

Crisp Production from Jerusalem artichoke (*Helianthus tuberosus* L.) and Investigation of Quality Parameters

Cem Baltacıoğlu^{1,✉}, Ali Esin²¹ Department of Food Engineering, Faculty of Agriculture, Selcuk University, Konya, Turkey² Department of Food Engineering, Faculty of Engineering, Middle East Technical University, Ankara, Turkey

Received (Geliş Tarihi): 15.05.2013, Accepted (Kabul Tarihi): 30.06.2013

✉ Corresponding author (Yazışmalardan Sorumlu Yazar): cembaltacioglu@selcuk.edu.tr (C. Baltacıoğlu)

☎ +90 312 210 57 93 📠 +90 312 210 27 67

ABSTRACT

Jerusalem artichoke has been grown in various regions without any special breeding technique. As a food, Jerusalem artichoke has a characteristic flavour and functional ingredients including inulin, other dietary fibers, and minerals. The production of crisp from Jerusalem artichoke was investigated in this study because it contains high amount of inulin. Inulin may provide health promoting effects especially for the people suffering from diabetes. Crisp production from Jerusalem artichoke was studied in the scope of properties such as moisture, oil, color, texture and sensory. After cleaning, tubers were boiled and given shape in the form of slices. Slices were cooked in the bench top deep fat fryer or microwave oven. For crisps with Jerusalem artichoke, best results for frying and microwave oven applications were obtained at 180 °C for 180s and at 900W for 60s, respectively.

Key Words: Jerusalem artichoke, Crisp production, Frying, Microwave cooking, Quality parameters.

Yer Elmasından (*Helianthus tuberosus* L.) Cips Üretimi ve Kalite Parametrelerinin İncelenmesi

ÖZET

Yer elması özel yetiştirme teknikleri olmadan birçok bölgede yetiştirilmektedir. Bir gıda olarak yer elması kendine özgü karakteristik lezzet ve fonksiyonel bileşen olarak inulin ve diğer lif ve mineralleri içermektedir. Yüksek oranda inulin içerdiğinden dolayı bu çalışmada yer elmasından cips üretimi araştırılmıştır. İnulinin özellikle diyabet hastası kişilerde sağlığa yararlı etkileri bulunmaktadır. Yer elmasından cips üretimi nem, yağ, renk, tekstür ve duyu özellikleri açısından incelenmiştir. Temizlenen yumrular, haşlanmış ve dilim formunda şekillendirilmiş ve tezgah üstü derin yağ kızartma makinesinde veya mikrodalga fırından pişirilmiştir. Yer elmasında mikrodalga fırın uygulamasında ve kızartmada en iyi sonuçlar sırasıyla 180 °C'de 180 saniye ve 900W'ta 60 saniye uygulama süresinde elde edilmiştir.

Anahtar Kelimeler: Yer elması, Cips üretimi, Kızartma, Mikrodalga pişirme, Kalite parametreleri

INTRODUCTION

The Jerusalem artichoke (*Helianthus tuberosus* L.) grows under various climatic conditions, and its tubers can be produced world-wide, including Europe, North America, and Asia [1]. In addition to Jerusalem artichokes being a potential source of biomass, its tubers are known to be a health-promoting food source

and contain inulin instead of starch [2] as a carbohydrate reserve. Inulin, a fructose polymer, and its degraded product oligofructose are the major compounds of interest in the food industry due to being functional food ingredients and low-calorie food materials. Foods containing starch and sucrose may induce an increase in blood sugar level. 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 [3, 4]. Preventive effects of inulin towards from diabetes and anti-carcinoma activities, have been reported [5-7]. A recent study also suggested the use of the tubers in the diet of patients with certain diseases, because the tubers contain low amounts of polyamines [8]. In the current study, a new way has been sought for the utilization of Jerusalem artichoke tubers in daily consumption with the purpose of individual health management and developed alternative products instead of commercial snack products were prepared by frying or baking.

Frying is the one of the oldest and most common cooking methods used in preparation of food with favorable sensory properties including a typical flavour, oil, color and texture [9]. In microwave heating, absorption of energy from the microwave field results in internal heat generation within the product. Previous studies have shown that microwaves propose tremendous advantages, such as time, energy, space and nutrient savings, in food processing operations [10].

Browning of Jerusalem artichoke during preparing is a significant problem in the production of crisps from tubers. Enzymatic browning, catalyzed by polyphenol oxidase (PPO), occurs when plant tissues are damaged and an economic problem raised for producers and consumers [11]. PPO locates in plastids, whereas phenolic compounds are in the vacuoles for most plant tissues. PPO only displays activity when its compartmentation is disrupted by any way, as observed in diseased tissues or cell disruption caused by processing and storage [12]. Of all the inhibitors tested in a recent study, sodium meta bisulphite was the most effective for inhibition of PPO of some mushrooms [13].

Texture is another important characteristic indicating product quality. Textural properties are generally determined by mechanical tests [14]. Textural properties of dehydrated products are normally measured as puncture force, which is a measure of the hardness of the product surface and is an indicator of the extent of case hardening that has occurred during drying [15].

Starch is a major component of plant foods and an important ingredient for the food industry. Starches are cooked or processed to develop their viscous properties, based on gelatinized starch [16]. Since Jerusalem artichoke contains no starch, hydrocolloids should be used to replace the starch. Hydrocolloids and starch are used in food systems as texture and stability improvers [17]. Xanthan gum, a well-known extracellular microbial polysaccharide, is used as a thickener in the pharmaceutical, cosmetic and food industries. When added to fluid foods, it increases low shear-rate viscosity while having little effect on the viscosity of the food at high shear rate [18]. The shear-thinning character of xanthan gum is more pronounced than those of other polysaccharide gums (guar gum, locust bean gum, hydroxyethylcellulose, sodium carboxymethylcellulose, sodium alginate, etc.) due to the unique rigid, rod-like

conformation of xanthan gum which is more responsive to shear than a random-coil conformation [19]. Xanthan gum was used in this study to modify texture, improve moisture retention, control water mobility, and maintain overall product quality during storage.

In this study two cooking methods were used and compared in terms of quality parameters. These parameters were defined as oil, moisture, color and texture and then the most popular product was figured out according to the sensory evaluation.

MATERIALS and METHODS

Crisp Preparation

Fresh Jerusalem artichoke purchased from the commercial market (Nedo Fruits and Vegetables, Ankara, Turkey) 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, peeled by hand and then mashed using a blender (Robokit 2154 Beko, Istanbul, Turkey) for a minute. Then the homogenized sample was waited in 1% (wet basis) sodium metabisulphite (Merck, Germany) solution for 1 hour. Inactivation of PPO in plant tissues is required, and chemical and physical applications have been introduced for this purpose including dipping into a sodium metabisulphite solution, blanching etc. PPO is responsible for color changing of mashed Jerusalem artichoke. Sodium metabisulphite was used during the crisp preparation to prevent browning of the mashed Jerusalem artichoke puree. Homogenized sample was filtered to separate sodium metabisulphite solution. Filtered sample was mixed with 2% (Xanthan gum/filtered Jerusalem artichoke puree) Xanthan gum (Sigma-Aldrich, USA). Crisps were shaped in 2 mm thickness and then cooked in the microwave oven or deep fat fryer.

Frying

Crisps were fried in the bench top deep fat fryer (HMT 872 L Bosch, Germany) for 120s, 180s and 240s at either 160, 170, 180 or 190°C. Fryer contains 2.5 L sunflower oil (Biryag, Turkey) and four or five pieces were immersed into frying oil each time. The oil was changed after each frying procedure. Fried samples were taken on paper tissue to remove excess oil on the surface and the analyses were performed.

Microwave Cooking

Jerusalem artichoke crisps were cooked in the microwave oven (TFB 9730 Bosch, Germany) for 60, 75, 90, 105, 120, 135 or 150 seconds at either 600 or 900W. Only one piece was located into microwave oven at the same place of turning plate and cooked. After cooking, sample was analyzed.

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. The sample was placed in the oven (ST 055 Simsek Labor teknik, Turkey) and held there until constant weight was attained. Moisture content of the sample was determined according to the standard gravimetric method [20].

Determination of Oil Content

The oil content of the fried sample was determined by using Soxhlet extraction method using n-hexane as extraction solvent for 6 hours after the Jerusalem artichoke sample was dried in the conventional oven [21]. Results were given in dry basis.

Measurement of Color

Color of fried and microwave cooked samples were determined using a Minolta Color Reader (CR-10 Konica Minolta, 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 [22].

Measurement of Texture

Texture measurement of Jerusalem artichoke sample was carried at the end of 60min following cooking, using a Texture Analyzer (TA-XT Plus, Stable Micro System, UK). Three point bend probe was attached to the instrument settled 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 (gravitational force) required for breaking of fried chips. Deformation distance at fracture (mm) was used to describe fracturability of products. The result was expressed as a mean of three determinations per sample.

Sensory Evaluation

Fifteen assessors were trained for approximately one hour before the test about the Quantitative Descriptive Analysis [23]. 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. Sensory response variables were selected as 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 chewing characteristics, and finally oil/greasy film was evaluated as a oiliness.

Statistical Analysis

All frying and microwave cooking experiments were performed at least in triplicates at each condition for all analyses, mean values were reported with standard error. Data obtained from the analysis were assessed by analysis of variance (ANOVA) to determine whether the parameters, time and temperature of frying and power and time of microwave cooking affect significantly quality parameters. If significant difference was found, Tukey's comparison test was applied to determine the difference among means ($p \leq 0.05$) (MINITAB for Windows, Version 15.0).

RESULTS and DISCUSSION

Crisp production from Jerusalem artichoke was found to have high potential as an alternative to the current snack foods. Our results displayed that the Jerusalem artichoke crisp produced from puree by two methods, frying and microwave cooking were found to have bright characteristics in terms of quality criteria defined by moisture, oil, color, texture and sensory analysis.

Moisture Content

The initial moisture content of the Jerusalem artichoke used in the study was 85.00% on a wet basis (wb) and 566.67 (g/g db). In the literature initial moisture content of raw Jerusalem artichoke tubers were reported in the range of 78 to 82% [24]. In deep fat frying, moisture content of crisps decreased as frying temperature and time increased (Fig. 1A). Variation of moisture content of microwave cooked samples was shown in Figure 1B and moisture content of samples decreased with treatment time and power level. The moisture content of samples fried at 190 and 180°C for 180s was comparable to samples cooked by microwave for 60 and 75s at 600W. When ANOVA was conducted to investigate the effect of frying temperature, power level of microwave and treatment time on moisture content, it was found that temperature and time for both cooking process were significant ($p \leq 0.05$) on moisture content. Ni and Datta [25] obtained similar results for the decreasing of moisture content of frying samples with process time. Lower final moisture content obtained in microwave treatment than frying applications (Fig 1). In addition average moisture remove rate of frying and microwave treatment were given 0.017 and 0.036 (g water/g dw.s). 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.

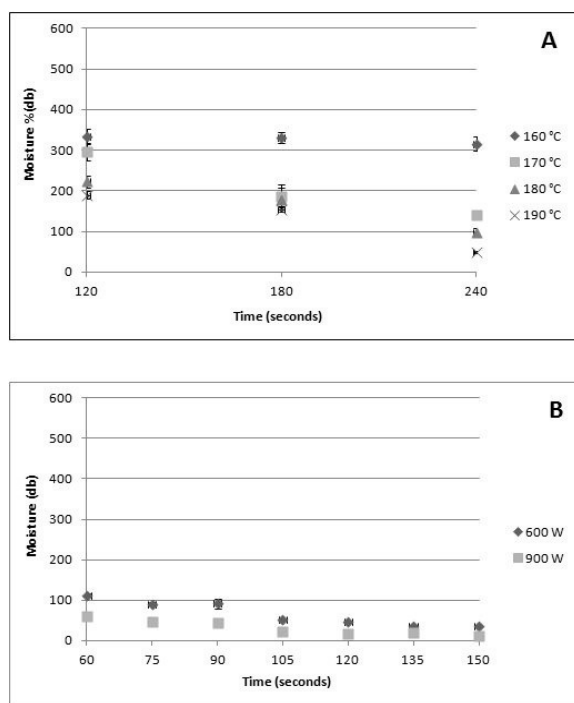


Figure 1. Variation of moisture content of Jerusalem artichoke crisps (A: frying, B: microwave cooking)

Oil Content

Oil content is the important quality attribute of a deep-fat fried product. The texture of a low-oil-content product can be soft and unpleasant. An increase in the oil level of the Jerusalem artichoke crisp was observed with the process time (Fig. 2). The experimental results for the oil contents of the crisp displayed statistically significant dependence on temperature and time ($p \leq 0.05$). [26] and [27] reported that the oil content of fried samples increases with treatment time.

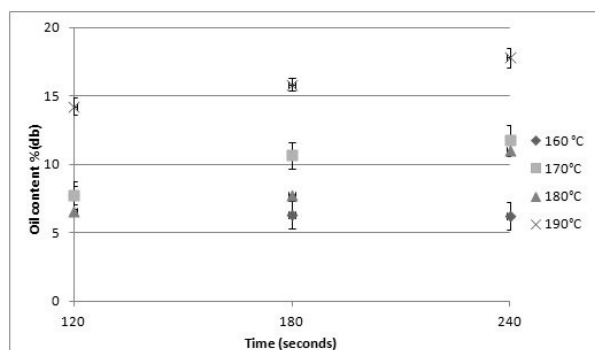


Figure 2. Oil content of frying Jerusalem artichoke crisps during frying

Color

One of the important quality parameters that consumers seek in fried products is product's color. The final colour of the fried product depends on the frying time and temperature, the absorption of oil and browning reactions [28]. The color readings were expressed by

CIE (L^* , a^* , b^*) color system. L^* , a^* , b^* values of the raw Jerusalem artichoke were given 74.3, -1.1, 7.8, respectively. Color values of the crisps were shown in Figure 3. While L^* values of the fried crisps decreased, a^* and b^* values increased with power level, frying temperature and processing time. It was previously shown that increasing the frying temperature and time in a conventional fryer increased the a^* value of potato slices [29], additionally, [30] reported that the change of a^* and b^* values fried potatoes significantly increased with temperature. According to the ANOVA results frying time and temperature were significantly affected a^* and b^* values, however, L^* values of crisps was affected only by temperature ($p \leq 0.05$).

In microwave treatment L^* values decreased, a^* values increased with increasing time and power level, but b^* values of microwave cooked samples increased up to 120s and then decreased. In microwave cooking time and power level statistically affected L^* and a^* values of samples ($p \leq 0.05$). Although, increases in a^* and b^* values of fried crisps was higher than microwave cooked ones, the highest L^* , a^* , b^* values obtained in microwave treatment because the shorter time required for cooking was not sufficient for completion of the Maillard reaction. Microwave treatment provides the opportunity to obtain fat-free products. Oduro and Clarke [31] performed quality assessment of gari (a fermented form of cassava) produced using microwave energy, and the L^* values increased slightly with time, producing pale colours and values of b^* also increased with time producing more yellowness. Vadivambal and Jayas [32] evaluated the quality attributes of microwave dried agricultural products by testing the colour and concluded that microwave dried products had better color than the air-dried product.

Texture

Hardness and fracturability of the fried Jerusalem artichoke products were determined to evaluate the texture which is an indicator for consumer demand. Changing of deformation distance and force values with treatment time, temperature and power level were given in Figure 4. High temperature and long process time resulted in harder products (Fig 4.A). This is also supported by the statistical finding in which processing temperature and treatment time were statistically ($p \leq 0.05$) important on the hardness values of the fried samples. Segnini et al. [33] reported that frying time significantly affected hardness of frying products and also Pedreschi et al. [34] shown that force for breaking increased with frying time due to the progressive development and hardening of the crust of the chips. Deformation distance values during frying increased with frying temperature and time (Fig 4.B) but only frying time was statistically significant ($p \leq 0.05$). Garayo and Moreira [35] also reported non-significant frying temperature effect on sample texture. Deformation force and distance values of the Jerusalem artichoke crisp for microwave cooking were shown in Figures 4.C and 4.D. The statistical analysis showed that neither the processing time nor the power level had significant influence ($p > 0.05$) on the hardness and fracturability of

microwave cooked Jerusalem artichoke crisp. For the crisps microwave cooked, during the first 105s of cooking, their hardness values decreased and then increased up with further operation to 135s. When comparing the hardness values of the microwave cooked samples and the deep fat fried samples, the

microwaved samples showed higher values than the fried ones (Figs 4.A and 4.C). A similar comparison of the fracturability values between the microwave cooked samples and the deep fat fried samples indicated deep fat fried ones displayed higher fracturability (Figs 4.B and 4.D).

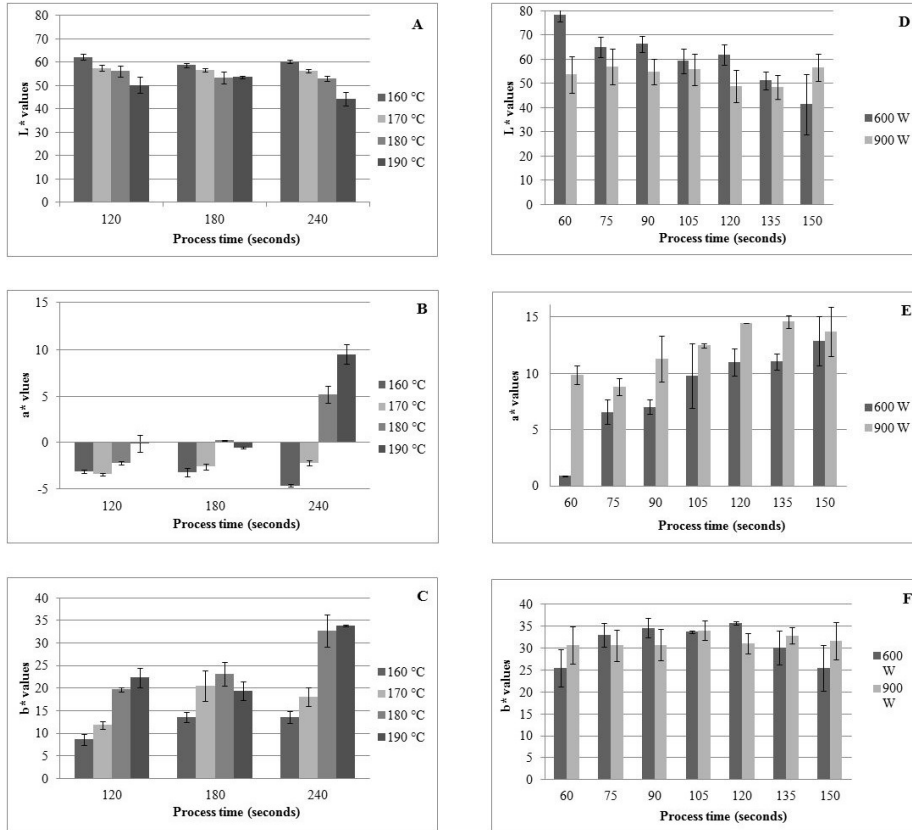


Figure 3. Color values of frying (A: L* values, B: a* values, C: b* values) and microwave cooking (D: L* values, E: a* values, F: b* values) Jerusalem artichoke crisps

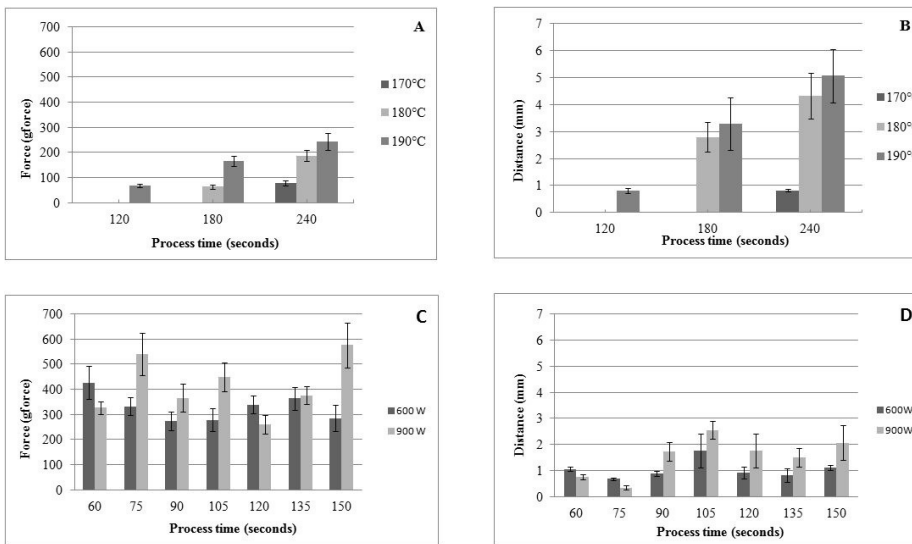


Figure 4. Variation of texture parameters of frying (A: Hardness, B: Fracturability) and microwave cooking (C: Hardness, D: Fracturability) Jerusalem artichoke crisps

Sensory Evaluation

Scores for the sensory properties of the fried and microwave cooked Jerusalem artichoke crisp are given in Table 1 and Table 2, respectively. Operation time and temperature were found not to significantly change the sensory properties of the fried Jerusalem artichoke crisp ($p>0.05$). There were no results at 160, 170, 180°C and at 600W for 60s because crisp form could not be shaped from the Jerusalem artichoke puree due to consistency. For the microwave cooked Jerusalem artichoke crisp products, the results showed that the

processing time and the power level were not significant ($p>0.05$) to cause any change in the texture and the chew down characteristics. Further, for the appearance only the time parameter was significant. In the overall standing product cooked at 180°C for 180s in frying and crisp processed at 900W for 60s in microwave cooking were the most desirable ones. Panelists liked microwave cooked crisps more than fried samples in terms of oil content. Average score of oil film for microwave cooking was higher than frying, because oil is not used in microwave cooking.

Table 1. Scores for the sensory properties of the fried Jerusalem artichoke crisp

Product	Process conditions		Sensory properties				
	Temp. (°C)	Time (s)	Appearance	Texture	Flavour	Chew down characteristics	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 2. Sensory properties of microwave cooked Jerusalem artichoke crisp

Product	Process conditions		Sensory properties				
	Power (W)	Time (s)	Appearance	Texture	Flavour	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

CONCLUSION

In this study, crisp production from Jerusalem artichoke in two cooking methods was studied investigating the parameters of frying temperature or microwave power level and treatment times. In the light of the experimental results it could be said that Jerusalem artichoke can be used to produce low or no calorie, no sugar snack foods. Microwave power level, frying temperature and treatment time were the process parameters which affected the quality parameters during processing. According to sensory evaluations microwave cooked product was chosen as the most popular, in addition, treatment time for cooking was significantly reduced when microwave cooking was used, as well oil being important factor in deep fat frying was not used in this process, thus, this method could be recommended as an alternative to conventional deep fat frying. As future studies, development of new products by using Jerusalem artichoke flour 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.

REFERENCES

- [1] Slimestad, R., Seljasen, R., Meijer, K., Skar, S.L., 2010. Norwegian-grown Jerusalem artichoke (*Helianthus tuberosus* L.): Morphology and content of sugars and fructo-oligosaccharides in stems and tubers. *Journal of the Science of Food and Agriculture* 90: 956–964.
- [2] Marx, S.P., Nosberger, J., Frehner, M., 1997. Seasonal variation of fructan-bfructosidase (FEH) activity and characterization of a β -(2→1)-linkage specific FEH from tubers of Jerusalem artichoke (*Helianthus tuberosus*). *New Phytologist* 135: 267–277.
- [3] Luo, J., Rizkalla, S.W., Alamowitch, C., Boussairi, A., Blayo, A., Barry, J.L., Laffitte, A., Guyon, F., Bornet, F.R., Slama, G., 1996. Chronic consumption of short-chain fructooligosaccharides by healthy subjects decreased basal hepatic

- glucose production but had no effect on insulin-stimulated glucose metabolism. *American Journal of Clinical Nutrition* 63: 939–945.
- [4] Yamashita, K., Kawai, K., Itakura, M., 1984. Effect of fructo-oligosaccharides on blood glucose and serum lipids in diabetic subjects. *Nutrition Research* 4: 961–966.
- [5] Kaur, N., Gupta, A.K., 2002. Applications of inulin and oligofructose in health and nutrition. *Journal of Biosciences* 27:703–714.
- [6] Niness, K.R., 1999. Inulin and oligofructose: What are they? *Journal of Nutrition* 129: 1402–1406.
- [7] Pan, L., Sinden, M.R., Kennedy, A.H., Chai, H., Watson, L.E., Graham, T.L., 2009. Bioactive constituents of *Helianthus tuberosus* (Jerusalem artichoke). *Phytochemistry Letters* 2: 15–18.
- [8] Righetti, L., Tassoni, A., Bagni, N., 2008. Polyamines content in plant derived food: A comparison between soybean and Jerusalem artichoke. *Food Chemistry* 111: 852–856.
- [9] Gazmuri, A.M., Bouchon, P., 2009. Analysis of wheat gluten and starch matrices during deep-fat frying. *Food Chemistry* 115(3): 999–1005.
- [10] Oztop, M.H., Sahin, S., Sumnu, G., 2009. Optimization of microwave frying of potato chips by using Taguchi Technique. *Journal of Food Engineering* 79: 83-91.
- [11] Dogan, S., Dogan, M., 2004. Determination of kinetic properties of polyphenol oxidase from Thymus (Thymus longicaulis subsp. chaubardii var. chaubardii). *Food Chemistry* 88:69-77.
- [12] Mazzafera, P., Robinson, S.P., 2000. Characterization of polyphenol oxidase in coffee. *Phytochemistry* 55: 285–296.
- [13] Colak, A., Sahin, E., Yildirim, M., Sesli, E., 2006. Polyphenol oxidase potentials of three wild mushroom species harvested from Liser High Plateau, Trabzon. *Food Chemistry* 103:1426-1433.
- [14] Krokida, M.K., Maroulis, Z.B., 2001. Quality changes during drying of food materials. In: *Drying Technology in Agriculture and Food Sciences* (Mujumdar A S, ed). Delhi, India.
- [15] Lin, T.M., Durance, T.D., Scaman, C.H., 1998. Characterization of vacuum microwave, air and freeze dried carrot slices. *Food Research International* 31(2): 111–117.
- [16] Arocas, A., Sanz, T., Fiszman, S.M., 2009. Improving effect of xanthan and locust bean gums on the freeze-thaw stability of white sauces made with different native starches. *Food Hydrocolloids* 23: 2478-2484.
- [17] Whistle, R.L., Bemiller, J.N., 1994. *Starch: Chemistry and technology*. 2nd ed. USA: Academic Press.
- [18] Speers, R.A., Tung, M.A., 1986. Concentration and temperature dependence of flow behavior of xanthan gum dispersions. *Journal of Food Science* 51: 96–98.
- [19] Urlacher, B., Noble, O., 1997. Xanthan Gum. Thickening and gelling agents for food. A. Imeson ed. London: Chapman & Hall.
- [20] Official Methods of Analysis. 1995. Association of Official Analytical Chemists 16th edition. Washington.
- [21] James, C.S., 1995. *Analytical Chemistry of Foods*. London: Blackie Academic and Professional.
- [22] McGuire, R.G., 1992. Reporting of objective color measurements. *Hortscience* 27(12): 1254-1255.
- [23] Meilgaard, M., Civille, G.V., Carr, B.T., 1991. *Sensory Evaluation Techniques*. 4th ed. Boca Raton: CRC Press.
- [24] Kays, S.J., Nottingham, S.F., 2008. *Biology and Chemistry of Jerusalem Artichoke: Helianthus tuberosus L.* Boca Raton: CRC Press.
- [25] Ni, H., Datta, A.K., 1999. Moisture, oil and energy transport during deep fat frying of food materials. *Food and Bioprocess Processing* 77(3): 194-204.
- [26] Krokida, M. K., Oreopoulou, V., Maroulis, Z.B., 2000. Water loss and oil uptake as a function of frying time. *Journal of Food Engineering* 44(1): 39-46.
- [27] Southern, C.R., Chen, X.D., Farid, M.M., Howard, B., Eyres, L., 2000. Determining internal oil uptake and water content of fried thin potato crisps. *Food and Bioprocess Processing* 78(3): 119-125.
- [28] Baixauli, R., Salvador, A., Fiszman, S.M., Calvo, C., 2002. Effect of addition of corn flour and colorants on the color of fried, battered squid rings. *European Food Research and Technol.* 215:457–461.
- [29] Pedreschi, F., Aguilera, J.M., Pyle, L., 2001. Textural characterization and kinetics of potato strips during frying. *Journal of Food Science* 66: 314–318.
- [30] Krokida, M.K., Oreopoulou, V., Maroulis, Z.B., Kouris-Marinou, D., 2001. Colour changes during deep fat frying. *Journal of Food Engineering* 48: 219-225.
- [31] Oduro I. Clarke, B., 1999. The quality assessment of gari produced by using microwave energy. *International Journal of Food Science and Technology* 34(4):365–370.
- [32] Vadivambal, R., Jayas, D.S., 2007. Changes in quality of microwave-treated agricultural products— a review. *Biosystem Engineering* 98: 1-16.
- [33] Segnini, S., Dejmek, P., Öste, R., 1999. Reproducible texture analysis of potato chips. *Journal of Food Science* 64(2): 309-312.
- [34] Pedreschi, F., Moyano P., Kaack, K., Granby, K., 2005. Color changes and acrylamide formation in fried potato slices. *Food Research International* 38: 1–9.
- [35] Garayo, J., Moreira, R., 2002. Vacuum frying of potato chips. *Journal of Food Engineering* 55: 181–191.