have found different convective heat transfer coefficients at the top and bottom surfaces of potatoes during frying which created an asymmetric temperature profile within the sample.

There are physical and chemical changes taking place during deep frying. Chemical changes are observed in the fried substance due to the effect of temperature and water losses. Also, some chemical interactions occur between food and frying oil. Reported alterations of chemical composition are generally much higher at the

surface and nearly negligible in deeper layers. Proteins are always present in fried foods in greater or lesser amounts. Amino acids and peptides are present in smaller quantities than proteins, but they are much more reactive. The main reaction of proteins during frying is denaturation. As the denaturation temperature is lower than 100°C, the protein fraction is denatured even in inner layers of fried food; this may influence the water holding capacity. Some biologically active substances, such as enzymes, are deactivated under frying conditions; therefore, fried products are usually more stable in storage than raw foods (Boskou and Elmadfa, 1999). The main reactions contributing to the appreciated golden browning of fried foods are considered to be those between proteins and carbohydrates in the complex mechanism of the Maillard reaction. Various intermediate products rapidly polymerized at frying temperatures into brown colored macromolecular melanoidins. The browning becomes very rapid at temperatures higher than 150°C. In the case of fried meat products, the crust browning is not simply due to Maillard reactions, thermal degradation of amino acids and proteins may also participate in browning reactions. An agreeable flavor is the main reason that fried foods are produced and widely accepted. The typical fried flavor is mainly due to lipid degradation products originating from frying oils, but various specific components of fried substances contribute to the overall flavor. Therefore, it is possible to distinguish between flavors of different fried foods (Boskou and Elmadfa, 1999).

1.3 Microwave

In microwave heating, absorption of energy from the microwave field results in internal heat generation within product.

Microwaves are part of the electromagnetic spectrum and are located between the frequencies of 300 MHz and 30 GHz. Microwave heating is defined as the heating of a substance by electromagnetic energy operating in that frequency range (Risman, 1991).

Microwaves are electromagnetic waves between radio waves and infrared waves on the electromagnetic spectrum with a frequency range of 300 MHz to 300 GHz, having wavelengths 1 mm to 1 m (Khraisheh et al., 1997). Since microwave frequencies are close to radio frequencies and can overlap radar range, the allowed values for public use are 2450 and 915 MHz (Giese, 1992).

The microwaves are created by magnetron which converts electrical energy at low frequencies into an electromagnetic field with centers of positive and negative charge that change direction billions of times each second.

Microwaves can be absorbed, transmitted and reflected. Microwaves can be transmitted through glass, ceramics, plastics, and paper, whereas metals such as aluminum foil and steel reflect microwaves. Metal containers should not be placed in the microwave oven since arcing may occur. (Giese, 1992).

Electric field component of microwave is responsible for heating of foods. The alternating electric field stimulates the oscillation of the dipoles of the molecules in the food. These dipolar molecules try to align with microwave field at a speed consistent with the microwave frequency. This rapid movement of polar molecules results in the development of heat, because of the friction between molecules (Knutson et al., 1987). Another mechanism responsible for heat generation is ionic polarization. Ionic polarization occurs when ions in solution move in response to the applied electric field component of microwave. Ions are accelerated by this electric field. Displacement of ions causes collision with other ions, converting kinetic energy into heat (Decareau and Peterson, 1986).

Microwave heating is greatly affected by the presence of water in foods (Nelson and Kraszewski, 1990). Water is the major absorber of microwave energy in the foods and consequently, the higher the moisture content, the faster the heating. The physical state of water in a food affects also microwave heating. Low moisture foods have more uniform heating rate because of deeper microwave penetration (Mudgett, 1989).

In previous studies have shown microwaves propose tremendous advantages, such as time, energy, space and nutrient savings, in food processing operations. (Sahin et al., 2007; Oztop et al., 2007).

Advantages of microwave oven usage can be listed as less start up time, faster heating, energy efficiency, space savings, precise process control, selective heating and food with high nutritional quality (Decareau & Peterson, 1986). Since microwaves penetrate within a food and do not retain just at the surface, heating occurs more rapidly and efficiently. Microwave processing can also be helpful to control energy costs, since heating takes place only in the food material being processed but not in the surrounding medium (Giese, 1992).

1.3.1 Mechanism of Microwave Heating

There are two mechanisms causing microwave heating of foods; dipolar rotation and ionic interaction (Owusu-Ansah, 1991).

Dipolar rotation mechanism is the basic phenomenon for heating of foods at the microwave frequencies (Schiffmann, 1987). Water molecule, being composed of two positively charged hydrogen atoms and one negatively charged oxygen atom, is the main polar molecule present in food products. When water molecules are exposed to an alternating electrical field, they experience a torque or rotational force attempting to orient them in the direction of the field because of their dipolar nature (Buffler, 1993). Due to the changing electrical field and orientation movements, water molecules start to collide with their neighbors randomly. In doing so, a considerable kinetic energy is extracted from microwave field and heating occurs (Buffler, 1993; Decareau & Peterson, 1986).

Distribution of water inside the food as well as shape of the food has the major effect on the amount of heating and causes differences in the rate of heating (Ohlsson and Bengtsson, 2002). Moreover the state of water in the food product, whether it is free

or bound, also affects the microwave absorption and heating. Bound water exhibits much lower microwave absorptivities (Decareau, 1992; Ramaswamy & Van de Voort, 1990).

In ionic interaction mechanism, the dissolved salts present in the food yield charged particles or ions which are accelerated as a result of the force alternating at the rate of microwave frequency. When an accelerating particle collides with an adjacent particle, the temperature of the particle starts to increase due to the effect of impact. As the particle interacts with its neighbors, it transfers agitation and heat to them and when all neighboring particles have had their temperature increased, heat is started to be transferred to the other parts of food material. Since microwave heating of a food material with this mechanism depends on the amount of ions that the microwave can interact with, heating capacity of such a material increases with its conductivity (Buffler, 1993).

1.4 Quality Parameters of Fried and Microwave Cooked Jerusalem Artichoke

Food quality is the sum of all the desirable characteristics that make a food acceptable for eating. Many factors can affect the quality of the final fried and microwave cooked food. Cooked food quality is not only related to the quality of raw materials (foods, frying oil) but also food pretreatment, food geometry, processing method and process parameters. The most important product properties that are measured and examined to determine related quality characteristics in this study are moisture content, oil content, color, texture.

1.4.1 Texture

The term texture is still not well defined in food technology; but it is a very important quality characteristic of the fried product. Texture is a sensory perception, which means that only the human can perceive, describe and quantify it. An

important texture characteristic for fried products is crispness without being very hard. Crispness indicates freshness and high quality (Szczesniak, 1988).

Textural quality is important attribute for the acceptability of fried foods. It consists of a number of different physical sensations or group of physical characteristics that: (1) arise from the structural elements of the food; (2) are sensed by touching; (3) are related to the deformation, disintegration, and flow of food under force and (4) are measured objectively by functions of mass, time, and distance (Bourne, 1982). An important texture characteristic for fried products is crispness. Crispness denotes freshness and high quality (Szczesniak, 1988). A crisp food should be firm and should snap easily when deformed, emitting a crunchy sound (Christensen and Vickers, 1981). Crispness is mostly associated with low moisture foods.

There are several factors affecting textural attributes of fried foods like ingredients, formula and processes (mixing and frying). Frying time and oil type were all found to be significant for the hardness of the fried products (Oztop, 2005).

The crisp final texture of the fried product can be investigated by means of instrumental or sensory techniques. Perhaps the most prevalent objective measurement for crispness is a determination via mechanical properties. The mechanical properties are associated with the structural properties of materials derived by means of the resistance to a compression of blade/probe and to a tensile that pulls the structure of food material apart by a universal testing machine such as Instron or a texture analyzer.

1.4.2 Moisture and Oil Contents

Demand for lower oil-content fried foods has increased with the growing health consciousness of the consumer. Therefore, oil contents of products have to be taken into consideration. Oil absorption into the product during deep-fat frying is influenced by many factors including frying temperature and time (Baumann and

Escher, 1995; Krokida et al., 2000, Kassama and Ngadi, 2004) and moisture content (Gamble et al., 1987; Lamberg et al., 1990).

Excess oil absorption may result from low frying temperatures or overloading the fryer beyond its capacity. At low temperatures, there is a tendency to cook food longer to obtain the desired color of the food. Therefore, oil absorption increases (Orthoefer et al., 1996). In contrast, Moreira et al. (1999) argued that higher oil temperatures lead to a faster crust formation and so favoring the conditions for oil absorption. The oil uptake was found to be negatively correlated with moisture content (Sahin et al., 2000).

1.4.3 Color

Color is one of the most important quality factors in deep fat fried products. The consumer generally uses the color of a product in order to determine the end of the frying process. During frying, the combination of dehydration and high temperature results in brown crust formation. The chemical browning reactions between reducing sugars and protein sources, the absorption of frying oil, density of the fried product, the temperature and frying time lead to color development during frying process (Loewe, 1993). Oztop et al. (2007) showed that frying time and oil type are all significant in color development of potatoes. The increase in darkness with increasing frying temperature and time has been reported for fried food products such as potatoes (Oztop et al., 2007). Ingredient composition and supplemental breading can contribute to perceived color through chemical means (denaturation of protein, gelatinization of starch and browning reaction of batter and breading system), or by physical means (granulation, absorptive capacity). Caramelization, involving thermal degradation of sugars without amine participation also takes place during frying process (Baik and Mittal, 2003).

1.5 Xanthan Gum

Hydrocolloids have been used widely in food products to modify texture, improve moisture retention, control water mobility, and maintain overall product quality during storage (Glicksman 1974). Because wheat starch is a basic ingredient of so many foods, changes in its granule structure and pasting properties in the presence of gums were studied to extend knowledge on the function of starch in cooked and baked products and to expand uses of wheat starch and low-gluten flours in protein-fortified foods (Christianson 1976, Christianson et al 1974).

Xanthan Gum is a high molecular weight exopolysaccharide produced by the bacterium Xanthomonas Campestris. The rheology of xanthan gum is of great practical interest because of its widespread use in the food (e.g., salad dressings, puddings, syrups, etc.) and agriculture (e.g., pesticide sprays) industries. Its most important properties are high viscosity at low shear, substantial shear thinning capability, and good resistance to shear degradation.

The primary structure of xanthan is based on a linear 1,4 β-Dglucose backbone, as in cellulose, with charged trisaccharide sidechains on every second residue. The proportion of pyruvate and acetate substituents present may vary from sample to sample. In most cases, the acetylation of the internal mannose of the sidechains is very nearly stoichiometric but the pyruvate substitution of the terminal mannose may vary from 30-lOO%, depending on the bacterial strain and the fermentation conditions. A detailed analysis of the structure has been presented by Jeanes et al.

The secondary structure (i.e., backbone conformation) is known to undergo an order → disorder (helix→ coil) transition dependent on conditions of salinity and temperature (Morris, 1977, Muller et al., 1986). In distilled water at 25°C, the backbone is disordered (or partially ordered in the form of a randomly broken helix) but highly extended due to the electrostatic repulsions from the charged groups on the sidechains. Due to the highly extended structure, the molecules may align and associate (due to hydrogen bonding) to form a weakly structured material. In this

state, as the temperature is increased, a transition to a coil-like configuration occurs, which causes a dissociation of the molecules and a subsequent change in rheological properties.

1.6 Sodium metabisulphite

The major processing problem for both sweet potato and yams (Greater yam, *Dioscorea alata* and white yam, *D. rotundata*) is the browning resulting from non-enzymatic and enzymatic reactions. Nonenzymatic browning during processing is caused mainly by the reducing sugars and amino acids, which undergo Maillard reaction at high temperatures (Marquez & Anon, 1986). Enzymatic browning caused by the oxidation of phenols by polyphenol oxidases and peroxidases is the most common phenomenon associated with the browning of yams and sweet potato during injury and processing at low temperatures (Almenteros & Del Rosario, 1985; Asemota,Wellington, Odutuga, & Ahmad, 1992; Ozo, Caygill, & Coursey, 1984; Walter & Purcell, 1980). The browning-associated phenolic fractions as well as their oxidizing enzymes have been studied in yams and sweet potato (Akissoe et al., 2003; Izundu, 1995; Osagie & Opoku, 1984; Ozo et al., 1984;Walter & Purcell, 1980;Walter & Schadel, 1981).

During the preparation of edible flour from sweet potato. Sodium metabisulphite is declared to inhibit polyphenol oxidase. Soaking solutions containing SMS raised the total phenols, probably resulting from the in situ synthesis in the cut chips. (Krishnan et al., 2010)

1.7 Objectives of the Study

In the present study, it was aimed;

- To use Jerusalem artichoke as a raw material,
- To produce a new chips and crisp products,

- To use Jerusalem artichoke as a replacer of potato and in chips and crisp production,
- To compare two cooking methods, frying and microwave cooking,
- To compare two preparation methods, chips and crisp,
- To investigate and to evaluate the influences of two proposed cooking and preparation methods on the characteristics of final product,

An additional task, rheological properties of the puree prepared from Jerusalem artichoke flour was investigated.

CHAPTER 2

MATERIALS AND METHODS

2.1 Materials

Jerusalem artichoke used for the experiments was purchased from the commercial market (Nedo Meyve Sebzecilik Ltd. Şti., Ostim, Ankara, Turkey). Sunflower oil (Biryağ, Trakya Birlik, Tekirdağ, Turkey) was chosen as the frying medium. Potato was obtained from the local market to compare quality parameters of Jerusalem artichoke products. Xanthan gum (Sigma, USA) for consistency of Jerusalem artichoke puree and sodium metabisuphite (Merck, Germany) for decoloring of Jerusalem artichoke puree were obtained from the dealers.

2.2 Sample Preparation

2.2.1 Chips Preparation

Fresh Jerusalem artichokes and potatoes were kept in the refrigerator (4263 TMB, Arçelik, Turkey) at +4°C until experiments were done. Raw materials were peeled with a knife and washed under tap water. Washed raw material tubers were sliced in about 2 mm thickness, then chips were cooked in the microwave oven or in the bench top deep fat fryer.

2.2.2 Crisp Preparation

Fresh Jerusalem artichoke was cleaned and washed under running tap water. For thermal treatment, tubers were boiled in a steam cooker (BKK-2175, Beko, Turkey) for 30 minutes. After boiling, tubers were washed again under running tap water. After cooling, tubers were peeled and mashed using a blender (Robokit 2154, BEKO, Turkey.) at its maximum speed for 1 min. The homogenized sample was waited in 1 % (wet basis) sodium metabisulphite solution for 1 hour. After waiting homogenized sample was filtered with filter paper. Filtered homogenized sample mixed with 2 % (wet basis) Xanthan gum and using a blender for the preparation of crisps. Crisps were shaped 2 mm in thickness and then cooked in the microwave oven or deep fat fryer.

2.2.3 Flour Preparation

Jerusalem artichoke puree was dried in an oven at 100 °C ± 2°C. Dried material was separated in small pieces with a blender. Jerusalem artichoke flour was obtained from this dried material with ceramic a mortar.

2.3 Frying

Potatoes, Jerusalem artichoke chips and crisp were fried in the bench top deep fat fryer (HMT 872 L, Bosch, Germany) for 120s, 180s and 240s at 160°C, 170°C, 180°C and 190°C. Fryer contains 2.5 liter oil and four or five pieces were immersed into frying oil each time. The oil was changed after each frying procedure. After fried samples were taken on dry towel and the analysis were done.

2.4 Microwave cooking

Jerusalem artichoke chips and crisp were cooked in the microwave oven (TFB 9730, Bosch, Germany) for 60s, 75s, 90s, 105s, 120s, 135s and 150s at 600 Watt and 900 Watt. One piece was cooked into microwave oven each time and after cooking samples were analyzed. IMPI 2-L test was performed to determine the power level of microwave oven. The procedure and results for the IMPI 2-L test is given in Appendix A.

2.5 Analysis of Samples

2.5.1 Determination of Moisture Content

For moisture measurement, standard gravimetric method was used. For this purpose samples were weighed by an electronic balance (EW-1500-2M, Kern, Germany) with a sensitivity of 1/100 g and placed in a petri dish. The sample was placed in the oven (ST 055, Şimşek Laborteknik, Ankara, Turkey) and held there until constant weight was attained. Moisture content of the sample was calculated from the dry weight (AOAC, 1995).

2.5.2 Determination of Oil Content

The oil content of the fried sample was determined by using Soxhlet extraction method with n-hexane for 6 hours after the Jerusalem artichoke sample was dried in the conventional oven (James 1995). Results are given in dry basis.

2.5.3 Measurement of Color

Color of fried and microwave cooked samples were measured using a Minolta Color Reader (CR-10, Konica Minolta, Osaka, Japan). The color readings were expressed

by CIE (L*, a*, b*) color system. Color readings were carried out at room temperature on three different sections of each sample and the mean value was recorded. The L* value represents 'lightness', from 0 (black) to +100 (white). The a* value represents 'redness' or 'greenness' ranging from +60 to -60 while b* value represents 'yellowness' or 'blueness' (McGuire, 1992).

2.5.4 Measurement of Texture

Texture measurement of Jerusalem artichoke samples was carried 60min after cooking, using a Texture Analyzer (TA-XT Plus, Stable Micro System, UK). Three point bend probe was attached to the instrument setted to; compression force mode; trigger force 5.0 g; pre-test speed 1.0 mm/s; test speed 5.0 mm/s; post-test speed 10.0 mm/s; and rupture distance 10 mm. Samples were assembled horizontally on the base of the equipment. Hardness of the products was quantified by measuring force (gforce) required for breaking of fried chips. Deformation distance at fracture (mm) was used to describe fracturability of products. The results were expressed as the arithmetic average of three determinations per sample.

2.5.5 Rheology Measurement

Jerusalem artichoke puree was used for rheological measurements. Rheological measurements were conducted using a TA rheometer (RA 2000ex, Sussex, UK). All measurements were conducted at 20°C, using parallel plate geometry with solvent trap system (40 mm diameter and 2 mm gap). The puree sample was placed between the plates and the edges were carefully trimmed with a spatula. The flow experiments were conducted under steady-shear conditions with shear rate ranging from 1 to $50s^{-1}$. For the relaxation of the residual stresses, the puree was rested at room temperature for 20 min before testing. In the case of the dynamic oscillatory experiments, first linear viscoelastic region of the samples were determined. Shear

stresses versus shear rate data were obtained. All the rheological experiments were performed at least twice and their averages were reported in the study.

2.5.6 Sensory Evaluation

Descriptive panel consist of totally semi-trained 15 panelists, 13 female and 2 male research assistants, 25-30 years old, in the Food Engineering Department of METU. Panelists were trained for approximately 1 hr before the test in the Quantitative Descriptive Analysis (Meilgraad, 1991). Training was given for descriptive terms, evaluation techniques, usage of sensory scales, scoring.

Among all scales and test methods, the 9-point hedonic scale has gained special consideration because of its suitability in measurement of product acceptance and preference. It was developed by Jones et al. (1955) and Peryam and Pilgrim (1957). The scale is easily understood by panelists and is easy to use.

Sensory response variables were selected as cooked Jerusalem artichoke roughness, oiliness, hardness, crispness, fracturability, crunchiness, moistness of mass, roughness of mass, persistence of crisp, oil film, sweet, bitterness, whiteness, char marks and yellow color. Score sheet form was attached in the Appendix B.

Roughness, char marks, whiteness and yellow color were evaluated as appearance, hardness, crunchiness, fracturability and crispness were evaluated as texture, bitterness, oiliness and sweetness were evaluated as flavor, moistness of the mass, roughness of mass and persistence of crisp were evaluated as a chew down characteristics, and finally oil/greasy film was evaluated as a residual characteristics.

Samples were coded by random 3-digit numbers, and each sample consisted of three products in single serving dishes. Evaluations were conducted in separate tables in a controlled temperature room under white fluorescent light. All references, water

(Pınar, Turkey), crackers (Altınbaşak, Ülker) required to clean palate before sampling, were provided during the tests.

2.5.7 Statistical Analysis

All frying and microwave cooked experiments were performed at least in triplicate at each condition for all analysis, mean values were reported. Data obtained from the analysis were assessed by analysis of variance (ANOVA) to determine the significant differences between the effects of frying time and frying temperature besides microwave power and cooking time on quality parameters of microwave cooked and deep-fat fried Jerusalem artichoke samples. If significant difference was found, Tukey's comparison test was applied to determine the difference among means ($p < 0.05$) (MINITAB for Windows, Version 15.0).

2.5.8 Digital Photography

Photographs of results of the experiments were taken using a standard digital camera (Fujifilm FinePix S5500, Fuji Photo Film Co. Ltd., Tokyo, Japan) at the same positions that the images were obtained for the samples.

CHAPTER 3

RESULTS AND DISCUSSIONS

3.1 Moisture Content

In this study one of the investigated properties of Jerusalem artichoke samples was their moisture contents subsequent to the cooking processes of deep fat frying and microwave cooking. For the experiments the Jerusalem artichoke samples to be cooked were prepared in two forms, as chips and as crisp and their moisture contents were determined as function of time, temperature and power level.

In the literature initial moisture content of raw Jerusalem artichoke tubers were given as 82.1% (Danish Food Compositions), 80.1% (FAO), 78% (Whitney, 1999), 79% (Stolzenburg, 2003), 78.9% (Kara et al., 2005). In our experiments moisture content of purchased samples were determined as 85.0% (wet basis) of the fresh weight.

When the chips was placed in hot oil, moisture was rapidly lost in a stream of steam bubbles and the moisture contents falls rapidly. During deep-fat frying, the food was immersed into the oil at a high temperature (180°C - 190°C) that leads to intensive vaporization of the water in the food and transport out through the surface. As water moves out, part of the pore spaces are taken up by the frying oil moving into the material.

Change in the moisture content of the fried Jerusalem artichoke chips and crisp are given in Figure 3.1 and 3.2 respectively. Changes in the moisture content are given as moisture of samples / initial moisture. For the chips it decreased with frying time and temperature. The lowest value was observed at 190°C and 240s , at the highest temperature studied.

Quite a similar behavior was observed for the crisp as well. However, with the crisp, a significant difference existed at all temperatures and times. This difference between the two forms can be consequence of the structure, i.e. fibrous-anisotropic chips as compared to highly uniform crisp most probably containing some entrapped air bubbles.

In both cases cooking temperature was found to be making the profile steeper which may be attributed to the increase in the moisture transfer rate, dM/dt, increasing with temperature.

In Figures 3.3 and 3.4 the results for microwave cooking of the chips and the crisp using 600W and 900W power levels are displayed in the practical range. Obviously, for both forms used the rate of moisture loss increased with the applied power.

As can be seen from Figure 3.1 cooking time was found to create significant differences at different frying temperatures.

Ni and Datta (1999) obtained similar results for the decreasing of moisture content of frying samples with frying time.

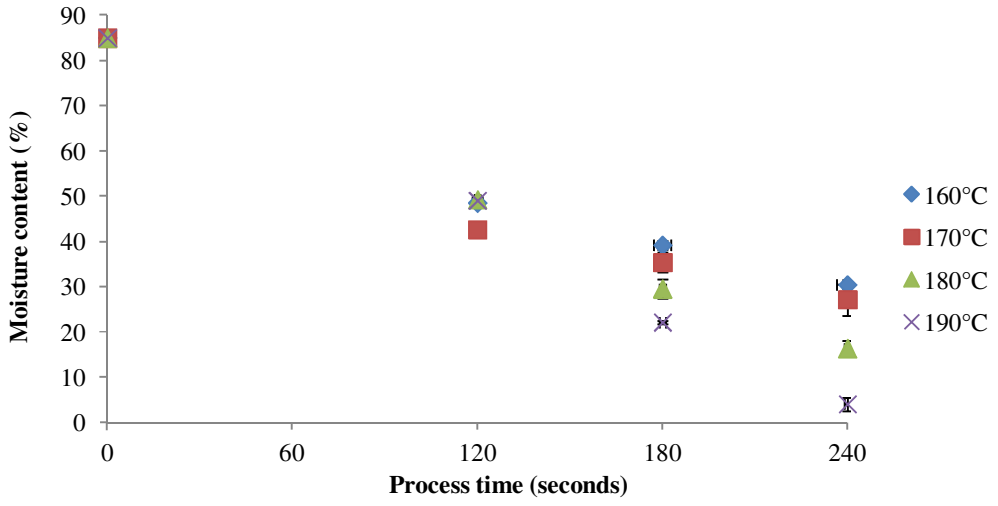

Figure 3. 1 Variation of moisture content of Jerusalem artichoke chips during frying

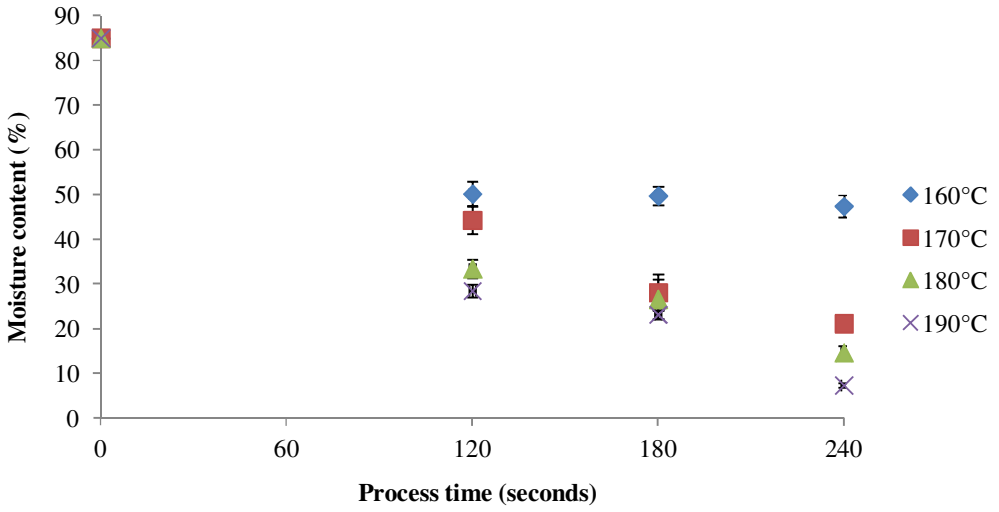

Figure 3. 2 Moisture content variation in Jerusalem artichoke crisp during frying

The effect of the method of cooking can be depicted from the comparison of Figures 3.1 versus 3.3 and 3.2 versus 3.4. The chips form showed that about the same degree of moisture removal is achieved in 120s in microwave treatment at 900W power compared to 240s in frying at 190°C. Thus, rate of moisture removal in microwave cooking is higher than frying. This is most probably due to the contribution of the heat transfer in microwave heating, from interior to surface, which is concurrent with the moisture flow and the pumping action caused by the vapor formed within the material.

Statistical analysis for the cooking processes of Jerusalem artichoke chips and crisp is summarized in Appendix C. Experimental results displayed are the statistically determined frying temperature, microwave power level and process time dependence of the moisture contents of chips and crisp ($p<0.05$).

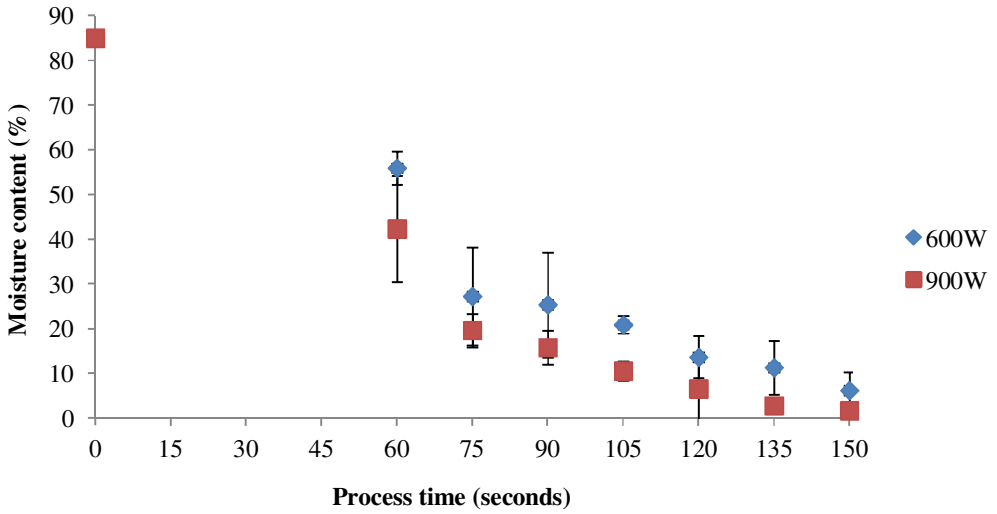

Figure 3. 3 Variation of moisture content in Jerusalem artichoke chips during microwave cooking

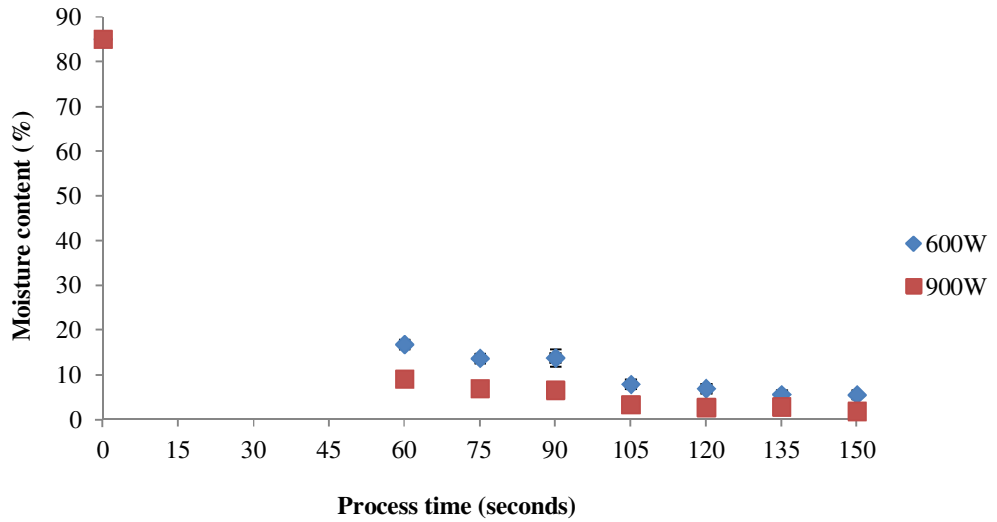

Figure 3. 4 Variation of moisture content in Jerusalem artichoke crisps during microwave cooking

Fried potatoes were also produced using the same method of Jerusalem artichoke chips and crisp. Moisture content of the fried potatoes are shown in Figure 3.5. Decrease in moisture content of the fried potatoes was smaller than the Jerusalem artichoke chips. Thus, final moisture content of the potatoes was higher than the Jerusalem artichoke at the same conditions.

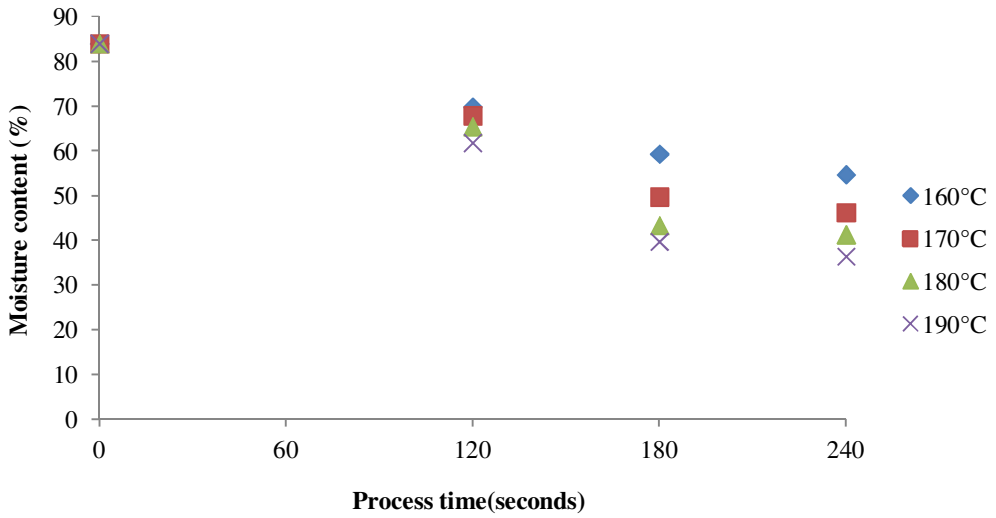

Figure 3. 5 Variation of moisture content in potatoes during frying

Table 3.1 shows moisture content of the commercial chips products and the Jerusalem artichoke samples. Samples for the latter were for the product at 190°C for 240s and at 900W for 150s for cooking methods frying and microwave cooking, respectively. The product obtained in the microwave seemed to be close to commercial products and the fried Jerusalem artichoke was about three times greater commercial products. Initial moisture content of raw materials and thickness of chips may be reasons for difference between moisture content fried Jerusalem artichoke and commercial products.

Table 3. 1 Moisture content of commercial products and Jerusalem artichoke

Products	Moisture content (% db)
Doritos	1.75
Lays	1.65
Ruffles	1.64
Jerusalem artichoke chips (fried)	5.40
Jerusalem artichoke chips (mw cooked)	2.00

3.2 Oil Content

Oil content is one of the most important quality attributes of a deep-fat fried product. The texture of a low-oil-content product can be soft and unpleasant. However, the high oil content is costly to the processor and results in an oily and tasteless product.

A study about frying showed that deep-fat frying is a widely used and industrially important food process. The fried food develops a crispy porous structure in addition to flavor and other chemical changes that is desired by the consumer. During deep fat frying, the food is immersed into the oil at a high temperature (180°C - 190°C) that leads to intensive vaporization of the water in the food and transport out through the surface. As water moves out, part of the pore spaces are taken up by the frying oil moving into the material (Ni et. al., 1999). The experiments with dyed oil showed conclusively that oil does not penetrate the potato chips during frying, but is taken up by the chips only when it is removed from the frying pan due to adhesion of oil to the surface of the chips (Ufheil et al. 1996).

Oil tends to replace water inside the product because the shrinkage of the product during frying is incomplete. Adhering oil being pulled into the chips when it is removed from the fryer due to the condensation of steam producing a vacuum. Oil contents of Jerusalem artichoke chips were determined after frying. The results are given in Figure 3.6. At all temperatures the level of oil for the studied treatment times increased. The weight percentages of oil absorbed increased from 6.9 % (w/w)

to 9.8% within the frying times of 120 to 240s at 160°C. When temperature of 190°C was employed, the highest increasing rate of oil was observed. Results in Appendix C showed that the oil content of frying Jerusalem artichoke chips is strongly dependent on temperature, whereas frying time was not a statistically significantly process variable ($p>0.05$).

It was shown in a previous study that oil content was not directly related to frying temperature but was more closely related to the remaining moisture present (Gamble et al. 1987). In addition Krokida et al. (2000) observed temperature of frying process increases the oil content for the same process time increases. Southern et al. (2000) reported that internal oil content of the flat cut crisps increases as the moisture content decreases.

Similarly, oil contents of Jerusalem artichoke crisp were determined for frying (Figure 3.7). However, the results at 160°C, a decrease from 7.72% to 6.26% within 120 to 240 sec were inconsistent with those at the other temperatures. When the temperature was increased to 190°C the oil contents of the crisp increased quite linearly from about 14.24% to 17.79% for the treatment times of 120 and 240s, respectively. Increase in the oil level of the crisp observed increased with the processing time as expected. The experimental results for the oil contents of the crisp displayed were found to be statistically depending on temperature and time ($p<0.05$) (Table C.5).

Process temperature has a positive effect on oil content of the Jerusalem artichoke products. Oil content of crisp samples at 190°C was higher than that of the chips, whereas at the other cooking temperatures oil content of the chips was more than the crisp products.

In looking at the oil content of commercial products sold in the markets, oil content of the Jerusalem artichoke products was less than these commercial competitors (Table 3.2). Difference between oil content of commercial and fried Jerusalem

artichoke products lends to support the decreasing moisture content of these products.

Table 3. 2 Oil content of commercial products

Sample	Oil content (%db)
Doritos	25
Lays	31
Ruflles	33
Fried potatoes (at 180°C for 180s)	22

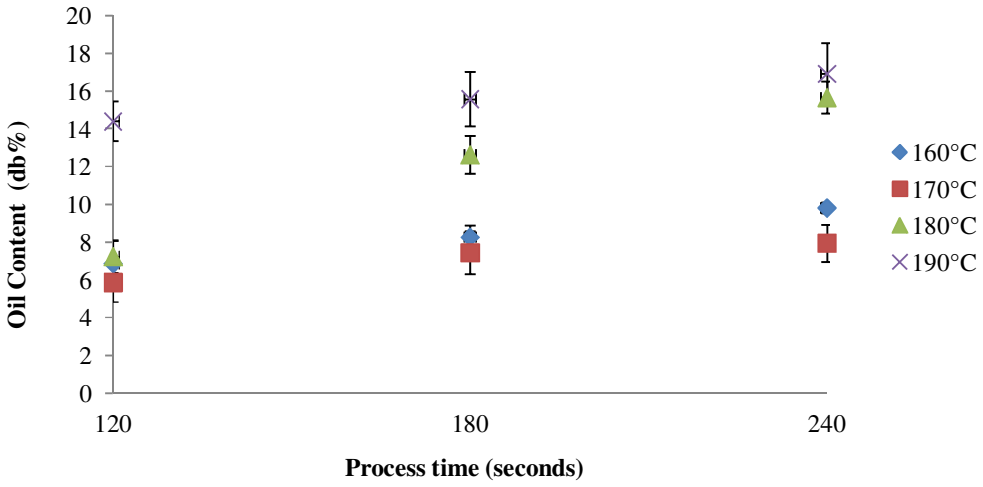

Figure 3. 6 Oil content of the fried Jerusalem artichoke chips

Increase in oil content of fried samples (Figures 3.6 and 3.7) was inversely proportional to decrease in moisture content of these samples (Figures 3.1 and 3.2). Based on this observation oil was taken instead of water away from the fried samples colud be called.

While less moisture reduction was observed in fried potatoes (Figure 3.5) compared to Jerusalem artichoke ones, oil uptake of fried potatoes was higher than Jerusalem artichoke samples. The reason for this shrinkage of Jerusalem artichoke samples was more than potatoes ones was thought.

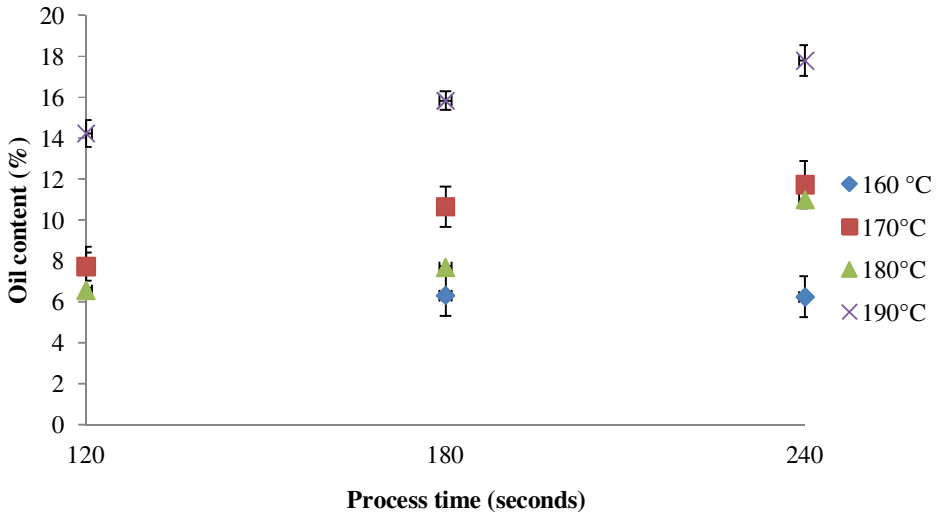

Figure 3. 7 Oil content of the fried Jerusalem artichoke crisp

3.3 Color

Color is an important factor influencing consumer acceptance of a fried product. It can indicate high-quality products such as the golden yellow of a potato. The producer generally uses the color of a product in order to determine the end of the frying process (Baixauli, Salvador, Fiszman and Calvo, 2002).

Color of fresh Jerusalem artichoke slice was given in Table 3.3. These values were obtained at three different points of the chips before the experiment.

Table 3. 3 Color values of raw Jerusalem artichoke slice

L^*	a^*	b^*
74.3	-1.1	7.8

Color values of the commercial chips samples are given in Table 3.4. Measured lightness (L^*) values of the commercial products were approximately the same with that of the fried Jerusalem artichoke chips. Lower a^* and b^* values were observed for Jerusalem artichoke compared to the commercial products and potatoes.

Table 3. 4 Color values of the commercial chips and fried potatoes

	L^*	a^*	b^*
Doritos	62.3	25.6	55.6
Ruffles	68.4	2.1	38.1
Lays	67.4	0.4	34.7
Fried potatoes	63.2	0.1	33.6

Color values of the fried products were examined first. Color change of the products of Jerusalem artichoke was evaluated at different temperatures or power levels and time combinations for frying process or microwave cooking. Color of the fried product is the result of the Maillard reaction required for desirable color, flavor and aroma production. It depends on the content of reducing sugars and amino acids or proteins at the surface, and temperature and time of frying. Acrylamide might be generated during a side reaction of the Maillard reaction. Crucial participants in this reaction are an amino acid (asparagine) and reducing sugars (fructose and glucose). In a previous study on the amount of reducing sugar in Jerusalem artichoke was

found to have a residual reducing power of 0.5-2.5% (after removal of mono and disaccharides) from the native inulin (Stevens et al. 2001). Acrylamide content of Jerusalem artichoke products could not been detected in this study.

The effect of time and temperature and power level on color of Jerusalem artichoke products was shown in terms of CIE L^*, a^*, b^* values. The three parameters were quantified on each sample with the color reader.

The first color parameter L^* values for the fried chips of Jerusalem artichoke indicated that in the studied range of 120s to 240s. Influence of temperature was observed on L^* values as a curve when the frying temperature was varied from 160°C to 190°C (Figure 3.8). Increase in temperature from 160°C to 170°C resulted in higher L^* values at different frying times whereas further increase of temperature up to 190°C caused a decrease in L^* values. As expected, an increase in frying temperature and time resulted in significant changes ($p<0.05$) in L^* values of Jerusalem artichoke chips (Table C.7). In addition, the change of color for the fried Jerusalem artichoke chips can be seen in Appendix D. Reduction in L^* and increase in a^* values of the fried Jerusalem artichoke chips with increasing frying time showed that they became darker and have more red, respectively. L^* values of commercial products and fried potatoes were close to the results of fried Jerusalem artichoke products (Table 3.4).

In the previous study about the effect of time and temperature on L^* and a^* values showed that color changes are confirmed by an increase in parameter a* and the reduction of L^* during conventional deep frying (Innawong et al., 2006; Dogan et al., 2005). In addition, a^* and b^* values generally showed an increase as frying time increased in accordance with the results of Krokida, Oreopoulou, Maroulis, Marinos-Kouris (2001b).

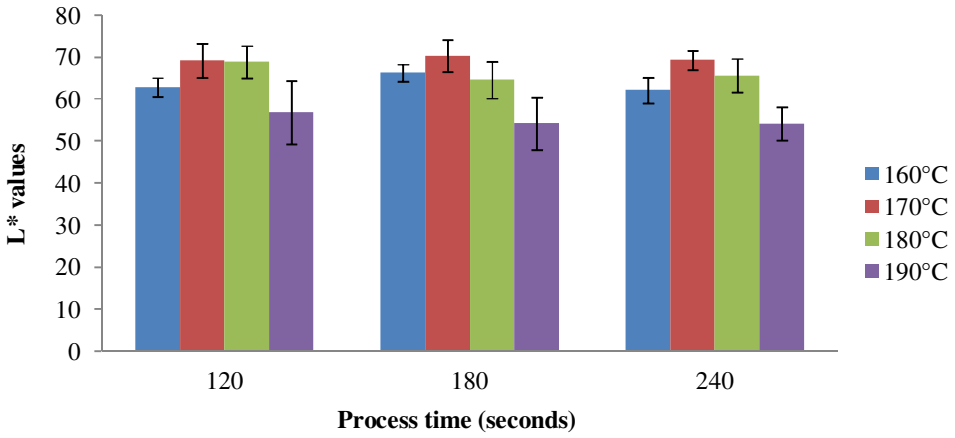

Figure 3. 8 L^* values of frying Jerusalem artichoke chips

As one of the other color parameters a^* values were investigated. The value of a^* of the fried Jerusalem artichoke chips at 190°C indicated a sharp increase with the frying time and considerable difference with the values at the other temperatures (Figure 3.9). As expected the lowest a^* values were observed at 160°C were it is also possible to state that up to 180s of frying the value is not much affected for an additional about 20°C increase in the frying temperature. However, as can be seen after 180s a sharp increase in the values of a^* seems to be inevitable at temperatures exceeding 160°C indicating a rapid color change. Statistical analysis for the effects of temperature and time were significantly important on a^* values ($p<0.05$) (Table C.8). While a^* values of the fried Jerusalem artichoke were lower than commercial products, they were higher than the fried commercial competitors at 190°C for all processing times (Table 3.4).

According to a study (Krokida et al. 2001a) conducted increase in a^* is not desired because that means a more red product, which is not acceptable especially for fried potatoes. The parameter a^* increases significantly during frying. As the temperature of frying increases, a^* increases for the same frying time.

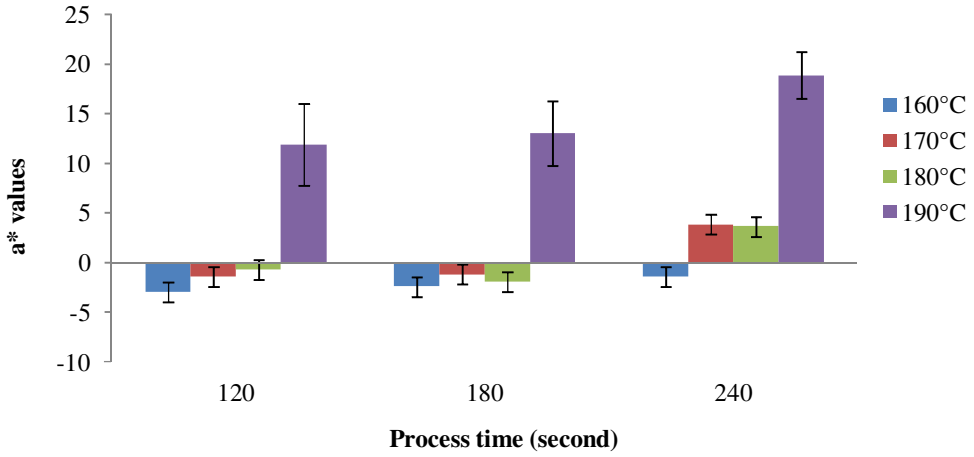

Figure 3. 9 a* values of frying Jerusalem artichoke chips

The last quantified color parameter was b* value to decide on the color of fried chips. In general higher b* values of products give more yellow products, which is desirable for the fried products. Changing the frying oil temperature from 160°C to 190°C resulted with an increase in b* values of the fried chips, but frying at 160°C and 180°C for 180s caused decrease in b* values compared to 120s and 240s processing. Higher b* values were measured with further increase of temperature up to 190°C (Figure 3.10). Krokida et al. reported that the change of b* values fried potatoes significantly increases with temperature. These results are in line with the results of fried Jerusalem artichoke chips.

Final b* values of the Jerusalem artichoke products were smaller than that of potatoes. A reason can be due to the initial b* value of Jerusalem artichoke was also smaller than potatoes, so less yellow products are obtained (Table 3.3)(Figures D1-D.4). Time and temperature were also found to be statistically important ($p<0.05$) on b* values of fried chips of Jerusalem artichoke (Table C.9). For the commercial products b* values were higher than the Jerusalem artichoke samples except those cooked at 190°C, for which values were nearly same with commercial alternatives (Table 3.4).

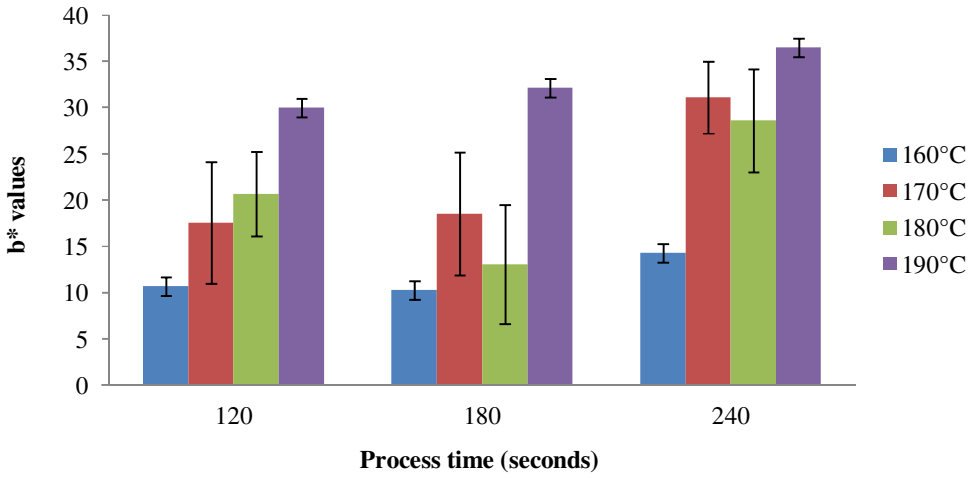

Figure 3. 10 b^* values of frying Jerusalem artichoke chips

For the color parameters of Jerusalem artichoke crisp samples were investigated and the L* values of fried crisp are given in Figure 3.11. Increase in temperature from 160°C to 190°C caused a decrease in L* values quite similar to the fried chips. In both cases, lightness decreased very gradually with the treatment time and decreased with the frying temperature. Temperature was found to be significantly ($p<0.05$) important on L^* values of fried Jerusalem artichoke crisp but time is not important statistically (Table C.10).

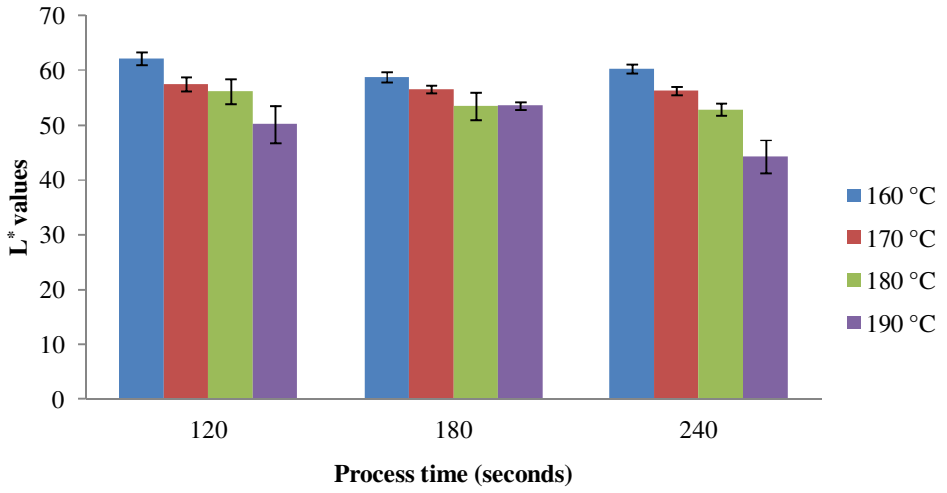

Figure 3. 11 L^* values of frying Jerusalem artichoke crisp

The variation for the a^* values of fried Jerusalem artichoke crisp seemed to be not affected up to about 180s of treatment but upon exceeding this time 180°C and 190°C variation showed a steep rise owing to the reason at again those 160°C and 170°C practically remained steady (Figure 3.12) . The lowest a^* value was observed at 240s for 160°C. Statistical analysis for the effects of temperature and time on this color parameters indicated that the changes in a^* value of fried Jerusalem artichoke crisp with time and temperature were statistically ($p<0.05$) important (Table C.11). Color change from yellow to brown of fried crisp can be seen Figures D.5 – D.8.

When crisp and chips were compared in terms of a^* value, it is possible to state nearly close values were obtained except at 190°C for the chips.

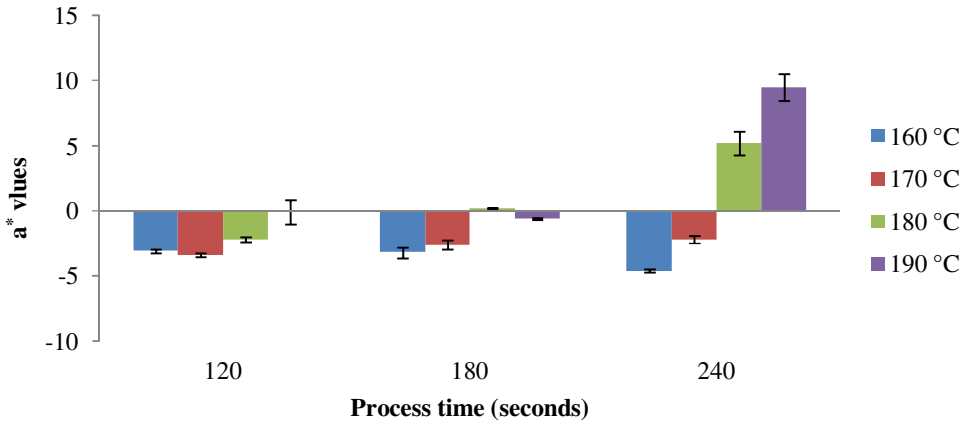

Figure 3. 12 a* values of frying Jerusalem artichoke crisp

The final color parameter b* value of fried Jerusalem artichoke crisp, in general increased with time and temperature (Figure 3.13). The treatment time and temperature were found to be statistically important ($p<0.05$) on b* values of fried crisp of Jerusalem artichoke (Table C.12). Desired golden yellow color was obtained during frying of the crisp.

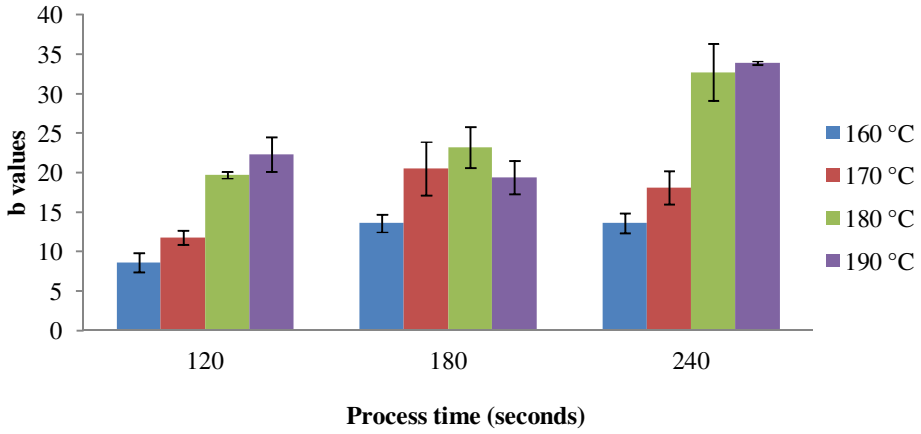

Figure 3. 13 b* values of frying Jerusalem artichoke crisp

Color values of microwave cooked Jerusalem artichoke samples were analyzed and results are given below. Color values of the microwave treated samples were determined similar to the fried ones. For the first color parameter, L^* values of the microwave cooked chips, experimentally determined effect of time and power level are given in Figure 3.14. Though a gradual decrease is present, the time of the treatment and power level were found to be a significant ($p<0.05$) variable affecting the L^* values of the chips in the studied range 60 to 150s (Table C.13). Color changes of microwave cooked samples can be seen in Figures D.9 – D.10. Higher L^* values were obtained in microwave cooked samples, because cooking process was faster than frying.

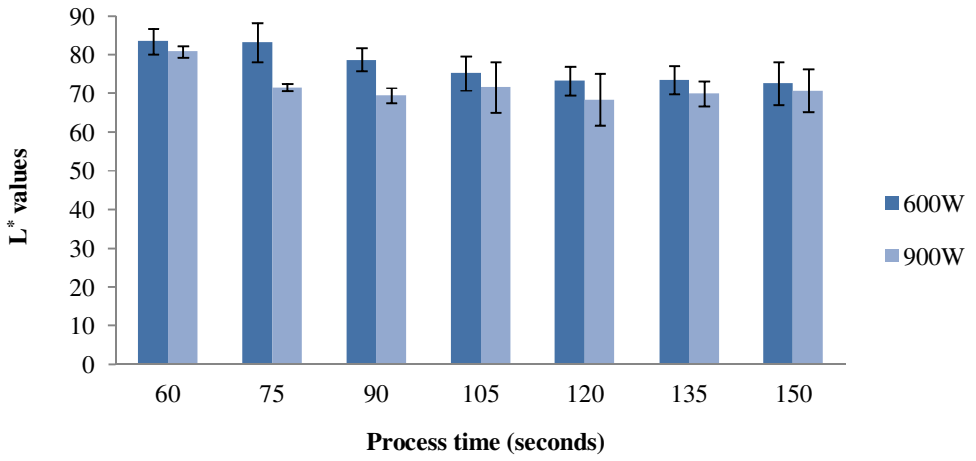

Figure 3. 14 L^* values of microwave cooked Jerusalem artichoke chips

The next color parameter a^* values of the microwave treated Jerusalem artichoke chips are given in Figure 3.15. The a^* values of the chips showed and S shaped trend and both the time and the power level were found to be significant ($p<0.05$) variables affecting the a^* values of the microwave treated Jerusalem artichoke chips (Table C.14). On the overall variation a greater change in the values was observed at 600W

power level. Also the trend showed that a^* values increased with increasing cooking time up to 120s after which it remained quite constant. a^* values of the microwaved samples were higher than that of the fried samples as the value of L^*.

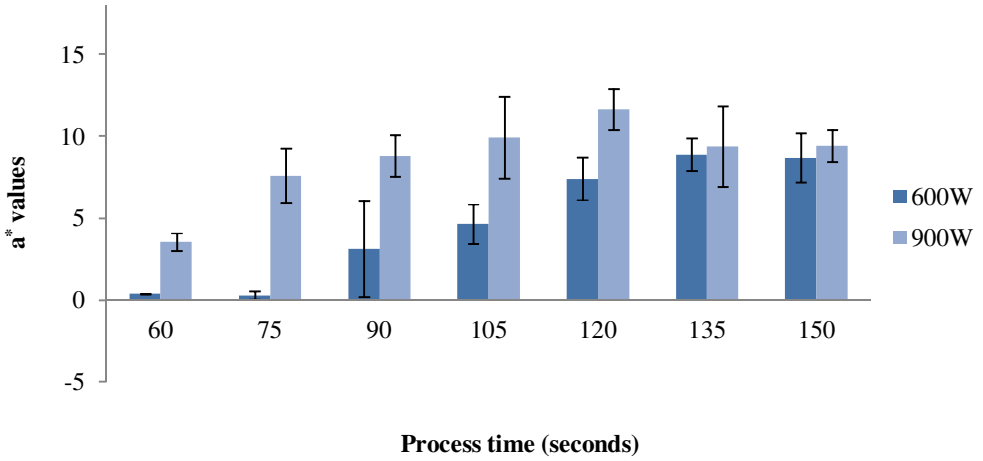

Figure 3. 15 Variation of a^* values of microwave cooked Jerusalem artichoke chips

Another quantified color parameter was b^* value to determine the color of the microwave cooked Jerusalem artichoke chips. The b^* values of cooked Jerusalem artichoke chips are given in Figure 3.16. Time of treatment and power level were determined to be significantly ($p<0.05$) effecting b^* values of chips (Table C.15). Cooking time from 60 to 150s resulted in increase in b^* values of cooked chips at both power levels. As expected b^* values at 900W were higher than those at 600W power level. The b^* values of the microwave cooked Jerusalem artichoke chips were higher than those of the fried samples, so color of the microwave cooked samples were close to yellow (Figures D.9 – D.10).

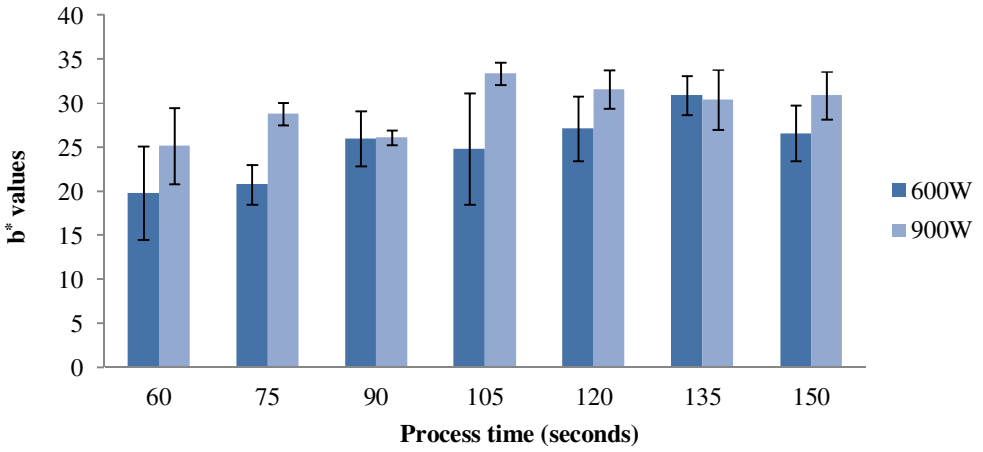

Figure 3. 16 Variation of b^* values for the microwave cooked Jerusalem artichoke chips

Krokida et al.(1999) found that lightness is not significantly affected by the drying method . Drying during in microwave processing to a degree seems to prevent the damage of color seen in frying. More specifically changes in redness and yellowness are more intense during microwave processing.

L^* values of microwave cooked Jerusalem artichoke crisp are given in Figure 3.17. The experimental results indicate a decrease in L^* value with increasing time at 600W but about a constant trend was observed at 900W. As an additional finding, for products prepared using up to about 120s treatment time L^* values at 600W power level were higher than those of 900W. According to the statistical evaluation the power level and the duration of the treatment were significantly ($p<0.05$) affected the L^* values of microwave cooked Jerusalem artichoke (Table C.16).

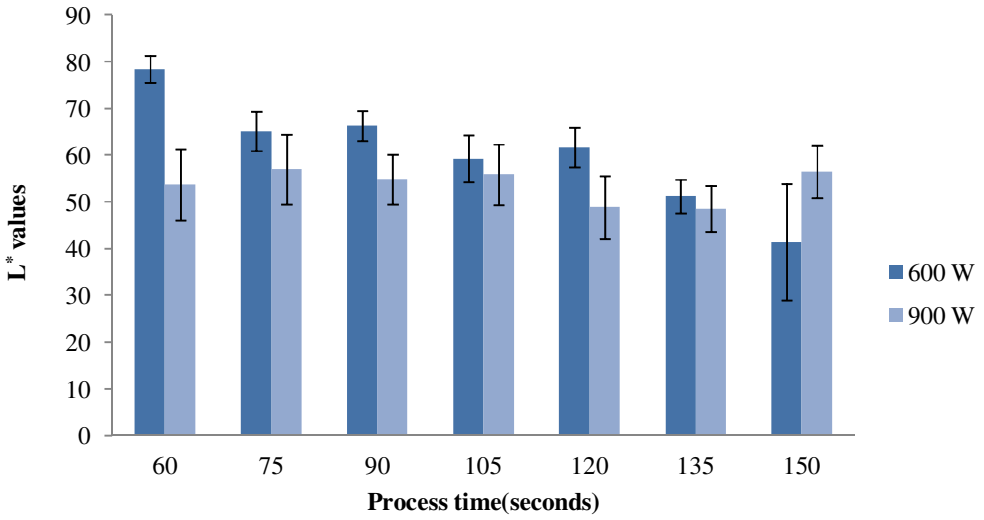

Figure 3. 17 The L^* values of the microwave cooked crisp samples

Another parameter in microwave cooking for the crisp of Jerusalem artichoke was a* values given in Figure 3.18. The a* values of the crisp indicated a strong change of these when a power level of 600W was used. For processing at 900W an increase was observed up to 120s (Figure 3.18). Figure 3.18 showed that a* values constant with increasing cooking time from 120s to 150s at 900W. The sharply increases of a* value was observed up to 105sec, after that slightly increases up to 150s at 600W.

Time and power level were found to be significant ($p<0.05$) variables affecting a* values of the microwave cooked Jerusalem artichoke crisp samples (Table C.17). Lower L^* values were obtained in microwave cooked chips, where color darkening of crisp can be seen in Figures D.11 and D.12.

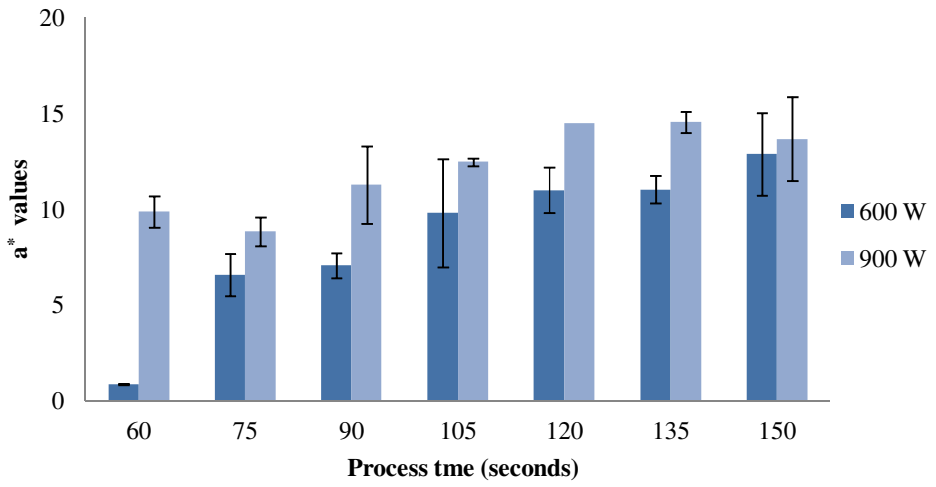

Figure 3. 18 The a* values of the microwave cooked crisp samples

The last quantified color parameter was b* value to determine the color of the microwaved cooked Jerusalem artichoke crisp samples. The b* values are given in Figure 3.19. There was no significant difference between b* values parameters at 900W power level and time on the other hand cooking time up to 75s resulted with a slight increase in b* values of the crisp at 600W power levels. However, b* values exhibited after processing time in the range decrease 135 to 150s at 600W (Figure 3.19). Time and power level were determined to be not significantly ($p>0.05$) effected b* values of microwave cooked Jerusalem artichoke crisp samples (Table C.18). Values of b* obtained for the crisp in microwave cooking were close to the chips samples.

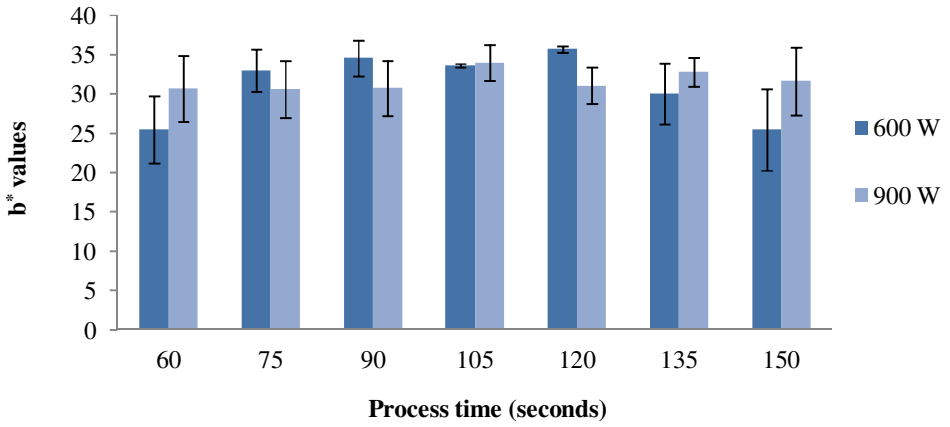

Figure 3. 19 The b^* values of microwave cooked crisp samples

Jerusalem artichoke puree was produced from its flour produced. In deciding about the form of the puree and flour, color was used as the primary parameter. Color values of Jerusalem artichoke puree and flour are shown in Table 3.5. Sodium disulfide added flour was whiter than that of not added. The whitest flour was obtained when sodium disulfide and Xanthan were added into the puree (Figures F.1-F.3) .

Table 3. 5 Color parameters of raw puree and Jerusalem artichoke flour

	L^*	b^*	b^*
Raw puree	59.8	-3.4	-3.2
$Na_2S_2O_5$ not added flour	40.6	17.5	24.3
$Na_2S_2O_5$ added flour	70.8	11.6	29.1
$Na_2S_2O_5$ + Xanthan added flour	88.7	2.1	21.5

3.4 Texture

Hardness and fracturability of the fried Jerusalem artichoke products were determined for the texture analysis which has an influence on consumer demand. Hardness of chips and crisp were quantified by measuring force (gforce) required for breaking the fried or microwaved products. Deformation distance at fracture (mm) was used to describe fracturability of the chips and the crisp.

Firstly, texture profiles of the fried Jerusalem artichoke chips products were evaluated. For fried chips products there was no result at 160°C, 170°C for all treartment times and 180°C for 120s. Therefore, only the fried products at 180°C and 190°C could be tested and these indicated that at higher temperatures and long processing times harder chips were produced, i.e. for 180s and 240s frying. This can be attributed to the lowered moisture content. However, these conditions were found not to be the best to produce chips (Figure 3.20). Treatment time and frying temperature were statistically ($p<0.05$) important on the hardness values (Table C.19).

While Kita et al. (2007) reported that frying temperature had no significant influence on the texture of potato crisp in sunflower oil, according to Segnini et al. (1999) frying time significantly affected hardness of potato chips. On the other hand, results have shown that of this study harder chips were obtained with increase in temperature and time of frying.

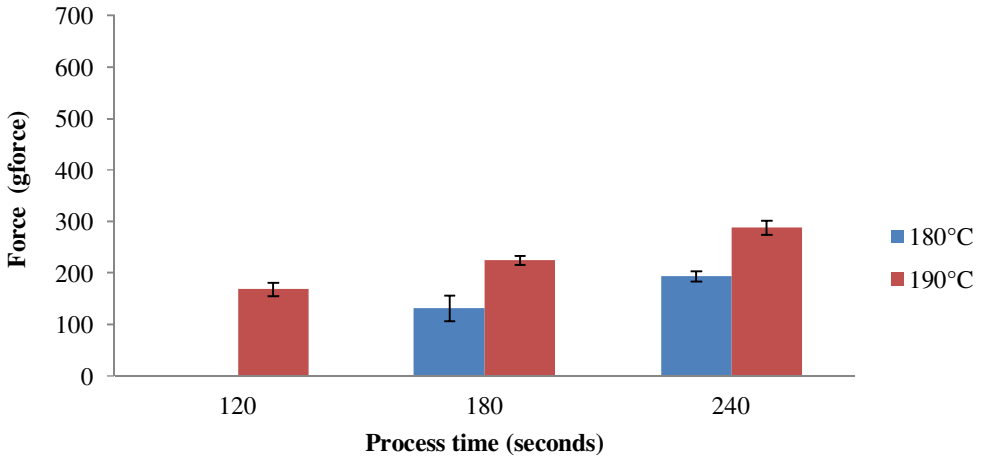

Figure 3. 20 Variation of the hardness of the fried Jerusalem artichoke chips

Again only the products at 180^{o} and 190^{o}C products could be tested for the deformation distance. Increase in the time of frying from 120 to 240s resulted in an increase in the distance values (Figure 3.21). Treatment time and frying temperature were found to be significant ($p<0.05$) variables affecting fracturability of the fried Jerusalem artichoke chips (Appendix C.20).

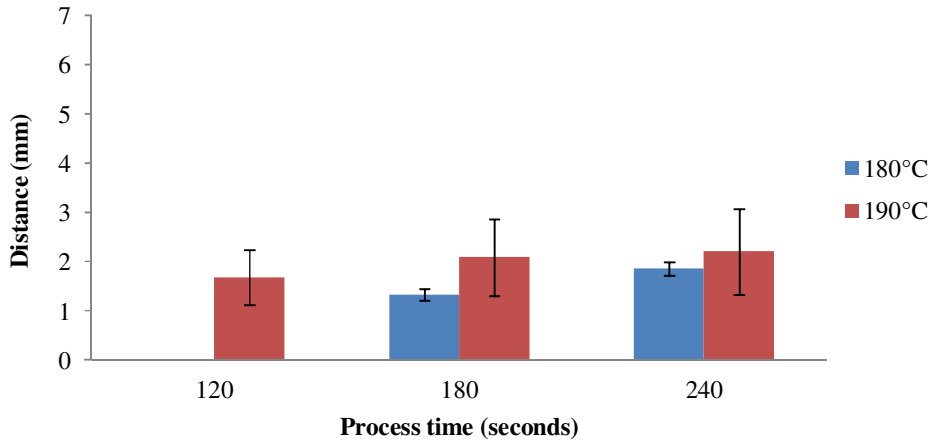

Figure 3. 21 Fracturability of the fried Jerusalem artichoke chips

Deformation force values of the fried Jerusalem artichoke crisps are given in Figure 3.22. Again it was not possible to test the samples prepared at 160^{o}C. The lowest value of the deformation force for the Jerusalem artichoke crisp sample was found for the products prepared at 170^{o}C for 240s processing time. As was pointed above for the chips, higher processing temperatures and longer times resulted in harder products. This is also supported by the statistical finding that processing temperature and treatment time were significantly ($p<0.05$) important on the hardness values of the fried Jerusalem artichoke crisp samples (Table C.21).

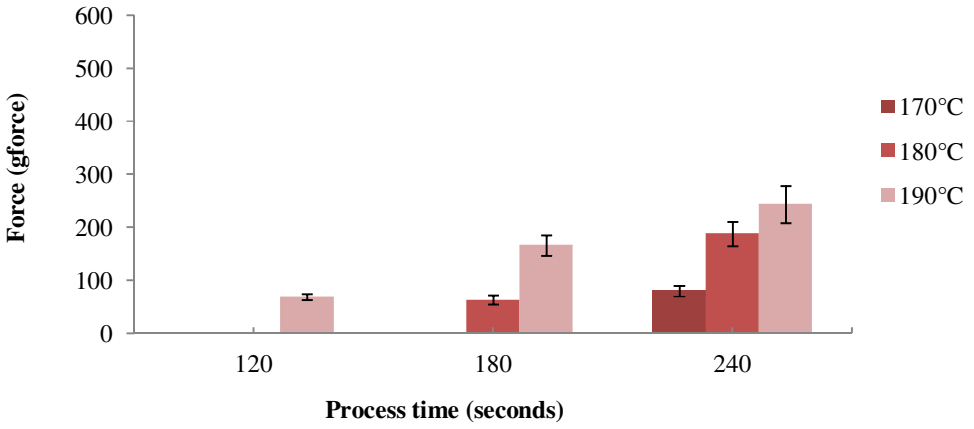

Figure 3. 22 Variation of the hardness of frying crisp samples

Deformation distance values of Jerusalem artichoke crisp for frying are given in Figure 3.23. Increasing time of frying from 120s to 240s resulted an increase in the distance values at 180°C and 190°C. Further, the deformation distances for these two temperatures were of about the same magnitude. Processing time was found as significantly ($p<0.05$) important on fracturability values of the fried Jerusalem artichoke crisp but temperature was not important ($p>0.05$) (Table C.22).

When compared the hardness values of the microwave cooked samples and the deep fat fried samples, the microwaved samples were showed higher value than the fried ones (Figures 3.22 and 3.24). A similar comparison for the fracturability values of the microwave cooked samples and the deep fat fried samples indicated close values as shown in Figures 3.23 and 3.27.

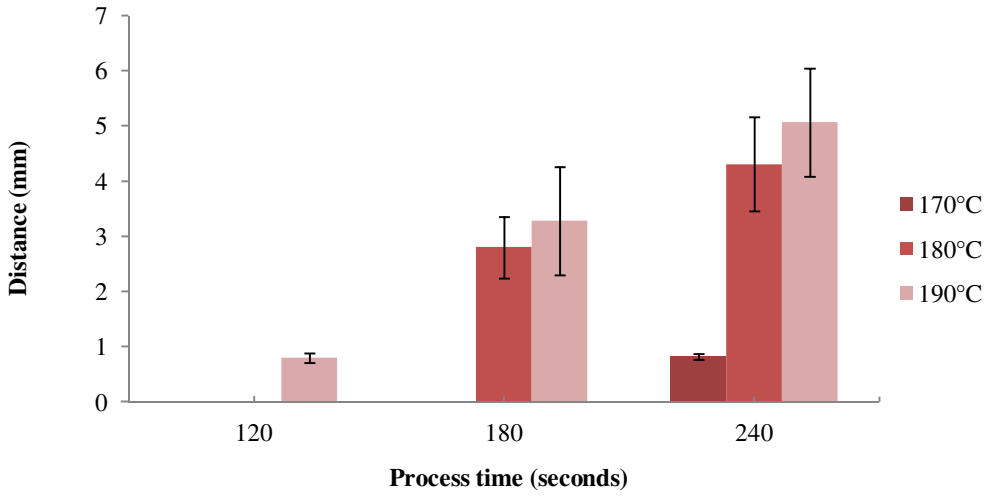

Figure 3. 23 Fracturability of frying crisp samples

In Table 3.6 the texture properties of the fried potatoes chips samples are given. When the Jerusalem artichoke products and the fried potatoes are compared in terms of hardness, while the Jerusalem artichoke chips and potatoes chips values exhibited close values each other, hardness of the crisp was smaller than these. A reason may be that the physical structure of the crisp was changed during the puree production and the final moisture content of the crisp was smaller than that of the chips. Deformation distance of the Jerusalem artichoke chips and the fried potatoes were close to each other but fracturability of the crisp was greater than that of the fried potatoes.

Table 3. 6 Texture properties of the fried potatoes chips

	180°C-180s	180°C-240s	190°C-120s	190°C-180s	190°C-240s
Hardness (gforce)	256.31	300.21	180.56	273.14	350.12
Fracturability (mm)	2.05	2.78	0.89	1.87	3.27

Texture properties of the commercial products are given in Table 3.7. While deformation force values in the first row are close to the microwave cooked Jerusalem artichoke products, hardness values of the fried Jerusalem artichoke products were in accordance with the second row in Table 3.7. The reason for the difference between commercial products may be attributed to the thickness of the products.

Table 3. 7 Texture properties of commercial products

	Hardness (gforce)	Fracturability (mm)
Ruffles	400	2.0
Lays	250	1.0

Hardness values of the microwave processed Jerusalem artichoke chips are given in Figure 3.24 for the products processed at different time-power combinations. Lowest hardness value was observed for the 60s product. The scatter in the data may be due to the non-uniform energy distribution in the oven. Further, processing at 600W or 900W power levels seemed to have no appreciable effect on the hardness. According

to the statistical evaluation, processing time was significantly ($p<0.05$) important on the hardness value of the microwaved cooked Jerusalem artichoke chips but the power level was not important statistically ($p>0.05$) (Table C.23). Hardness values of the fried chips were lower than that of the microwaved cooked products. Low humidity values of the microwave cooked products compare to fried samples may be held responsible for the low hardness values.

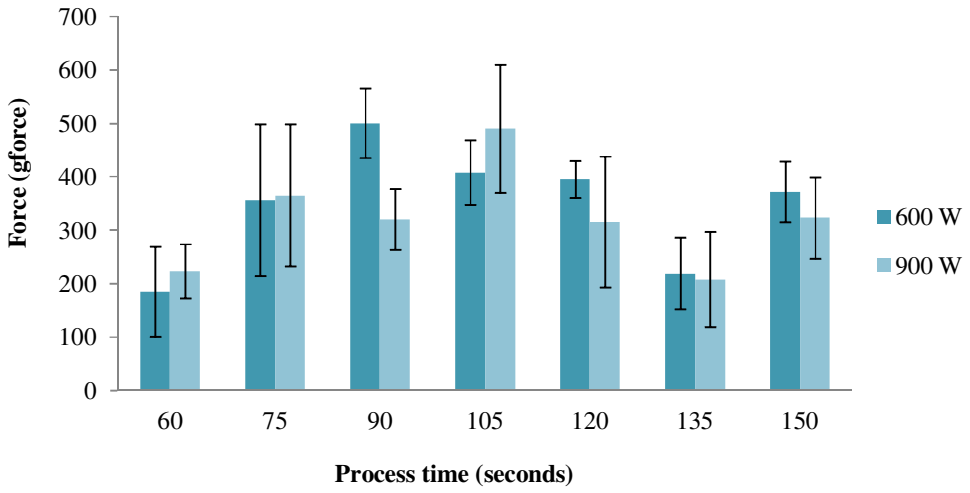

Figure 3. 24 Variation of the hardness of the microwave cooked Jerusalem artichoke chips

Deformation distances at fracture of the microwave cooked chips are given in Figure 3.25. The least value of deformation distance was observed for the both power levels for the 60s processed products. Despite the presence of scatter owing to the reason explained above, it can be said that the fracturability of the 600W and the 900W microwave cooked samples were of about the same magnitude and they attain a final value around 2.5mm. The statistical findings were also found to support this conclusion ($p>0.05$) (Table C.24). As a further means to check the hardness values, deformation distance values were obtained for the microwave cooked samples.

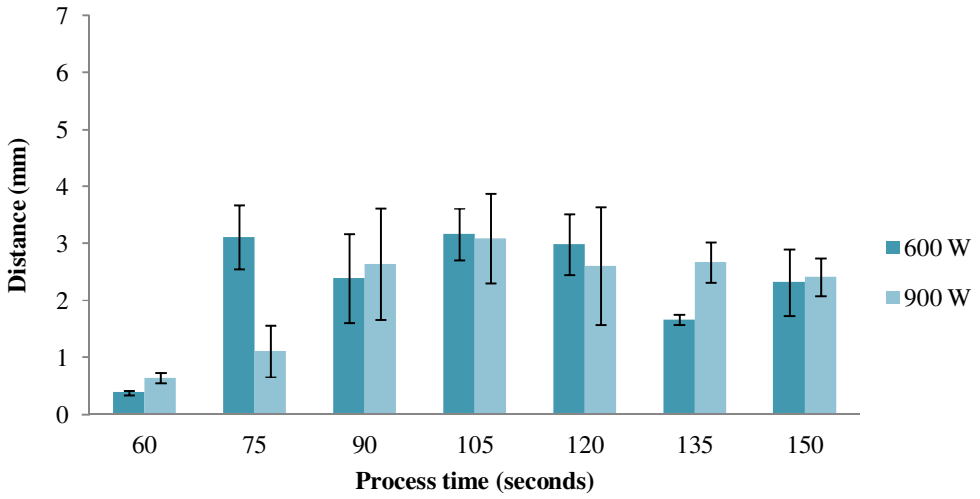

Figure 3. 25 Fracturability of the microwave cooked chips of Jerusalem artichoke

Deformation force values of the Jerusalem artichoke crisp for microwave cooking are shown in Figure 3.26. Owing to the scatter due to the non-uniform energy absorption during processing and the porous structure of the product, the results could be interpreted in an overall frame. Thus, at 600W power level range of the hardness values were 270 - 420gforce with an average of about 320gforce. The corresponding values for 900W were 260 - 570gforce and about 400gforce. Above interpretation is verified by the statistical analysis which showed that neither the processing time nor the power level had significant influence ($p>0.05$) on the fracturability of microwave cooked Jerusalem artichoke crisp (Table C.25). The hardest products were obtained by this method and with an advantage of being fat free.

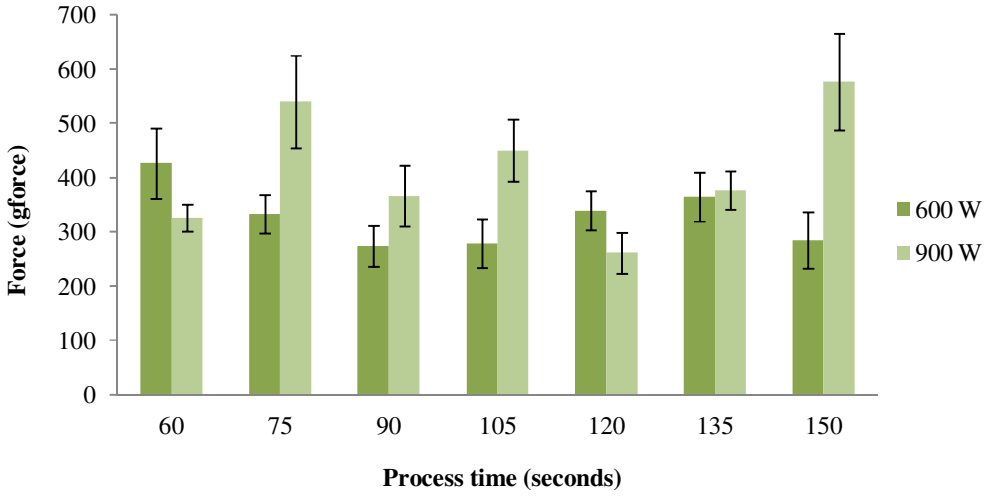

Figure 3. 26 Variation of the hardness of microwave cooked crisp

Deformation distance values for the microwave cooked crisp are given in Figure 3.27. Again at both power levels a coincident variation in the deformation distance was observed in microwave cooked for crisp. The highest deformation distance value was observed at 105s at both power levels. The processing time and the microwave power level were found to be statistically not important ($p>0.05$) on the fracturability of the microwave cooked Jerusalem artichoke crisp (Table C.26).

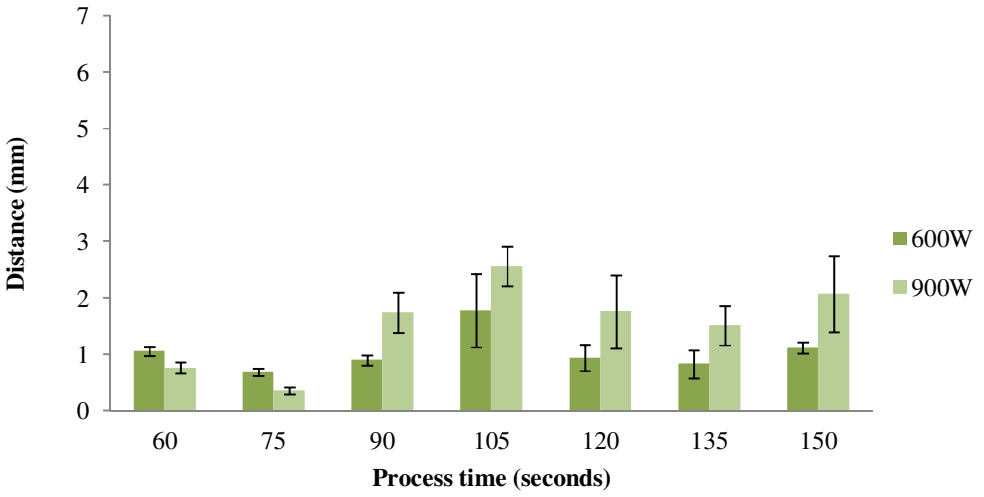

Figure 3. 27 Fracture results of the microwave cooked crisp

3.5 Rheology of Jerusalem artichoke puree

In this section rheological properties of Jerusalem artichoke puree were investigated. This is undertaken to obtain an idea for possible industrial production. Fresh Jerusalem artichokes were boiled, peeled and mashed and then was expressed as pure containing no gum (fresh Jerusalem artichoke puree). Sodium metabisulphite and Xanthan gum were added this pure puree before drying. After drying Jerusalem artichoke flour was obtained. The shear stress versus shear rate data for all puree samples are shown in Figure 3.29.

Picture of Jerusalem artichoke flour can be seen in Appendix F. Sodium metabisulphite was added to get a lighter colored flour (Figure F.3). Akubor (1997) and Krishnan (2010) also used sodium metabisulphite for production of sweet potato flour of desired color. In a previous study about inhibition of polyphenoloxidases showed that sodium metabisulphite was the most effective inhibitor followed by ascorbic acid in the potatoes (Duangmal et al., 1999). El-Beltagy et al. (2007) reported sensory properties of cakes flavored by adding fresh and dried strawberry.

There were no differences noticed in mean score of both cakes taste and flavor among fresh and pretreated with sodium metabisulphite dried strawberry.

Different proportions of water 1-1 to 1-5 parts with 0.5 increments were added to the 2% Xanthan gum containing flour to obtained the Jerusalem artichoke puree samples. This can be seem the rheological behaviour of the original puree and these prepared from the containing 1–4.5 and 1–5.0 part water are quite similar. Though the presence of 2% Xanthan gum in the latter of samples. This shows that by dilution the contribution of the gum decreased.

Rheological properties of the original (85% water, zero Xhantan gum), 1% (wb) and 2% (wb) Xanthan gum added puree are shown in Figure 3.28. Shear stress values of the puree samples increased with the increase in gum content. The value of 2% was preferred in terms of consistence. This consistence was appropriate to bring the chips shape.

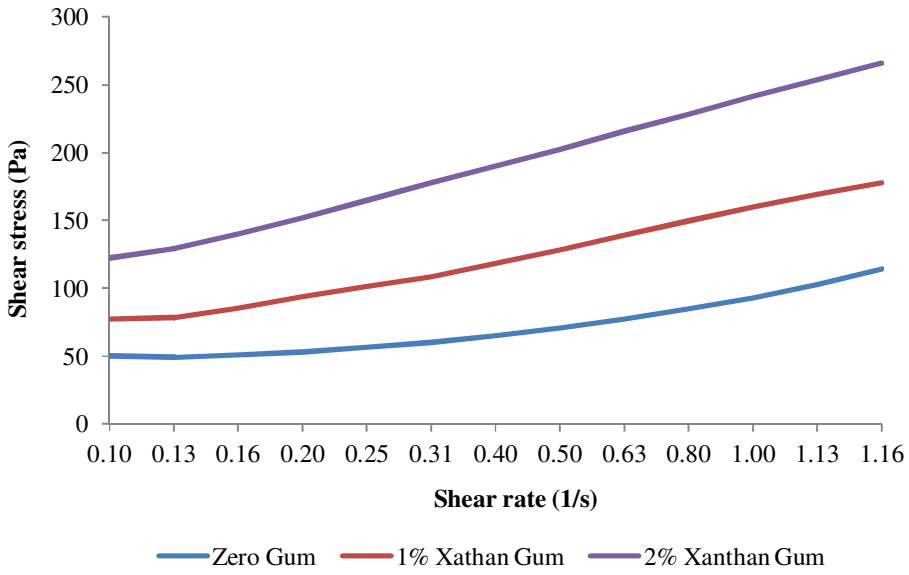

Figure 3. 28 Rheological properties of the Jerusalem artichoke puree and the Xanthan gum added Jerusalem artichoke puree

The shear stress versus shear rate data for all of the different water content puree samples are shown in Figure 3.29. It is observed that for the puree samples containing water higher than the 1-2 ratio, the behaviour can be well represented by a Bingham plastic type relation. For the puree samples below the 1-2 water content most probably consistency phenomena should be considered (Figure 3.28 and 3.29).

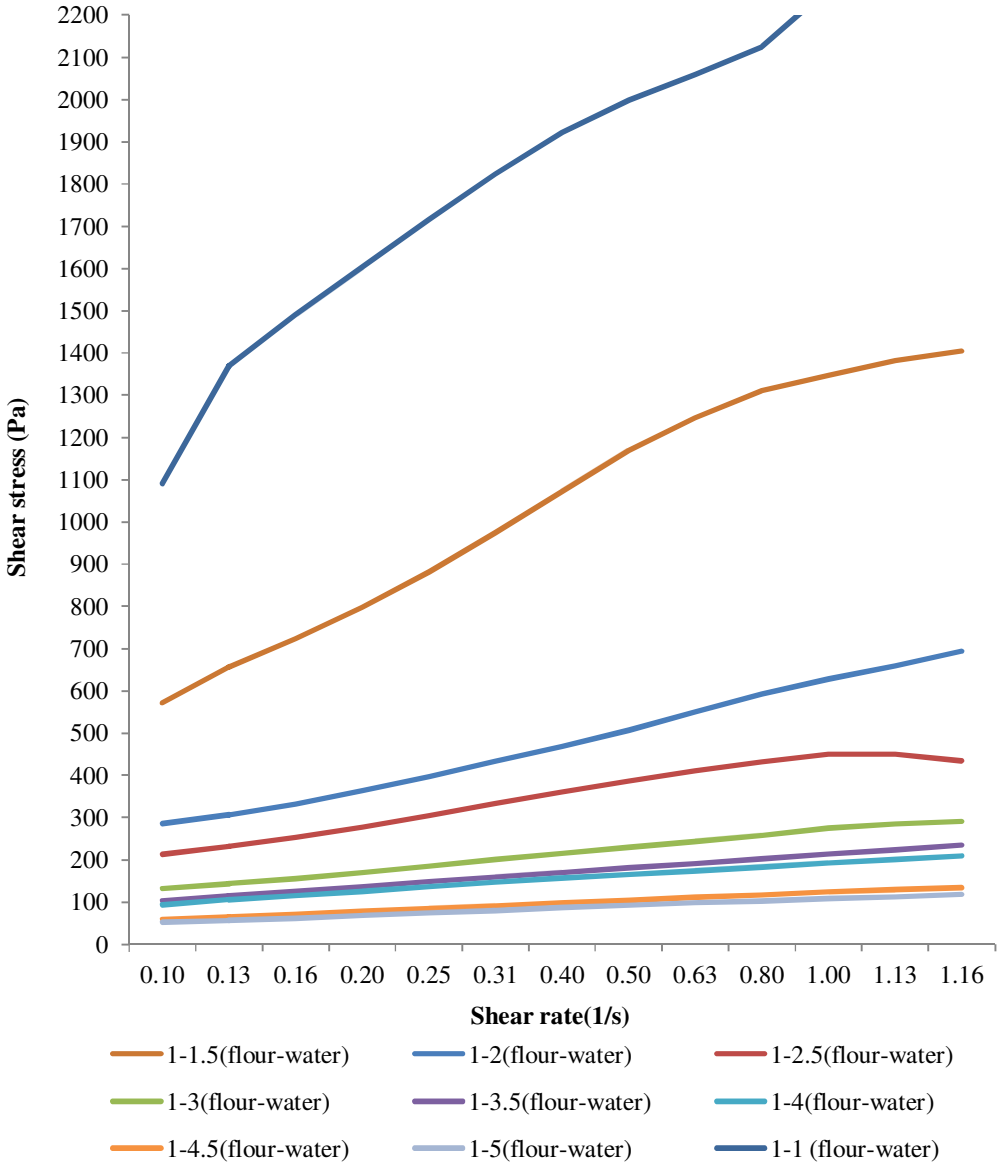

Figure 3. 29 Rheological properties of Jerusalem artichoke puree

3.6 Sensory analysis

A descriptive sensory analysis was applied by 15 trained panelists to all of the products. The sensory evaluations were evaluated according to the ranking test developed for measuring the food acceptability, in which higher score means higher acceptability. The results on the sensory properties of fried Jerusalem artichoke chips are shown in Table 3.8.

While processing time and temperature were not significantly ($p<0.05$) important on the appearance, they appeared to be important on the texture properties and the chew down characteristics. Further, processing temperature was found as significantly ($p<0.05$) important on the flavor of the fried Jerusalem artichoke chips but the processing time was not. For the oil film of the fried Jerusalem artichoke chips processing time turned out to be significantly ($p<0.05$) important but temperature was not (Table C.27).

On the basis of the scores obtained the highest scores for the appearance and the chew down characteristics were product 12. These scores were slightly greater than score of the products 8 and 9. On the other hand, for the texture, flavor and oil film product 9 was favored (Table 3.8). As an overall evaluation the results indicated that the products 9 and 12 can be ranked at the top as the first and second, respectively.

Table 3. 8 Scores for the sensory properties of the fried Jerusalem artichoke chips

	Process conditions		Sensory properties				
Product	Temp (°C)	Time (s)	Appearence	Texture	Flavour	Chew down chracteristics	Oil film
1	160	120	5.0	2.5	2.6	2.6	2.0
2	160	180	5.3	3.2	3.0	2.6	2.5
3	160	240	7.0	4.0	3.3	3.0	4.5
4	170	120	6.1	1.9	3.8	3.2	1.0
5	170	180	7.4	3.9	4.3	3.7	3.0
6	170	240	6.8	7.4	5.5	7.2	2.5
7	180	120	5.5	4.5	4.3	5.2	1.0
8	180	180	7.3	6.1	6.5	7.5	3.0
9	180	240	7.3	8.9	7.0	7.8	9.0
10	190	120	7.0	7.0	6.8	6.2	4.0
11	190	180	6.4	8.9	5.5	8.3	5.5
12	190	240	7.6	8.4	6.5	8.3	6.5

The results of the sensory properties of the fried Jerusalem artichoke crisp are shown in Table 3.9. For the sensory properties of the fried Jerusalem artichoke crisp (Table C.28) both the processing time and the temperature were insignificant ($p>0.05$) on all of the products. There were no results at 160°C, 170°C and at 180°C, because chips form could not be shaped from the Jerusalem artichoke puree due to consistency. The highest scores for the flavour chew down characteristics and oil film were given to the product 1. On the other hand, the highest point for appearance was achieved by the product 3, whereas for the texture the products 1 and 5 were qualified. On the product 1 processed at 180°C for 180s was the most liked one. When the overall evaluation results of the fried chips and the fried crisps are compared for the best products, i.e. product 9 of Table 3.8 and product 1 of Table 3.9, the forms appears to be slightly more preferred. This may be due to the very new taste of the crisp models.

Table 3. 9 Scores for the sensory properties of the fried Jerusalem artichoke crisp

	Process conditions		Sensory properties				
Product	Temp (°C)	Time (s)	Appearence	Texture	Flavour	Chew down chracteristics	Oil film
1	180	180	4.8	8.0	5.9	6.9	4.5
2	180	240	3.7	7.7	4.2	5.9	3.0
3	190	120	7.1	6.9	5.2	6.0	2.5
4	190	180	3.8	6.8	4.5	5.6	2.0
5	190	240	6.1	8.0	4.5	6.3	2.5

Table 3.10 shows sensory properties of microwave cooked Jerusalem artichoke chips. The sensory evaluation results obtained for the microwave cooked Jerusalem artichoke chips (Table C.29) indicated that effects of the processing time and the power level were insignificant ($p>0.05$). The parameters for the highest scores achieved by the various products were for appearance product 3 and 4, for texture at product 6 and 12, for flavor, chew down characteristics and oil product 8. Overall evaluation indicated product 8 as the most liked product

Table 3. 10 Scores for the sensory properties of the microwave cooked Jerusalem artichoke chips products

	Process conditions		Sensory properties				
Product	Power (W)	Time (s)	Appearance	Texture	Flavor	Chew down characteristics	Oil film
1	600	60	5.7	5.9	7.6	6.3	8.3
2	600	75	7.5	6.4	7.6	6.0	8.0
3	600	90	7.8	7.1	7.7	7.3	8.3
4	600	105	7.8	7.8	8.3	7.9	8.3
5	600	120	6.5	7.5	6.7	7.2	8.3
6	600	135	6.7	7.8	6.3	7.2	8.0
7	600	150	6.8	7.4	6.7	7.1	8.0
8	900	60	7.0	7.6	8.6	8.0	8.7
9	900	75	6.9	7.0	7.7	7.8	8.0
10	900	90	7.3	7.6	7.9	7.1	8.0
11	900	105	7.2	7.6	7.2	7.3	8.0
12	900	120	6.3	7.8	6.4	7.3	7.7
13	900	135	6.0	7.6	6.0	7.2	7.7
14	900	150	5.3	7.4	6.0	7.0	8.0

Finally, for the microwave cooked Jerusalem artichoke crisp products the findings showed that the processing time and the power level, as parameters, were not of significant ($p>0.05$) importance on the texture and the chew down characteristics (Table C.30). However, these two process parameters were determined to significant ($p<0.05$) importance on the flavour and the oil film. Further, for the appearance only the time parameter was significant. Because the crisp shape could not be obtained, at 600W for 60s, processing conditions data does not exist. The highest scores for the properties of appearance, flavor and texture were product 7, for chew down characteristics product 11 and for oil film product 2, product 4 and product 7 appeared to the best (Table 3.11). In the overall standing product 7, i.e. crisp processed at 900W for 60s was the most liked. Average score of oil film for microwave cooking was higher than frying, because oil is not used in microwave cooking.

Table 3. 11 Sensory properties of microwave cooked Jerusalem artichoke crisp

	Process conditions		Sensory properties				
Product	Power (W)	Time (s)	Appearance	Texture	Flavor	Chew down characteristics	Oil film
1	600	75	7.8	5.5	7.9	5.0	7.5
2	600	90	6.0	7.0	8.0	7.0	9.0
3	600	105	8.0	7.8	8.5	7.2	8.5
4	600	120	6.8	7.9	8.1	7.3	9.0
5	600	135	5.5	8.0	6.4	7.8	8.5
6	600	150	4.4	6.8	6.6	6.4	8.0
7	900	60	8.3	8.6	8.7	7.7	9.0
8	900	75	7.0	6.6	7.2	5.5	7.0
9	900	90	7.5	5.3	7.0	5.3	5.5
10	900	105	5.0	7.3	4.9	5.0	7.0
11	900	120	7.3	8.0	7.4	8.3	7.5
12	900	135	3.9	7.5	5.0	5.5	7.5
13	900	150	4.3	6.6	6.3	6.7	6.0

A further comparison can be made among the best products of the four processing methods. In Table 3.12 these products are displayed with their sensory scores and ranking accordingly.

Table 3. 12 Comparison of the best products

Product	Type	Appearence	Texture	Flavour	Chew down chracteristics	Oil film	Ranking
9	Fried chips	7.3	8.9	7.0	7.8	9.0	3
1	Fried crisp	4.8	8.0	5.9	6.9	4.5	4
4	Mw cooked chips	7.8	7.8	8.3	7.9	8.3	2
7	Mw cooked crisp	8.3	8.6	8.7	7.7	9.0	1

The table clearly indicates that though there is not much difference between the top two microwave cooked crisp product appears to be the best. This is primarily

because, it is a brand new product for which no palate test experience had been practiced.

CHPATER 4

CONCLUSION AND RECOMMENDATIONS

In this study, the use of Jerusalem artichoke for production of diabetic and/or dietary chips and crisp like products was investigated using the parameters of frying temperature, microwave power, and time of treatment.

In the light of the experimental results obtained it can be said that Jerusalem artichoke, either as chips or as crisp, can be used for production of low or no calorie, no sugar chips.

Frying temperature and time were found to be significant factors on moisture and oil content, color parameters (L^*, a^*, b^* values), texture parameters (hardness and fracturability), where moisture content and lightness of the Jerusalem artichoke products have decreased, but redness and yellowness values, hardness, fracturability and oil content increased with increase with these parameters. However these parameters were found not to be significant on majority of sensory properties (texture, flavour, chew down characteristics, oil film) of fried Jerusalem artichoke products.

While microwave power and treatment time were determined to be significant factors on moisture content, color parameters (L^*, a^*, b^* values) of microwave cooked products, where moisture content and lightness of the microwave cooked Jerusalem artichoke products have decreased, but a^* and b^* values of microwave cooked products increased. Hardness and fracturability values of the products increased with time and then decreased. The texture parameters (hardness and fracturability) and sensory properties (texture, flavour, chew down characteristics, oil film) were not significantly affected by these parameters.

The best result for the studied conditions and combinations for frying was obtained for the chips at 180°C for 240s, for the crisp at 180°C for 180s. For the microwave cooking the best result was for chips at 600W for 105s and for crisp at 900W for 60s.

Microwave cooked Jerusalem artichoke crisp products obtained at the best combination above has also the highest overall grade in the sensory analysis ranking. It is followed by the microwave cooked chips product. The fried Jerusalem artichoke temperature-time combinations were of the third and fourth degree respectively according to the evaluation of the panelists.

Since treatment time for cooking is significantly reduced when microwave cooking is used, this method can be recommended as an alternative to conventional deep fat frying, as oil is not used as well.

Rheological properties Jerusalem artichoke puree with Xanthan gum (2% wb) and sodium metabisulphite (1%wb) showed Bingham plastic behaviour for all puree samples with water content above 50%.

As future studies, development of new products by using Jerusalem artichoke flour and their shelf-lives is promising. In that respect, Jerusalem artichoke flour may be a healthy alternative or substitute for infant foods and baking products. The physical and chemical properties of this product may be investigated.

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APPPENDIX A

POWER MEASUREMENT BY IMPI 2-L TEST

The oven was operated at the highest power level with load of 2000±5 g water placed in two 1-L Pyrex beakers. Initial temperature of water was 20±2 °C. Final temperatures of water were measured immediately after 2 min and 2 s of heating. The power was calculated from the following formula:

$$P\ (W) = (70(\Delta T_1 + \Delta T_2))/2 \qquad (1)$$

Where ΔT_1 and ΔT_2 are the temperature rises of the water in the two beakers calculated by subtracting the initial water temperature from the final temperature. 900W power level was used in this test to measure the power of microwave oven and result was obtained as 75.44% .

The power measurement should be run three times, with the oven power is the average of the three readings. If any individual measurement is more than 5% from the average, the complete test should be repeated. (Buffer, 1993)

Table A. 1 Results of IMPI 2-L Test

Run	**ΔT_1**	**ΔT_2**	**Power (W)**
1	9.7	9.4	668.5
2	9.9	9.5	679.0
3	9.8	9.9	689.5
Average			**679.0**

APPPENDIX B

SCORE AND TRAINING SHEET FOR QUANTITAVE DESCRIPTIVE ANALYSIS

Sample No: Date:
Name :

Please consume all of your sample in order to evaluate all attributes.
Please answer the following questions by completely score that best reflects your feelings about this sample.

Dislike extremely	1
Dislike very much	2
Dislike moderately	3
Dislike slightly	4
Neither dislike nor like	5
Like slightly	6
Like moderately	7
Like very much	8
Like extremely	9

Appearence

Roughness .....
Char marks .....
Whiteness .....
Yellow Color .....

Texture Parameter

Hardness .....
Crunchiness .....
Fracturability .....
Crispness .....

Flavor

Bitterness .....
Oilness .....
Sweetness .....

Chew Down Characteristics:

Moistness of mass .....
Roughness of mass .....
Persistence of crisp .....

Residual Characteristics:

Oily/greasy film .....
-Overall, how do you score this sample? .....
-How do you score the color of this sample? .....
-How do you score the flavor of this sample? .....
-How do you score the texture of this sample? .....
-Do you prefer this product as a snack food? Yes No
-Do you prefer this chips instead of potato chips? Yes No

Roughness: The amount of irregular particles in the surface of the sample. Hold sample to mouth and feel the surface of the sample with tonque and lips.

Oilness: The amount of oily or greasy residue (regardless of the thickness) felt on the lips after placing the sample in mouth. Place sample between lips, compress, and release. Using the tounge to feel the surface of the lips, evaluate the amount of oily/greasy residue felt on the lips.

First Bite

Hardness is defined as the peak force during the first compression cycle. The force required to compress the sample. Compress or bite through the sample one time with molars and incisors.

Crispness: The amount of small breaks felt (percieved as having many light, airy, small breaks), and the degrre of pitch and sound heard when the sample is cracked, broken, or compressed once.

Fracturability: Force with which the sample ruptures when placed between molars and bitten completely down at a fast rate.

Crunchiness: is the gustatory sensation of muffled grinding of a foodstuff. Crunchiness differs from crispiness in that a crispy item is quickly atomized, while a crunchy one offers sustained, granular resistance to jaw action. While crispiness is difficult to maintain, crunchiness is difficult to overcome.

Chew Down Characteristics

Moistness of mass: The amount of wetness/oiliness felt on the surface of the mass. Chew sample with molar teeth 8-10 chews and evaluate. How wet does the sample feel?

Roughness of mass: The amount of roughness percieved in the chewed sample. Chew sample with molars 8-10 times and evaluate the irregularities in the sample mass.

Persistence of crisp: The amount of mastication before the crisp sound changes. Chew sample with molars and count the number of chews completed before the pitch or crisp sound changes.

Residual Characteristics

Oily/greasy film: The amount and degree of residue felt by the tongue when moved over the surface of the mouth. Expectorate thesample and feel the surface of the mouth with tongue to evaluate.

Basic Tastes

Sweet: The basic taste, perceived on the tongue, stimulated by sugars and high-potency sweeteners.

Bitterness is the most sensitive of the tastes, and is perceived by many to be unpleasant, sharp, or disagreeable. Common bitter foods and beverages include coffee, unsweetened cocoa.

Appearance

Whiteness: The amount pure whiteness in the sample. Observe all the chips on the tray.

Char marks: The amount of charred markings on the surface of the sample (usually on one side) that appears to becharred from the baking surface. Observe all the chips on the tray.

APPPENDIX C

ANOVA TABLES

Table C. 1 ANOVA tables of moisture content for fried Jerusalem artichoke chips

```
Factor  Type   Levels  Values
Temp    fixed       4  160; 170; 180; 190
Time    fixed       3  2; 3; 4

Analysis of Variance for Mois, using Adjusted SS for Tests

Source     DF   Seq SS   Adj SS   Adj MS       F      P
Temp        3   659,05   659,05   219,68   23,58  0,000
Time        2  3109,71  3109,71  1554,86  166,92  0,000
Temp*Time   6   585,94   585,94    97,66   10,48  0,000
Error      12   111,78   111,78     9,32
Total      23  4466,48

S = 3,05205   R-Sq = 97,50%   R-Sq(adj) = 95,20%
```

Table C. 2 ANOVA tables of moisture content for fried Jerusalem artichoke crisp

```
Factor  Type   Levels  Values
Temp    fixed       4  160; 170; 180; 190
Time    fixed       3  2; 3; 4

Analysis of Variance for Moisture, using Adjusted SS for Tests

Source     DF   Seq SS   Adj SS  Adj MS       F      P
Temp        3  2733,26  2733,26  911,09  673,44  0,000
Time        2   970,93   970,93  485,46  358,83  0,000
Temp*Time   6   466,99   466,99   77,83   57,53  0,000
Error      12    16,23    16,23    1,35
Total      23  4187,42
S = 1,16314   R-Sq = 99,61%   R-Sq(adj) = 99,26%
```

Table C. 3 ANOVA tables of moisture content for microwave cooked Jerusalem artichoke chips

```
Factor  Type   Levels  Values
Power   fixed       2  600; 900
Time    fixed       7  60; 75; 90; 105; 120; 135; 150

Analysis of Variance for Moisture, using Adjusted SS for Tests

Source      DF    Seq SS   Adj SS   Adj MS      F      P
Power        1    801,90   801,90   801,90  19,12  0,000
Time         6   8333,21  8333,21  1388,87  33,11  0,000
Power*Time   6     73,12    73,12    12,19   0,29  0,936
Error       28   1174,38  1174,38    41,94
Total       41  10382,61

S = 6,47626   R-Sq = 88,69%   R-Sq(adj) = 83,44%
```

Table C. 4 ANOVA tables of moisture content for microwave cooked Jerusalem artichoke crisp

```
Factor  Type   Levels  Values
Power   fixed       2  600; 900
Time    fixed       7  60; 75; 90; 105; 120; 135; 150

Analysis of Variance for Moisture, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS   Adj MS       F      P
Power        1  195,466  195,466  195,466  541,34  0,000
Time         6  322,248  322,248   53,708  148,74  0,000
Power*Time   6   22,484   22,484    3,747   10,38  0,000
Error       14    5,055    5,055    0,361
Total       27  545,253

S = 0,600898   R-Sq = 99,07%   R-Sq(adj) = 98,21%
```

Table C. 5 ANOVA tables of oil content for frying Jerusalem artichoke chips

Factor	Type	Levels	Values
Temp (°C)	fixed	4	160; 170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for Oil, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	266,27	266,27	88,76	4,39	0,026
Time (min)	2	64,70	64,70	32,35	1,60	0,242
Temp (°C)*Time (min)	6	27,94	27,94	4,66	0,23	0,959
Error	12	242,59	242,59	20,22		
Total	23	601,50				

S = 4,49617 R-Sq = 59,67% R-Sq(adj) = 22,70%

Table C. 6 ANOVA tables of oil content for frying Jerusalem artichoke crisp

Factor	Type	Levels	Values
Temp (°C)	fixed	4	160; 170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for Oil, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	292,468	292,468	97,489	38,05	0,000
Time (min)	2	29,516	29,516	14,758	5,76	0,018
Temp (°C)*Time (min)	6	23,200	23,200	3,867	1,51	0,256
Error	12	30,748	30,748	2,562		
Total	23	375,932				

S = 1,60072 R-Sq = 91,82% R-Sq(adj) = 84,32%

Table C. 7 ANOVA tables of L^* values for frying Jerusalem artichoke chips

Factor	Type	Levels	Values
Temp (°C)	fixed	4	160; 170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for L values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	176,27	176,27	58,76	3,06	0,048
Time (min)	2	1008,45	1008,45	504,23	26,24	0,000
Temp (°C)*Time (min)	6	701,06	701,06	116,84	6,08	0,001
Error	24	461,15	461,15	19,21		
Total	35	2346,93				

S = 4,38343 R-Sq = 80,35% R-Sq(adj) = 71,35%

Table C. 8 ANOVA tables of a^* values for frying Jerusalem artichoke chips

Factor	Type	Levels	Values
Temp (°C)	fixed	4	160; 170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for a values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	398,19	398,19	132,73	8,65	0,000
Time (min)	2	1483,11	1483,11	741,55	48,34	0,000
Temp (°C)*Time (min)	6	310,51	310,51	51,75	3,37	0,010
Error	36	552,27	552,27	15,34		
Total	47	2744,08				

S = 3,91674 R-Sq = 79,87% R-Sq(adj) = 73,72%

Table C. 9 ANOVA tables of b^* values for frying Jerusalem artichoke chips

Factor	Type	Levels	Values
Temp (°C)	fixed	4	160; 170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for b values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	760,18	760,18	253,39	3,85	0,015
Time (min)	2	2375,58	2375,58	1187,79	18,03	0,000
Temp (°C)*Time (min)	6	708,28	708,28	118,05	1,79	0,121
Error	48	3161,88	3161,88	65,87		
Total	59	7005,91				

S = 8,11618 R-Sq = 54,87% R-Sq(adj) = 44,53%

Table C. 10 ANOVA tables of L^* values for frying Jerusalem artichoke crisp

Factor	Type	Levels	Values
Temp (°C)	fixed	4	160; 170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for L, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	417,053	417,053	139,018	23,10	0,000
Time (min)	2	36,243	36,243	18,121	3,01	0,087
Temp (°C)*Time (min)	6	65,544	65,544	10,924	1,82	0,179
Error	12	72,220	72,220	6,018		
Total	23	591,060				

S = 2,45323 R-Sq = 87,78% R-Sq(adj) = 76,58%

Table C. 11 ANOVA tables of a^* values for frying Jerusalem artichoke crisp

Factor	Type	Levels	Values
Temp (°C)	fixed	4	160; 170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for a values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	181,588	181,588	60,529	55,28	0,000
Time (min)	2	73,651	73,651	36,825	33,63	0,000
Temp (°C)*Time (min)	6	105,679	105,679	17,613	16,09	0,000
Error	12	13,140	13,140	1,095		
Total	23	374,058				

S = 1,04642 R-Sq = 96,49% R-Sq(adj) = 93,27%

Table C. 12 ANOVA tables of b^* values for frying Jerusalem artichoke crisp

Factor	Type	Levels	Values
Temp (°C)	fixed	4	160; 170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for b values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	796,33	796,33	265,44	28,05	0,000
Time (min)	2	320,97	320,97	160,49	16,96	0,000
Temp (°C)*Time (min)	6	236,43	236,43	39,41	4,16	0,017
Error	12	113,56	113,56	9,46		
Total	23	1467,30				

S = 3,07632 R-Sq = 92,26% R-Sq(adj) = 85,17%

Table C. 13 ANOVA tables of L^* values for microwave cooked Jerusalem artichoke chips

Factor	Type	Levels	Values
Power (watt)	fixed	2	600; 900
Time (sec)	fixed	7	60; 75; 90; 105; 120; 135; 150

Analysis of Variance for L values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	408,50	408,50	408,50	19,61	0,000
Time (sec)	6	872,63	872,63	145,44	6,98	0,000
Power (watt)*Time (sec)	6	412,76	412,76	68,79	3,30	0,007
Error	56	1166,24	1166,24	20,83		
Total	69	2860,13				

S = 4,56353 R-Sq = 59,22% R-Sq(adj) = 49,76%

Table C. 14 ANOVA tables of a^* values for microwave cooked Jerusalem artichoke chips

Factor	Type	Levels	Values
Power (watt)	fixed	2	600; 900
Time (sec)	fixed	7	60; 75; 90; 105; 120; 135; 150

Analysis of Variance for a values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	222,50	222,50	222,50	16,84	0,000
Time (sec)	6	353,37	353,37	58,89	4,46	0,001
Power (watt)*Time (sec)	6	154,13	154,13	25,69	1,94	0,089
Error	56	739,78	739,78	13,21		
Total	69	1469,78				

S = 3,63462 R-Sq = 49,67% R-Sq(adj) = 37,98%

Table C. 15 ANOVA tables of b^* values for microwave cooked Jerusalem artichoke chips

```
Factor        Type   Levels  Values
Power (watt)  fixed       2  600; 900
Time (sec)    fixed       7  60; 75; 90; 105; 120; 135; 150

Analysis of Variance for b values, using Adjusted SS for Tests

Source                   DF   Seq SS  Adj SS  Adj MS      F      P
Power (watt)              1   361,16  361,16  361,16  26,82  0,000
Time (sec)                6   488,55  488,55   81,42   6,05  0,000
Power (watt)*Time (sec)   6   257,91  257,91   42,98   3,19  0,009
Error                    56   754,09  754,09   13,47
Total                    69  1861,70

S = 3,66959   R-Sq = 59,49%   R-Sq(adj) = 50,09%
```

Table C. 16 ANOVA tables of L^* values for microwave cooked Jerusalem artichoke crisp

```
Factor        Type   Levels  Values
Power (watt)  fixed       2  600; 900
Time (sec)    fixed       7  60; 75; 90; 105; 120; 135; 150


Analysis of Variance for L values, using Adjusted SS for Tests

Source                   DF  Seq SS  Adj SS  Adj MS      F      P
Power (watt)              1  1110,9  1110,9  1110,9  11,11  0,002
Time (sec)                6  2343,4  2343,4   390,6   3,91  0,006
Power (watt)*Time (sec)   6   610,0   610,0   101,7   1,02  0,435
Error                    28  2800,0  2800,0   100,0
Total                    41  6864,3


S = 10,0000   R-Sq = 59,21%   R-Sq(adj) = 40,27%
```

Table C. 17 ANOVA tables of a^* values for microwave cooked Jerusalem artichoke crisp

Factor	Type	Levels	Values
Power (watt)	fixed	2	600; 900
Time (sec)	fixed	7	60; 75; 90; 105; 120; 135; 150

Analysis of Variance for a values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	225,875	225,875	225,875	55,99	0,000
Time (sec)	6	306,871	306,871	51,145	12,68	0,000
Power (watt)*Time (sec)	6	85,478	85,478	14,246	3,53	0,010
Error	28	112,960	112,960	4,034		
Total	41	731,185				

S = 2,00855 R-Sq = 84,55% R-Sq(adj) = 77,38%

Table C. 18 ANOVA tables of b^* values for microwave cooked Jerusalem artichoke crisp

Factor	Type	Levels	Values
Power (watt)	fixed	2	600; 900
Time (sec)	fixed	7	60; 75; 90; 105; 120; 135; 150

Analysis of Variance for b values, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	84,58	84,58	84,58	2,70	0,112
Time (sec)	6	194,67	194,67	32,44	1,03	0,424
Power (watt)*Time (sec)	6	151,20	151,20	25,20	0,80	0,575
Error	28	877,93	877,93	31,35		
Total	41	1308,37				

S = 5,59951 R-Sq = 32,90% R-Sq(adj) = 1,75%

Table C. 19 ANOVA tables of hardness values for fried Jerusalem artichoke chips

Factor	Type	Levels	Values
Temp (°C)	fixed	2	180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for Hardness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	1	19969	33581	33581	94,09	0,000
Time (min)	2	33471	33471	16736	46,89	0,000
Error	16	5711	5711	357		
Total	19	59151				

S = 18,8921 R-Sq = 90,35% R-Sq(adj) = 88,54%

Table C. 20 ANOVA tables of fracture values for fried Jerusalem artichoke chips

Factor	Type	Levels	Values
Temp (°C)	fixed	2	180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for Fracture, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	1	13,817	22,069	22,069	9,31	0,008
Time (min)	2	20,091	20,091	10,045	4,24	0,033
Error	16	37,934	37,934	2,371		
Total	19	71,842				

S = 1,53977 R-Sq = 47,20% R-Sq(adj) = 37,30%

Table C. 21 ANOVA tables of hardness values for fried Jerusalem artichoke crisp

Factor	Type	Levels	Values
Temp (°C)	fixed	3	170; 180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for Hardness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	2	4244	25784	12892	10,64	0,011
Time (min)	2	39924	39924	19962	16,48	0,004
Error	6	7268	7268	1211		
Total	10	51436				

S = 34,8043 R-Sq = 85,87% R-Sq(adj) = 76,45%

Table C. 22 ANOVA tables of fracture values for fried Jerusalem artichoke crisp

Factor	Type	Levels	Values
Temp (°C)	fixed	3	170; 180; 190
Time	fixed	3	2; 3; 4

Analysis of Variance for Fracture (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	2	16,214	22,394	11,197	3,63	0,092
Time	2	31,142	31,142	15,571	5,05	0,052
Error	6	18,487	18,487	3,081		
Total	10	65,843				

S = 1,75532 R-Sq = 71,92% R-Sq(adj) = 53,20%

Table C. 23 ANOVA tables of hardness values for microwave cooked Jerusalem artichoke chips

```
Factor  Type   Levels  Values
Power   fixed       2  600; 900
Time    fixed       7  60; 75; 90; 105; 120; 135; 150

Analysis of Variance for Hardness (g), using Adjusted SS for Tests

Source  DF  Seq SS  Adj SS  Adj MS     F      P
Power    1    2622    2622    2622  0,71  0,433
Time     6  103884  103884   17314  4,67  0,041
Error    6   22237   22237    3706
Total   13  128742

S = 60,8781   R-Sq = 82,73%   R-Sq(adj) = 62,58%
```

Table C. 24 ANOVA tables of fracture values for microwave cooked Jerusalem artichoke chips

```
Factor  Type   Levels  Values
Power   fixed       2  600; 900
Time    fixed       7  60; 75; 90; 105; 120; 135; 150


Analysis of Variance for Fracture (mm), using Adjusted SS for Tests

Source  DF   Seq SS  Adj SS  Adj MS     F      P
Power    1   0,0502  0,0502  0,0502  0,12  0,746
Time     6   8,3802  8,3802  1,3967  3,21  0,091
Error    6   2,6081  2,6081  0,4347
Total   13  11,0385

S = 0,659311   R-Sq = 76,37%   R-Sq(adj) = 48,81%
```

Table C. 25 ANOVA tables of hardness values for microwave cooked Jerusalem artichoke crisp

```
Factor  Type   Levels  Values
Power   fixed       2  600; 900
Time    fixed       7  60; 75; 90; 105; 120; 135; 150

Analysis of Variance for Hardness (g), using Adjusted SS for Tests

Source  DF  Seq SS  Adj SS  Adj MS     F      P
Power    1   19488   19488   19488  1,92  0,181
Time     6  112049  112049   18675  1,84  0,142
Error   20  202890  202890   10144
Total   27  334426

S = 100,720   R-Sq = 39,33%   R-Sq(adj) = 18,10%
```

Table C. 26 ANOVA tables of fracture values for microwave cooked Jerusalem artichoke crisp

```
Factor  Type   Levels  Values
Power   fixed       2  600; 900
Time    fixed       7  60; 75; 90; 105; 120; 135; 150


Analysis of Variance for Fracture (mm), using Adjusted SS for Tests

Source  DF   Seq SS  Adj SS  Adj MS     F      P
Power    1    0,011   0,011   0,011  0,00  0,955
Time     6   32,866  32,866   5,478  1,57  0,208
Error   20   69,913  69,913   3,496
Total   27  102,791


S = 1,86967   R-Sq = 31,98%   R-Sq(adj) = 8,18%
```

Table C. 27 ANOVA tables of sensory properties for fried Jerusalem artichoke chips

```
Factor      Type   Levels  Values
Temp (°C)   fixed       4  160; 170; 180; 190
Time (min)  fixed       3  2; 3; 4


Analysis of Variance for Appearence, using Adjusted SS for Tests

Source      DF  Seq SS  Adj SS  Adj MS     F      P
Temp (°C)    3   5,375   5,375   1,792  0,82  0,500
Time (min)   2   6,255   6,255   3,128  1,43  0,265
Error       18  39,328  39,328   2,185
Total       23  50,958

S = 1,47814   R-Sq = 22,82%   R-Sq(adj) = 1,38%


Analysis of Variance for Texture, using Adjusted SS for Tests

Source      DF   Seq SS  Adj SS  Adj MS     F      P
Temp (°C)    3   84,871  84,871  28,290  5,78  0,006
Time (min)   2   40,658  40,658  20,329  4,16  0,033
Error       18   88,028  88,028   4,890
Total       23  213,557

S = 2,21143   R-Sq = 58,78%   R-Sq(adj) = 47,33%


Analysis of Variance for Flavour, using Adjusted SS for Tests

Source      DF  Seq SS  Adj SS  Adj MS     F      P
Temp (°C)    3  40,698  40,698  13,566  7,41  0,002
Time (min)   2   5,615   5,615   2,808  1,53  0,243
Error       18  32,975  32,975   1,832
Total       23  79,288

S = 1,35349   R-Sq = 58,41%   R-Sq(adj) = 46,86%
```

Table C. 27 (continued)

Analysis of Variance for **chew down characteristics**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	86,842	86,842	28,947	10,77	0,000
Time (min)	2	21,259	21,259	10,630	3,96	0,038
Error	18	48,371	48,371	2,687		
Total	23	156,472				

S = 1,63929 R-Sq = 69,09% R-Sq(adj) = 60,50%

Analysis of Variance for **Oil film**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	3	35,458	35,458	11,819	2,58	0,085
Time (min)	2	53,083	53,083	26,542	5,80	0,011
Error	18	82,417	82,417	4,579		
Total	23	170,958				

S = 2,13979 R-Sq = 51,79% R-Sq(adj) = 38,40%

Table C. 28 ANOVA tables of sensory properties for fried Jerusalem artichoke crisp

Factor	Type	Levels	Values
Temp (°C)	fixed	2	180; 190
Time (min)	fixed	3	2; 3; 4

Analysis of Variance for **Appearence**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	1	5,017	1,037	1,037	0,56	0,483
Time (min)	2	7,180	7,180	3,590	1,94	0,224
Error	6	11,121	11,121	1,853		
Total	9	23,318				

S = 1,36142 R-Sq = 52,31% R-Sq(adj) = 28,46%

Table C. 28 (continued)

Analysis of Variance for **Texture**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	1	0,9500	0,4278	0,4278	0,52	0,499
Time (min)	2	0,7611	0,7611	0,3806	0,46	0,652
Error	6	4,9578	4,9578	0,8263		
Total	9	6,6690				

S = 0,909012 R-Sq = 25,66% R-Sq(adj) = 0,00%

Analysis of Variance for **Flavour**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	1	0,195	0,500	0,500	0,11	0,755
Time (min)	2	1,949	1,949	0,975	0,21	0,818
Error	6	28,100	28,100	4,683		
Total	9	30,244				

S = 2,16409 R-Sq = 7,09% R-Sq(adj) = 0,00%

Analysis of Variance for **chew down chracteristics**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	1	0,288	1,531	1,531	0,79	0,407
Time (min)	2	3,475	3,475	1,737	0,90	0,455
Error	6	11,582	11,582	1,930		
Total	9	15,345				

S = 1,38936 R-Sq = 24,52% R-Sq(adj) = 0,00%

Analysis of Variance **for Oil film**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp (°C)	1	4,817	4,500	4,500	2,84	0,143
Time (min)	2	0,583	0,583	0,292	0,18	0,836
Error	6	9,500	9,500	1,583		
Total	9	14,900				

S = 1,25831 R-Sq = 36,24% R-Sq(adj) = 4,36%

Table C. 29ANOVA tables of sensory properties for microwave cooked Jerusalem artichoke chips

Factor	Type	Levels	Values
Power (watt)	fixed	2	600; 900
Time (sec)	fixed	7	60; 75; 90; 105; 120; 135; 150

Analysis of Variance for **Appearance**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	1,720	1,720	1,720	0,69	0,411
Time (sec)	6	14,327	14,327	2,388	0,96	0,466
Error	34	84,446	84,446	2,484		
Total	41	100,494				

S = 1,57598 R-Sq = 15,97% R-Sq(adj) = 0,00%

Analysis of Variance for **Texture**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	1,430	1,430	1,430	1,06	0,311
Time (sec)	6	6,435	6,435	1,072	0,79	0,581
Error	34	45,893	45,893	1,350		
Total	41	53,757				

S = 1,16180 R-Sq = 14,63% R-Sq(adj) = 0,00%

Analysis of Variance for **Flavor**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	0,200	0,200	0,200	0,07	0,791
Time (sec)	6	22,759	22,759	3,793	1,35	0,263
Error	34	95,666	95,666	2,814		
Total	41	118,625				

S = 1,67741 R-Sq = 19,35% R-Sq(adj) = 2,75%

Table C. 29 (continued)

Analysis of Variance for **Chew down**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	1,382	1,382	1,382	0,65	0,426
Time (sec)	6	1,747	1,747	0,291	0,14	0,990
Error	34	72,323	72,323	2,127		
Total	41	75,453				

S = 1,45847 R-Sq = 4,15% R-Sq(adj) = 0,00%

Analysis of Variance for **Oil film**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	0,3810	0,3810	0,3810	0,51	0,482
Time (sec)	6	1,6190	1,6190	0,2698	0,36	0,900
Error	34	25,6190	25,6190	0,7535		
Total	41	27,6190				

S = 0,868045 R-Sq = 7,24% R-Sq(adj) = 0,00%

Table C. 30 ANOVA tables of sensory properties for microwave cooked Jerusalem artichoke crisp

Factor	Type	Levels	Values
Power (watt)	fixed	2	600; 900
Time (sec)	fixed	7	60; 75; 90; 105; 120; 135; 150

Analysis of Variance for **Appearance**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	0,357	2,042	2,042	1,05	0,318
Time (sec)	6	43,019	43,019	7,170	3,70	0,014
Error	18	34,865	34,865	1,937		
Total	25	78,240				

S = 1,39173 R-Sq = 55,44% R-Sq(adj) = 38,11%

Table C. 30 (continued)

Analysis of Variance for **Texture**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	0,001	0,419	0,419	0,22	0,642
Time (sec)	6	19,022	19,022	3,170	1,70	0,179
Error	18	33,655	33,655	1,870		
Total	25	52,678				

S = 1,36739 R-Sq = 36,11% R-Sq(adj) = 11,27%

Analysis of Variance for **Flavor**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	5,851	10,010	10,010	7,28	0,015
Time (sec)	6	22,129	22,129	3,688	2,68	0,049
Error	18	24,743	24,743	1,375		
Total	25	52,722				

S = 1,17243 R-Sq = 53,07% R-Sq(adj) = 34,82%

Analysis of Variance for **Chew down**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	1,458	2,968	2,968	1,47	0,242
Time (sec)	6	18,737	18,737	3,123	1,54	0,221
Error	18	36,439	36,439	2,024		
Total	25	56,633				

S = 1,42280 R-Sq = 35,66% R-Sq(adj) = 10,64%

Analysis of Variance for **Oil film**, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Power (watt)	1	11,693	16,667	16,667	16,36	0,001
Time (sec)	6	13,512	13,512	2,252	2,21	0,090
Error	18	18,333	18,333	1,019		
Total	25	43,538				

S = 1,00922 R-Sq = 57,89% R-Sq(adj) = 41,52%

APPENDIX D

PICTURES OF COOKED JERUSALEM ARTICHOKE PRODUCTS

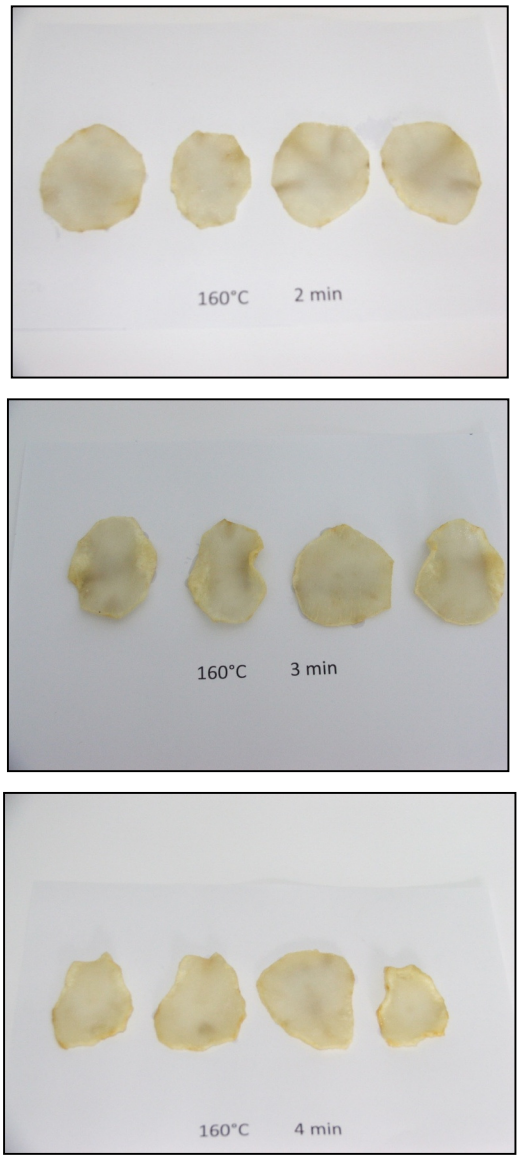


Figure D. 1 Pictures of fried Jerusalem artichoke chips at 160°C

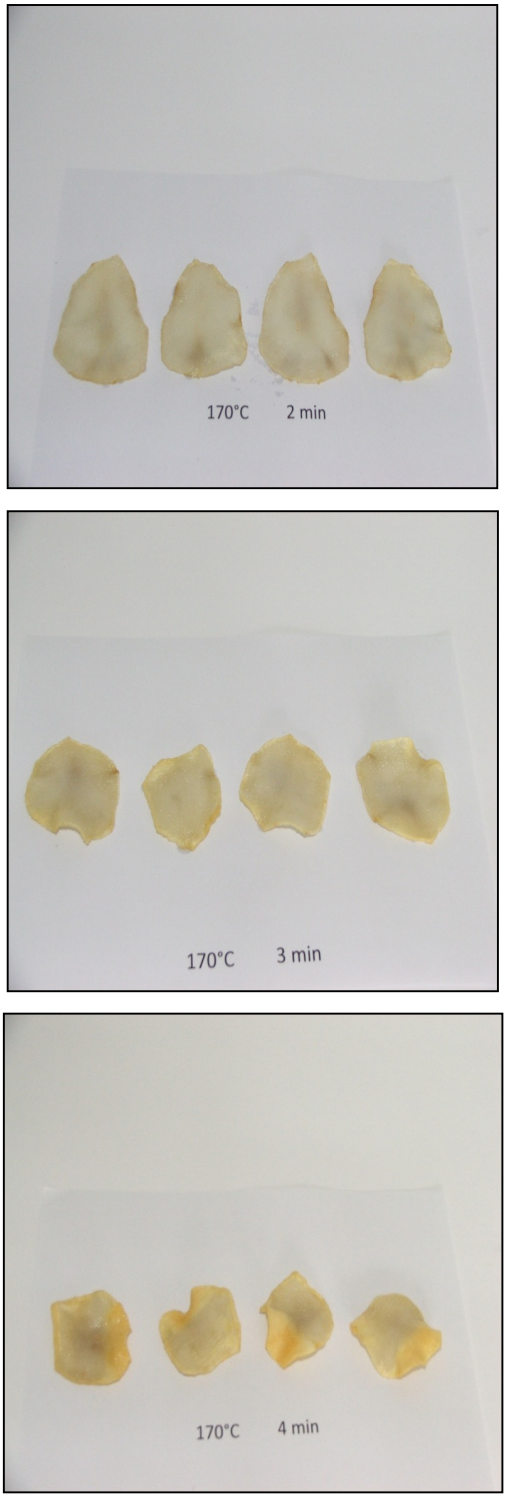


Figure D. 2 Pictures of fried Jerusalem artichoke chips at 170°C

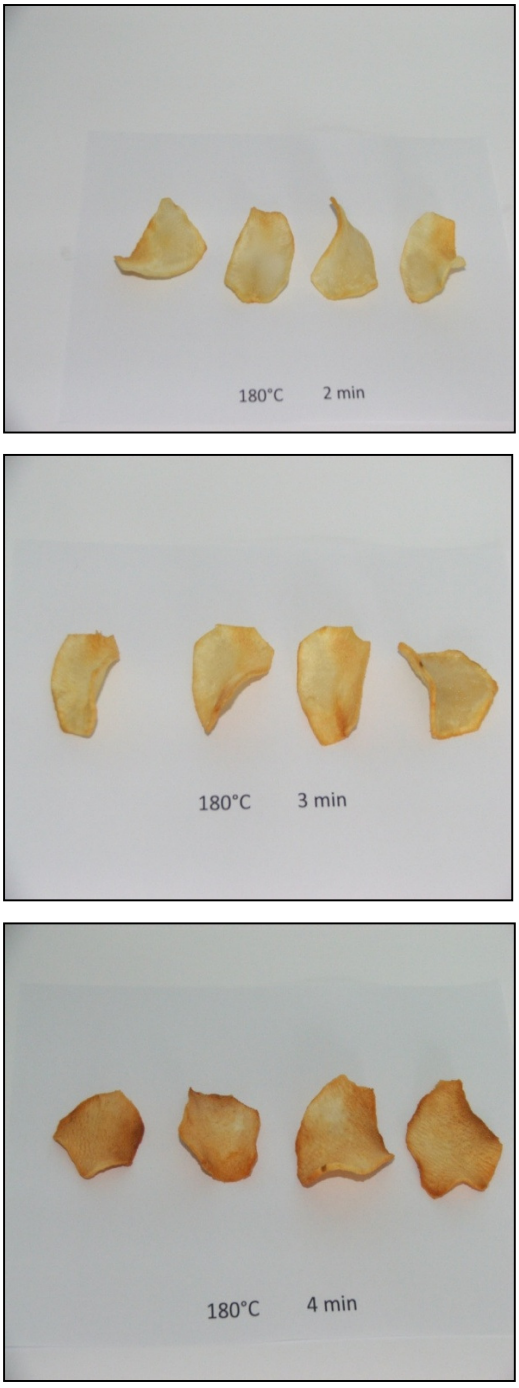


Figure D. 3 Pictures of fried Jerusalem artichoke chips at 180°C

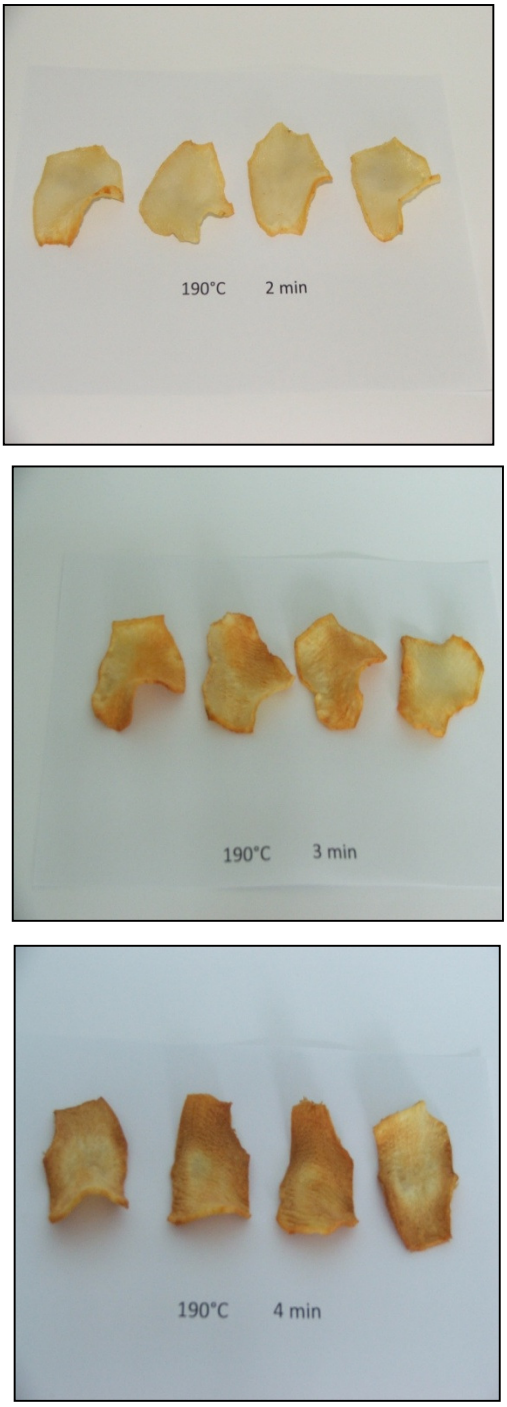


Figure D. 4 Pictures of fried Jerusalem artichoke chips at 190°C

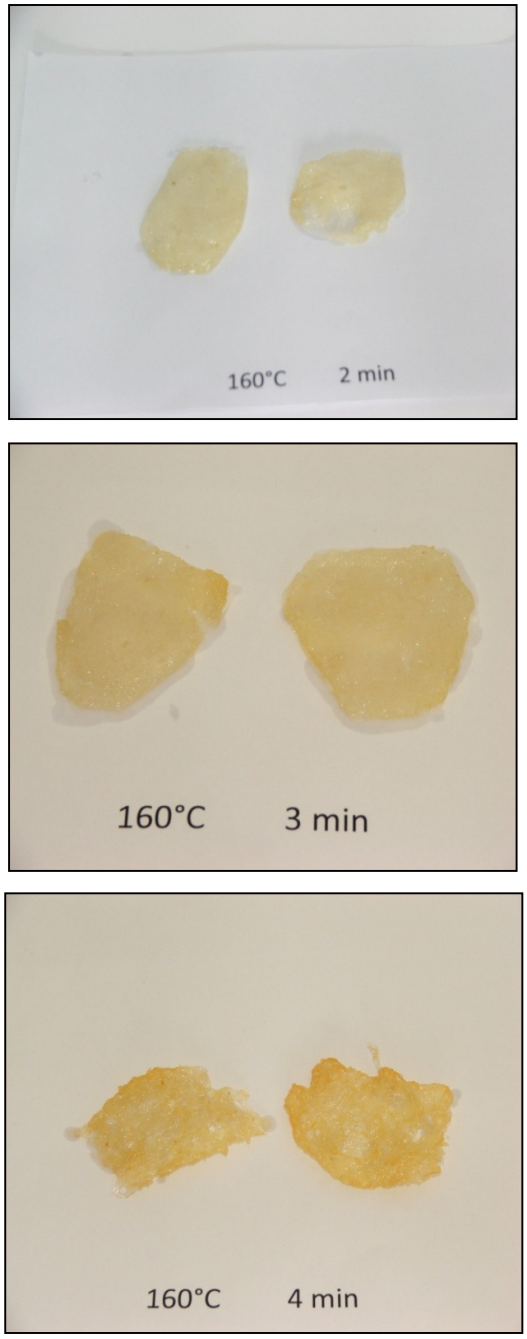


Figure D. 5 Pictures of fried Jerusalem artichoke crisp at 160°C

Figure D. 6 Pictures of fried Jerusalem artichoke crisp at 170°C

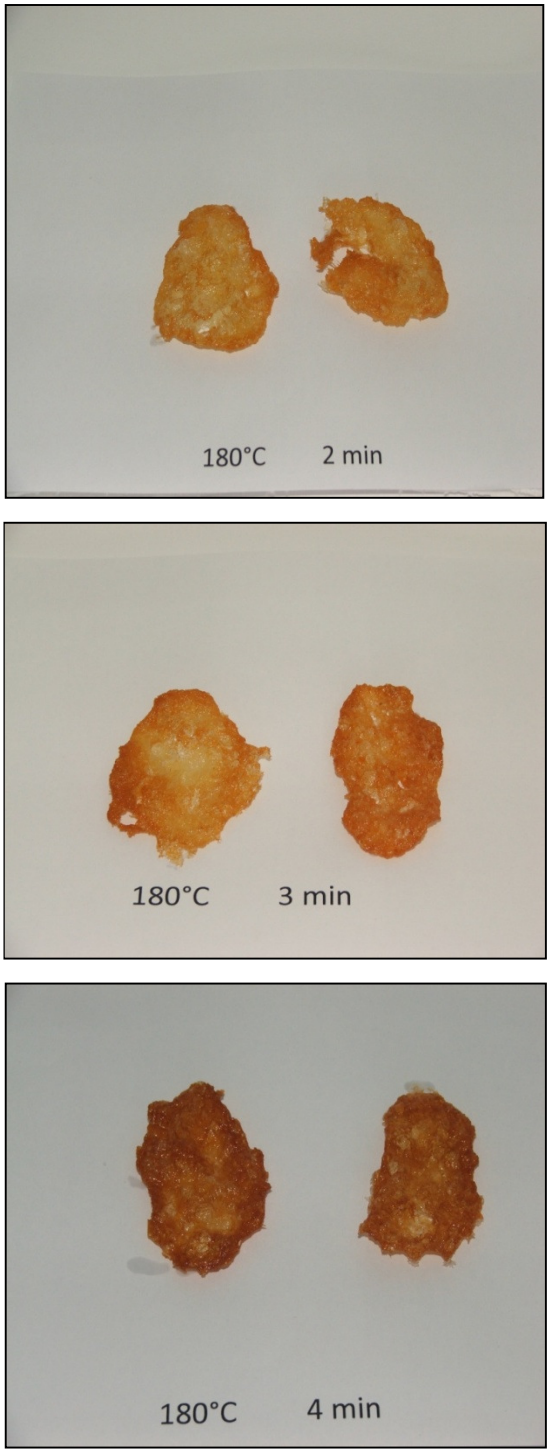


Figure D. 7 Pictures of fried Jerusalem artichoke crisp at 180°C

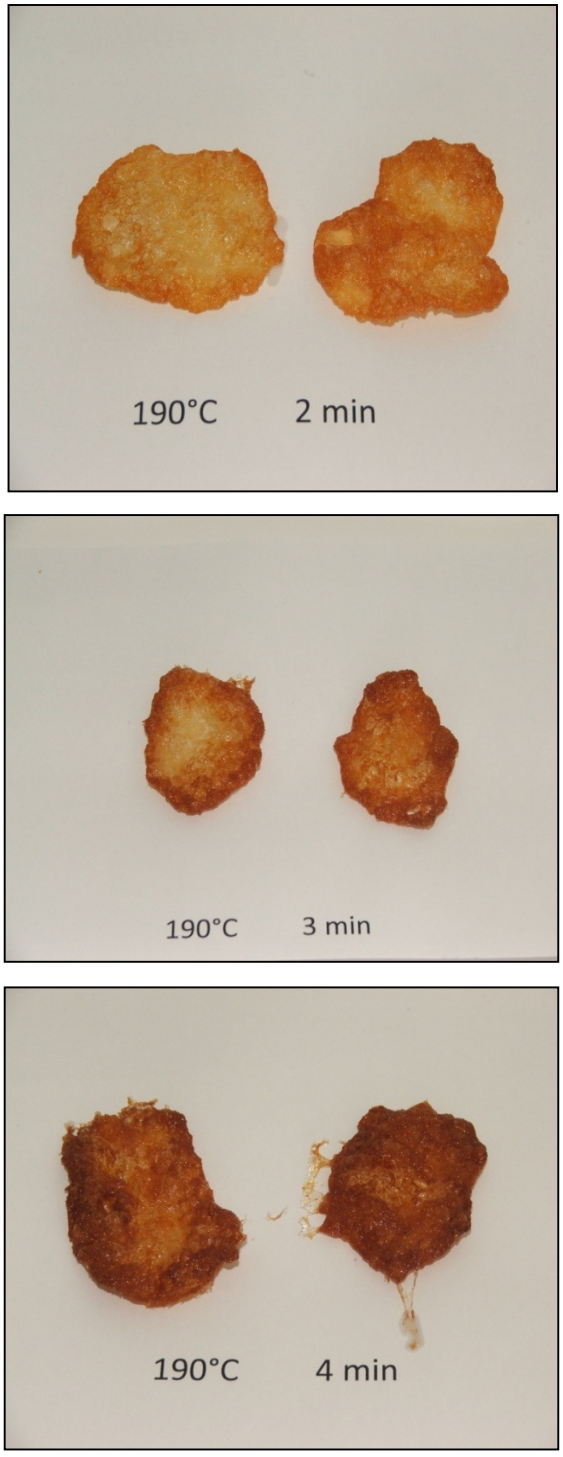


Figure D. 8 Pictures of fried Jerusalem artichoke crisp at 190°C

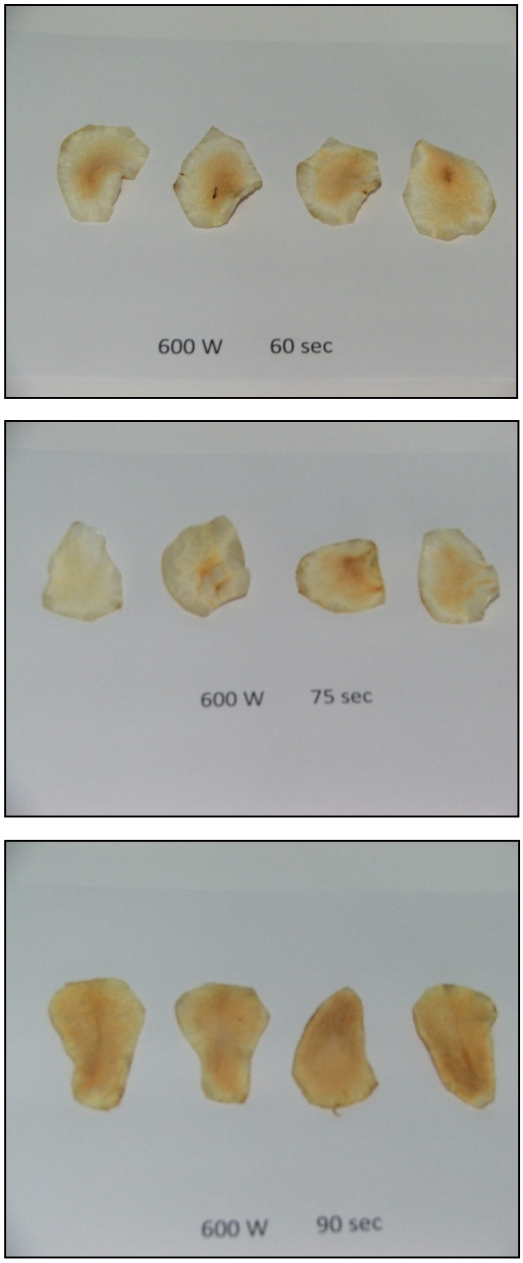
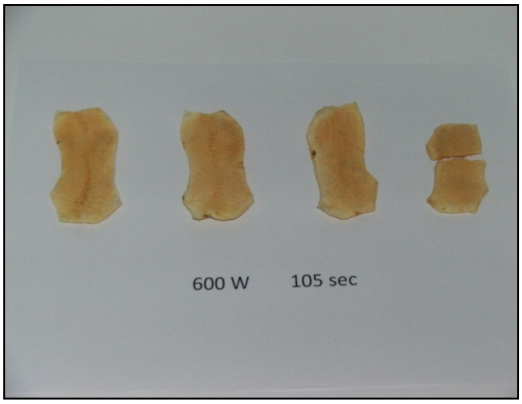
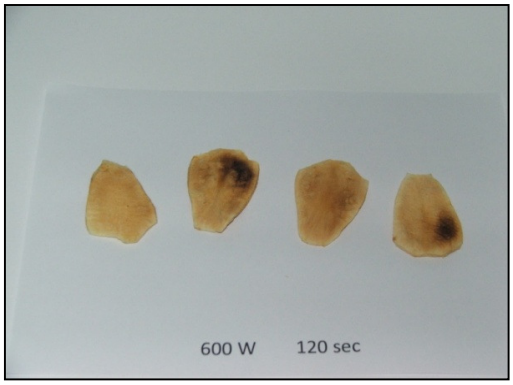
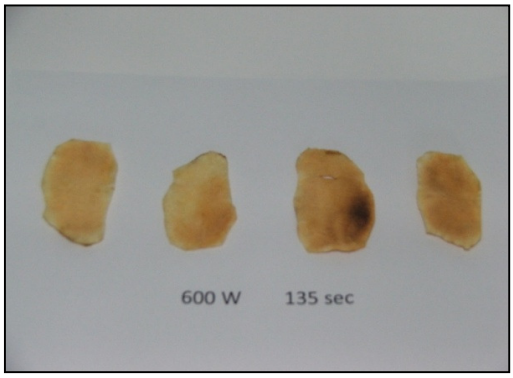


Figure D. 9 Pictures of microwave cooked Jerusalem artichoke chips samples at 600W







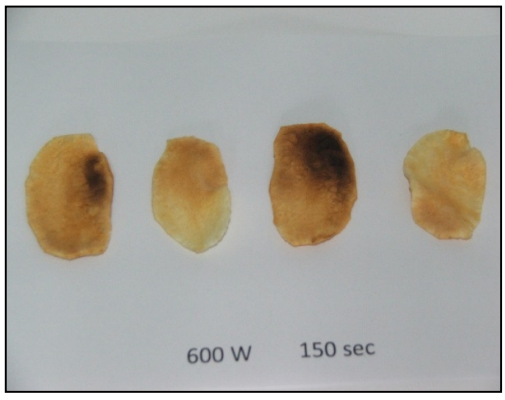


Figure D. 9 (continued)

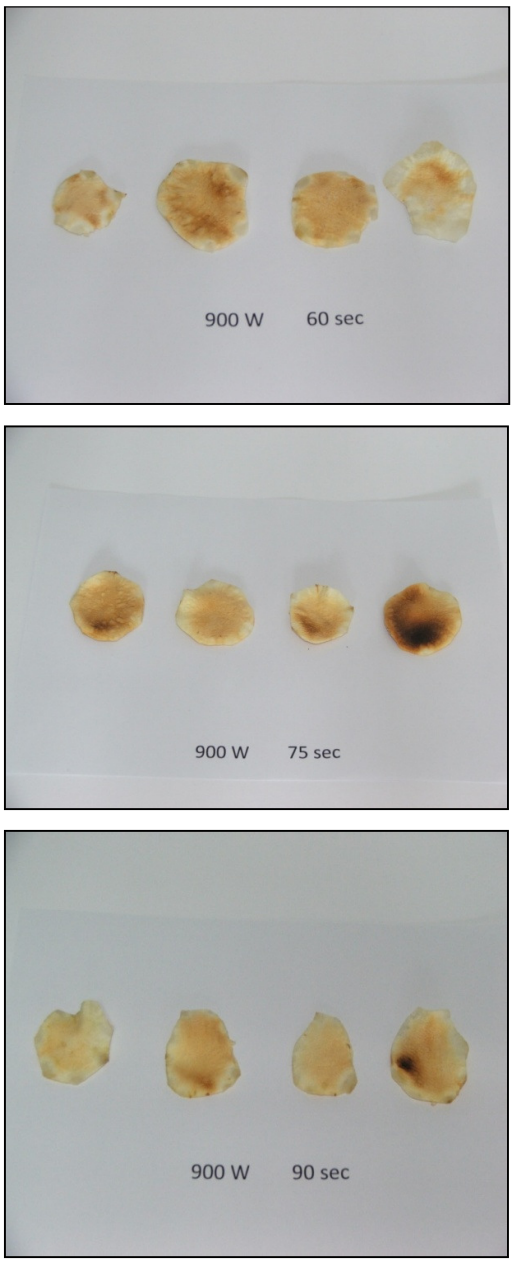


Figure D. 10 Pictures of microwaved cooked Jerusalem artichoke chips samples at 900W

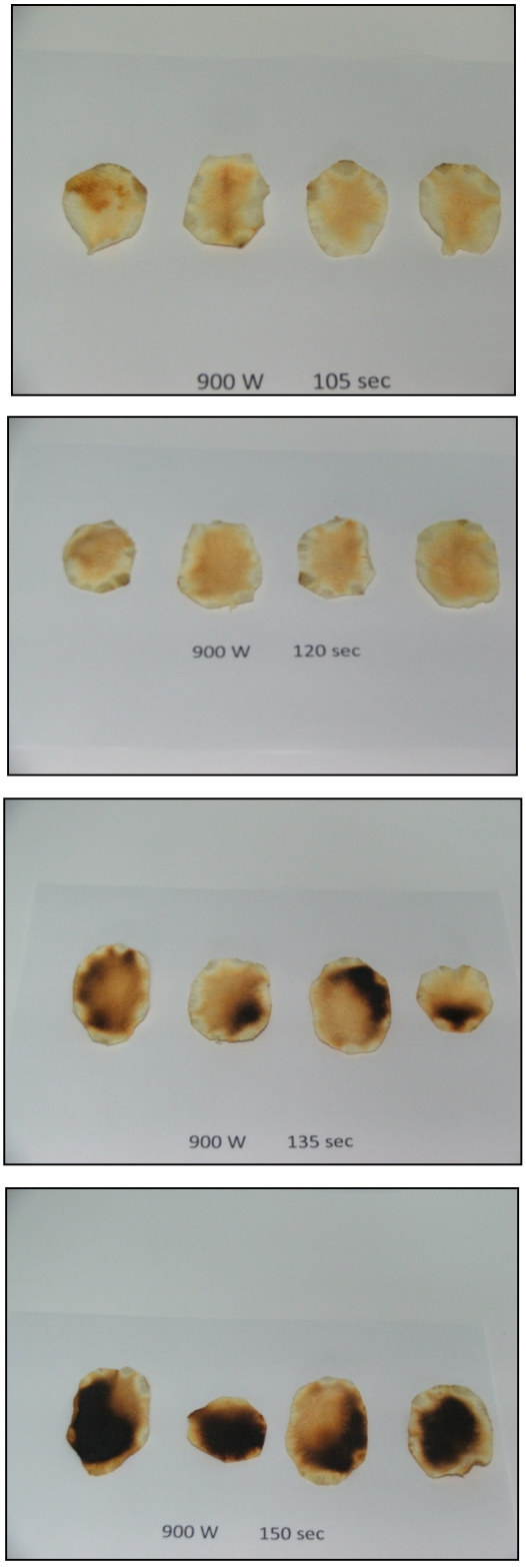


Figure D. 10 (continued)

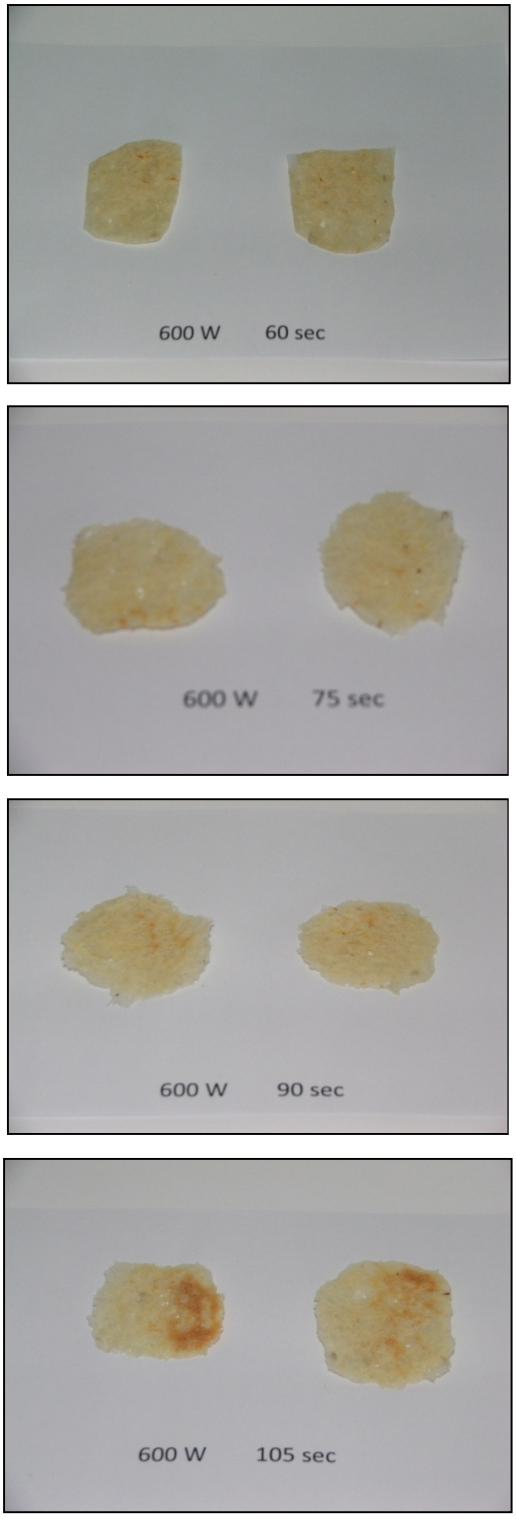
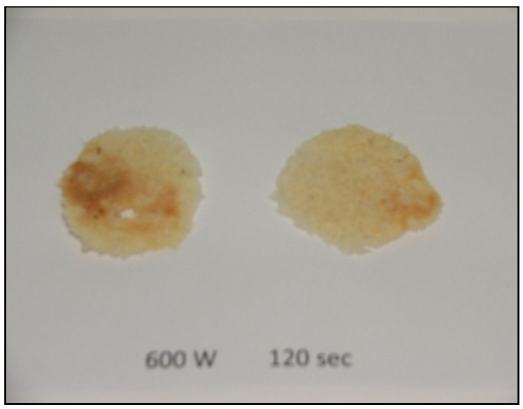
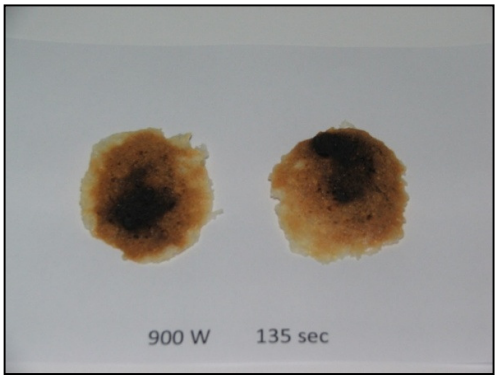


Figure D. 11 Pictures of microwave cooked Jerusalem artichoke crisp samples at 600W





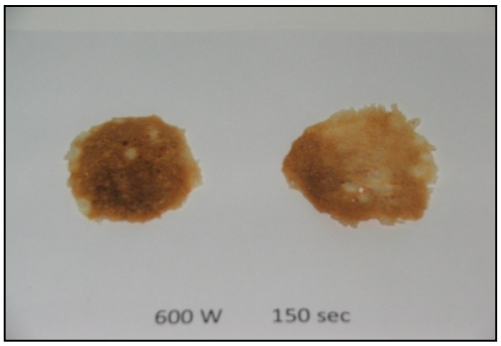


Figure D. 11 (continued)

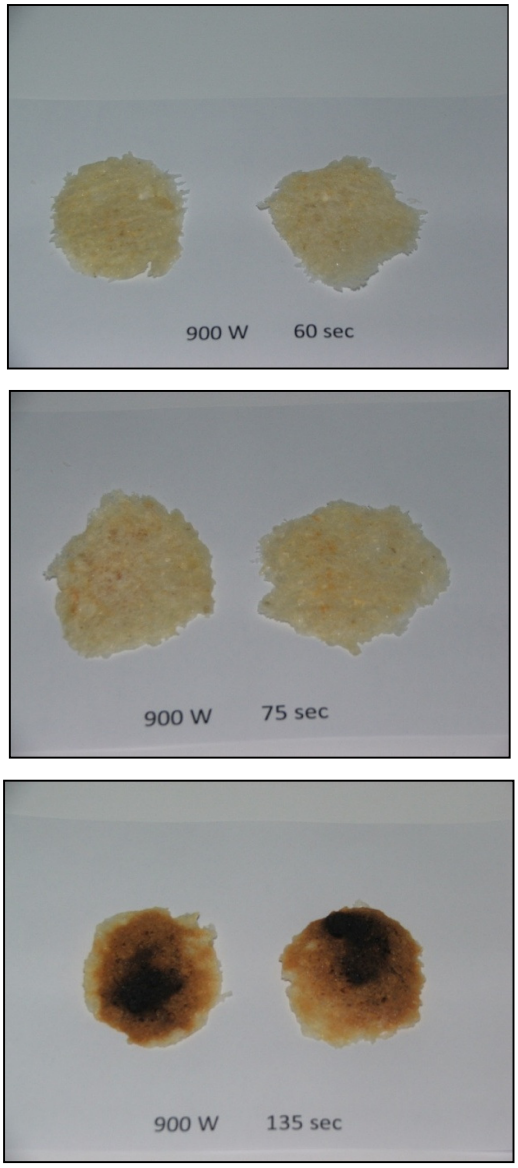


Figure D. 12 Pictures of microwave cooked Jerusalem artichoke crisp samples at 900W

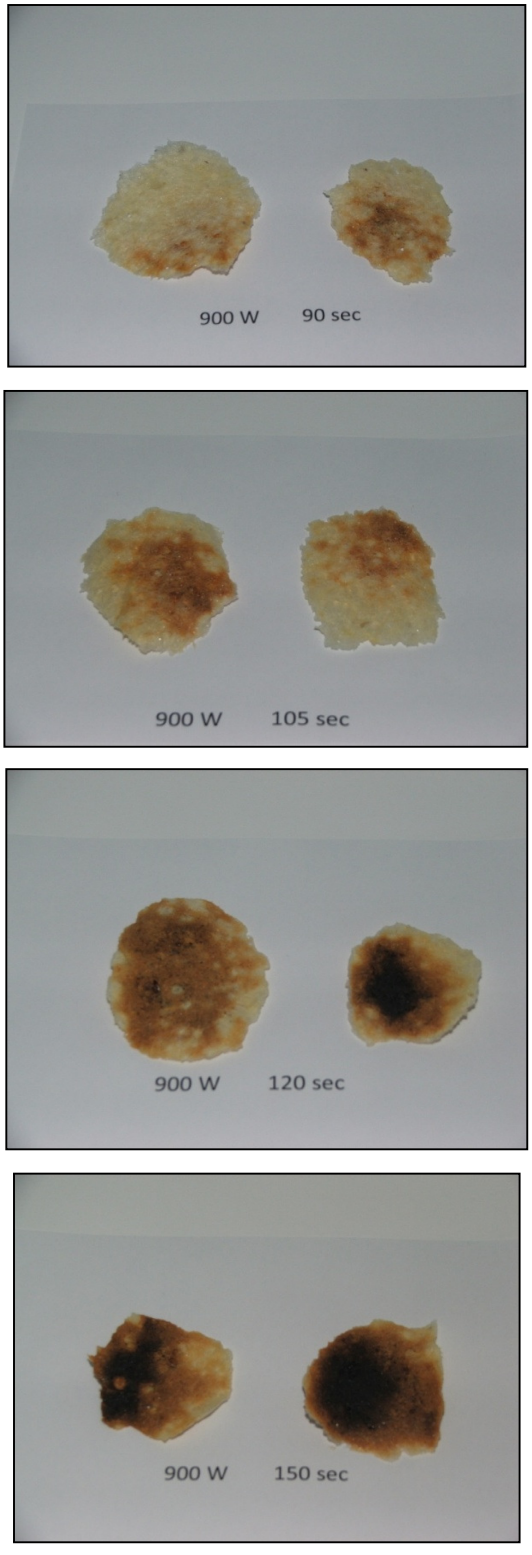


Figure D. 12 (continued)

APPENDIX E

PICTURES OF DRIED JERUSALEM ARTICHOKE PUREE

Figure E. 1 Dried Jerusalem artichoke puree with Xanthan Gum + $Na_2S_2O_5$

Figure E. 2 Dried Jerusalem artichoke puree with Xanthan gum

Figure E. 3 Dried Jerusalem artichoke puree

APPENDIX F

PICTURES OF JERUSALEM ARTICHOKE FLOUR

Figure F. 1 Jerusalem artichoke flour with Xanthan gum

Figure F. 2 Jerusalem artichoke flour with Xanthan gum and $Na_2S_2O_5$

Figure F. 3 Jerusalem artichoke flour

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2004-Present	METU Food Engineering	Teaching Assistant

FOREIGN LANGUAGES

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PUBLICATIONS

1. Baltacıoğlu, C., Velioğlu, S., Karacabey, E. Changes in Total Phenolic and Flavonoid Contents of Rowanberry Fruit During Postharvest Storage. Journal of Food Quality 34, 278-283, 2011.

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1. Baltacıoğlu, C., Velioğlu, S., Esin, A. 2009. The Change of Phenolic Substance Distribution of Rowanberry Fruit During Ripening. 5th International Technical Symposium of CIGR Food Processing Monitoring Technology in Bioprocesses and Food Quality Management,Aug 31st - Sept2nd, Potsdam, Germany, p. 277.

2. Baltacıoğlu, C., Velioğlu, S., 2010. The Change of Chemical Compounds of Rowanberry Fruit During Ripening. 1st International Congress on Food Technology, November 3-6. Antalya, Türkiye.

3. Baltacıoğlu, C., Esin, A., 2010. Use of Jerusalem Artichoke as a Potato Substittute in Chips Productions. 1st International Congress on Food Technology, 3-6th November. Antalya, Türkiye.

4. Baltacıoğlu, C., Karacebey, E., Çevik, M., 2011. Kinetic Modeling of Microwave Drying of Jerusalem Artichoke (Helianthus tuberosus L.). 4th International Congress on Food and Nutrition together with 3rd Consortium International Congress on Food Safety. 12 – 14th October 2011, İstanbul, Türkiye.

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1. Baltacıoğlu, C., Esin, A., 2011. Yer Elmasından Mikrodalga Kullanılarak Cips Elde Edilmesi. 7. Gıda Mühendisliği Kongresi. 24-26 Kasım, Ankara.