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Relationship Between Chemical Composition and Sensory Evaluation of Potato Chips Made from Six Potato Varieties with Emphasis on the Quality of Fried Sunflower Oil

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Abstract: The aim of this work was to determine the relationship between the sensory evaluation of potato chips and chemical composition of six potato varieties (Osina, Sponta, Glactica, Valour, Ledy valour and Hana). Sunflower oil was fried at 180± 5°C, 4hr every day for five consecutive days. Aliquots of potato chips made from different potato varieties were fried in the aforementioned oil. Organoleptic tests were performed on fried chips and quality limits of the sunflower oil samples were measured by some physico-chemical properties. Also, water loss and oil uptake of potato chips were determined. Organoleptic results for fried potato chips indicated that Osina, Sponta and Glactica potato varieties obtained from fried sunflower oil were categorized good. Also, these varieties were effective in improving the overall quality of sunflower oil. In conclusion, Osina, Sponta and Glactica potato varieties more suitable for frying processes than other varieties under study.

Key words: Deep-fat frying · New varieties · Organoleptic evaluation · Proximate analysis

INTRODUCTION

Deep-fat frying is one of the oldest processes of food preparation and basically includes the immersion of food pieces in hot oil. The high temperature causes an evaporation of the water, which moves away from the food and through the surrounding oil. Oil is absorbed by food, replacing some of lost water. The deep-fat frying seal the food by immersing it in the hot oil so that all flavors and the juices are retained by the crisp crust [1]. During the frying process, the physical, chemical and sensory characteristics of foods are modified, despite, texture, color and oil content are the main quality parameters of fried potatoes [2]. Texture is a sensory attribute of uppermost importance for potato preference [3] and it is a critical parameter for fried potato quality [4]. During frying heat is transferred to the product, while water is evaporated [5]. Traditional atmospheric frying and vacuum frying are two common types of applied frying processes [6]. In addition to these processes, high pressure frying, whereas the vapor naturally released from the products generates adequate pressure which is another approach for frying food products. In pressure frying, the boiling temperature as determined by the pressure might be a parameter for process modification to obtain consumer-desired characteristics [7]. Pressure frying has been shown to yield juicier and tender products depending upon the way to buildup the pressure [8,9]. It is also known to take less time compared to conventional deep fat frying (atmospheric frying) resulting in using less energy with longer lasting oil or fat. A frying process consists of four stages [10] initial heating (from immersion of the product until surface temperature equals to the boiling point where the natural convection dominates the heat transfer from frying medium), surface boiling (apparent bubble formation with nucleate boiling), falling rate bubble formation with nucleate boiling), falling rate (increase in product's internal temperature to the boiling point, formation of crust and its increased thickness) and bubble end point (final stage of frying when the process is extended to longer times). With start of surface boiling, water starts vaporizing and bubbling increases to a maximum value [11] after initial heating. The second stage is characterized by increase in heat transfer coefficient and sudden loss of free moisture from surface with crust formation [12]. In this stage, surface conditions change from free convection to boiling with a further increase in surface

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renewal [12]. In the last stage, heat transfer rate is expected to decrease due to increased thickness of lower thermal conductivity crust and reduced mass transfer from the product.

The texture of potato was found to be directly related to specific gravity, total solids, starch content, cell size and surface area and pectin [13]. Textural changes during frying are the result of many physical, chemical and structural changes produced in this complex process unit operation, which includes heat and mass transfer together with chemical reactions. Good quality French fries must have a crispy crust of about 1-2 mm whereas most of the oil is located and awed, a soft center, like a cooked potato. For potato chips, a very crispy texture is expected all way through since crispness is an indicator of freshness and high quality [14]. It is a well known fact that texture of this product depends on the quality of raw potato and technology parameters used in the course of production [15]. Crisp texture is connected with the dry matter of raw potato tubers [3]. Crisps obtained from potatoes rich in dry matter (above 25 %) can exhibit hard texture, whereas crisps of too low a specific gravity (low in dry matter), containing much oil, are characterized by greasy and sticky texture. The dry matter of potato tubers is composed of various substances: starch (15 %), sugar, nitrogen compounds, lipids, organic acids, phenolic compound, mineral substances and non-starch polysaccharides.

Several factors have been reported to strongly affect oil absorption in potatoes fried at atmospheric pressure. Some of the most important are oil quality and composition, product shape, temperature and frying time, moisture content, initial porosity and pre and post treatments [16]. Erdogdu and Dejemek [17] determined that the major oil fraction is suctioned by the microstructure of the potato piece when this is removed from the fryer during the cooling period, suggesting that the oil absorption is strictly linked to moisture loss. Oil absorption is mainly a surface phenomena and most of the oil is absorbed by the fried product in the post- frying period [18]. However, oil absorption during vacuum frying follows transport mechanisms more complexly than those elucidated in conventional frying and is currently the subject of intensive study.

The aim of this work was to determine the relationship between the organoleptic evaluation of potato chips and chemical composition of six potato varieties (Osina, Glactica, Sponta, Valour, Ledy valour and Hana) and to study the physico-chemical properties of sunflower oil samples during deep fat frying.

MATERIALS AND MEHODS

Source of Potatoes: Potatoes varieties (Osina, Glactica, Valour, Ledy valour, Sponta and Hana) used for frying experiments were purchased from El-Bosali experiment station and Research, Al-Beheira governorate, Egypt.

Source of Sunflower Oil: Refined sunflower oil was obtained from Savola Sime Company (Ramadan City, Sharkia Governorate, Egypt. Peroxide and acid values of the oil were 0.50 active oxygen peroxides per kilogram of oil and 0.09 mg KOH per gram of oil, respectively.

Frying Process: A known amount (c.2 kg) of refined sunflower oil was placed in a stainless steel pan fryer (60 cm diameter x 30 cm height) and heated at 180 ± 5°C, then potato chips (2 mm thickness) of different potato varieties previously soaked in NaCL solution (10 % w/v) were fried. The frying process was repeated for five consecutive days for 4hr every day. Hence, the total continuer frying period was 20 hr. The oil samples were left to cool down and then stored at 5°C for further analysis.

Quality Assurance Testes for non Fried and Fried Sunflower Oil: Refractive index, acid value and peroxide value were determined according to A.O. A .C [19]. Smoke point refers to the temperature at which the oil sample begins to smoke and is recorded as out lined by Nielsen [20]. A Lovibond tintometer apparatus (The Tintometer Ltd., Salisbry, England was applied to measure the color of non-fried and fried sunflower oil samples. The yellow glass slides were fixed at 35 and the intensity of red glasses was assigned through matching with the oil samples [20]. The relative flow times of the different sunflower oil samples were measured using an Ostwald Viscometer (Brookfield Engineering Laboratories. Inc., Stoughon, MA, USA) according to Joslyin [21]. Thiobarbituric acid (TBA) value, petroleum ether-insoluble oxidized fatty acids and insoluble polymer contents sunflower oil samples were determined according to the methods of Sidwell *et al*. [22] and Wu and Nawar [24], respectively. Polar and non-polar components in sunflower oil samples were measured by column chromatography according to the method described by Waltking and Wessels [25]. All physical and chemical determinations for non-fried and fried sunflower oil samples with different varieties of potatoes were carried out three and the results are presented as average values.

Organoleptic Evaluation of Fried Potato Chips: Sensory evaluation was performed on potato chips (different varieties) fried in sunflower oil at 180 ± 5°C. The organoleptic testes of the fried potato chips were carried out every 4 hr of frying period and compared with a commercial product called Chipsy produced by Chipsy for Food Industries, 6th October city, Giza, Egypt. Prior to the sensory tests, the panelists (twenty persons) were trained to evaluate the attributes of the chips produced in this study and become proficient. The sensory evaluation of fried potato chips were conducted two times and the mean score values were reported in the text. The potato chips samples were rated on a 10 point scale (1,2: bad; 3,4: poor; 5,6: fair; 7,8: good and 9,10 excellent). The potato chips from each variety, placed randomly in codified plates with three-digit cods, were served to each panelist. Judges were placed in different places to avoid communication during the evaluation and asked to score chips for taste, texture, appearance, color, odour and overall acceptability [26].

Chemical Composition of Fresh Potatoes and Fried Potatoes: Moisture, ash, fiber, protein, lipid, reducing sugar and carbohydrate contents in fresh potatoes were determined according to A.O. A.C [19]. After frying, fried products were ground and weighted. The oil content was determined by solvent extraction using the Soxhlet technique [19]. Each extracted group was then dried in a forced air oven at 105°C for 3hr (to constant mass), cooled in desiccators and then weighted to obtain the dry solids content. The moisture content was obtained from the difference between the original weight and the dry solids plus the oil content. Moisture loss was reported on a dry basis and was calculated from the difference between the original moisture content and the moisture content after frying.

Statistical Analysis: Analysis of variance was carried out using stat graphic statistical package (Statistical Graphics Corporation, Version 4, Rackville, USA) including multiple range tests ($P \geq 0.05$) for separation of least square means.

RESULTS AND DISCUSSION

Potato varieties "Osina, Glactica, Valour, Ledy valour, Sponta and Hana" were used in this investigations. Sponta variety is most commonly used raw materials for the production of chips in Egypt but all those varieties are France grow now in Egypt (in the region of EL-Bosali,) ($P \geq 0.05$) for experimental and selection variety suitable for frying and production for potato chips. The content of moisture ranged from 75.53-83.27%, while the content of total carbohydrates was 15.30-18.70% (Table 1). Percentage of crude protein in potato varieties ranged from 1.50-2.73%, while the content of reducing sugar ranged from 0.32-1.11%. Those compounds and especially protein, could influence the quality of chips.

Sensory Evaluation of Deep-fat Fried Potato Chips: The objective of this study was to evaluate the sensory of deep-fried chips produced from frying different varieties potato-tubers in sunflower oil at 180 ± 5°C for 20 hr compared with commercial potato chips (Crispy) was obtained from local market. Sensory quality characteristics evaluation for colour, texture, flavour, appearance, odour and overall acceptability of the chips made 6 cultivar was performed and data present in Table 2. Significant differences ($P \geq 0.05$) in score for colour, texture, flavour, appearance, odour and overall acceptability in chips made from different cultivars were evident as compared with commercial potato chips (Crispy). In texture, flavour and overall acceptability, varieties Sponta, Osina and Glactica had higher scores as compared to variety Valour, Ledy valour and Hana. The chips made of Sponta, Osina and Glactica varieties were characterized by an appropriate golden-yellow colour, a slightly darker colour characterizing the chips produced from Valour, Ledy valour and Hana potato varieties. The latter varieties contains more reducing sugar, which is the crucial factor regarding of colour of a ready products. The effects of sugar quantities on chips colour were the subject of numerous research papers [27].

Some Physical and Chemical Properties of Sunflower Oil During Frying for Different Potato Varieties: A set of experiments was conducted to evaluate the different potato varieties during frying in sunflower oil at 180 ± 5°C for 20 hr, 4hr / day. Some physical (refractive index, smoke point, colour and viscosity) and chemical (acid value, peroxide value, thiobarbituric acid, polar content, polymer content and oxidized fatty acids levels) tests were carried out to follow up the course of sunflower oil oxidation during frying different potato varieties.

Refractive Index: Table 3 shows changes in the refractive index of sunflower oil during frying different potato varieties (Osina, Glactica, Valour, Ledy valour, Sponta and Hana). Frying process caused gradual decrease in the refractive index values for all varieties. Frying potato varieties Osina, Sponta and led to significant ($P \geq 0.05$) decrease in refractive index lower than other varieties Valour, Ledy valour and Hana.

Table 1: Chemical composition of six varieties of potato tubers

	Potato variety					
Component (%)	Osina	Glactica	Valour	Ledy valour	Sponta	Hana
Moisture	75.53±4.20	79.58±5.03	83.27±7.51	82.28±7.20	79.33±5.09	81.38±6.20
Protein	2.73±0.41	1.50±0.30	1.90±0.38	2.30±0.40	1.20±0.20	1.00±0.18
Fat	0.30±0.01	0.25±0.01	0.33±0.03	0.39±0.05	0.35±0.05	0.29±0.02
Ash	0.97±0.56	0.92±0.50	0.89±0.48	0.85±0.45	0.90±0.49	0.95±0.53
Fiber	1.30±0.62	1.20±0.59	1.27±0.55	1.19±0.52	1.22±0.50	1.31±0.61
Carbohydrates	18.70±22.30	18.00±2.20	16.50±1.90	15.30±1.82	15.90±1.91	15.20±1.85
Reducing sugar	0.32±0.10	0.40±0.15	1.11±0.40	1.05±0.38	0.36±0.12	1.00±0.36

Mean value ± standard deviation (SD)

Table 2: Sensory evaluation of fried potato chips for different varieties potato tubers and the commercially prepared potato chips

		Fried potato variety						
	Attribute	Osina	Glactica	Valour	Ledy valour	Sponta	Hana	Commercial Sample (crispy)
4- hr frying period	Taste	9.20	8.20	6.50	6.30	9.10	6,50	7.66
	Texture	9.33	7.96	5.20	6.15	9.30	6,40	8.10
	Appearance	9.20	8.33	5.90	5.50	9.15	5.90	8.26
	Color	9.66	9.03	5.50	5.11	9.60	5.30	8.66
	Odor	9.86	9.15	5.40	5.80	9.70	6.12	9.00
	Overall	9.45	8.52	6.30	6.50	9.30	6.00	8.33
	Quality	Excellent	Good	Fair	Fair	Excellent	Fair	Good
12- hr frying period	Taste	8.46	8.02	6.40	5.90	8.30	6.14	7.80
	Texture	8.93	8.10	5.81	6.11	8.40	6.00	7.93
	Appearance	9.03	8.60	8.20	6.20	8.90	6.00	8.10
	Color	8.90	8.90	5.00	5,81	8.02	5.50	8.70
	Odor	8.93	9.02	6.10	6.00	8.40	5.12	8.83
	Overall	8.85	8.50	6.20	6.14	8.50	5.01	8.27
	Quality	Good	Good	Fair	Fair	Good	Fair	Good
20 – hr frying period	Taste	8.20	8.10	6.23	6.00	8.10	5.80	7.70
	Texture	8.50	7.20	5.81	6.11	8.20	5.22	7.00
	Appearance	8.03	8.04	6.11	5.90	8.00	5.85	8.20
	Color	8.50	8.20	5.49	5.11	8.10	6.00	8.80
	Odor	8.40	8.10	5.50	5.30	8.20	5.20	8.90
	Overall	8.20	8.90	5.20	5.71	8.00	5.00	8.70
	Quality	Good	Good	Fair	Fair	Good	Fair	Good

Each value represents the parameter mean value from 20 panelists

- Overall quality of fried potato chips was rated a 10-point scale

- The overall quality scale was 1,2 bad; 3,4 poor; 5,6 fair; 7,8 good and 9,10 excellent

Table 3: Changes in physical properties of sunflower oil during frying for different potato varieties

		Fried potato variety					
Frying Time (hr)		Osina	Glactica	Valour	Ledy valour	Sponta	Hana
Refractive index (25°C)	0	1.4726±0.001	1.4726±0.001	1.4726±0.001	1.4726±0.001	1.4726±0.001	1.4726±0.001
	4	1.4727±0.001	1.4728±0.001	1.4728±0.001	1.4728±0.001	1.4728±0.001	1.4728±0.001
	8	1.4728±0.001	1.4729±0.001	1.4730±0.001	1.4730±0.001	1.4729±0.001	1.4730±0.001
	12	1.4729±0.001	1.4730±0.001	1.4732±0.001	1.4733±0.001	1.4731±0.001	1.4731±0.001
	16	1.4731±0.001	1.4731±0.001	1.4735±0.001	1.4734±0.001	1.4732±0.001	1.4734±0.001
	20	1.4733±0.001	1.4732±0.001	1.4736±0.001	1.4735±0.001	1.4733±0.001	1.4736±0.001

Table 3: Continued

Smoke point (°C)	0	234±3.20	234±3.20	234±3.20	234±3.20	234±3.20	234±3.20
	4	232±3.00	231±2.90	230±3.11	231±3.18	232±3.15	230±3.13
	8	230±2.85	228±2.81	225±2.50	226±2.86	230±3.00	225±2.56
	12	227±2.79	225±2.71	220±2.13	221±2.41	226±2.66	222±2.34
	16	222±2.50	219±2.49	216±2.00	215±2.20	220±2.41	217±2.30
	20	215±2.13	213±2.11	208±1.90	210±2.06	214±2.13	211±2.20
Color (red) yellow at 35	0	2.30±0.40	2.30±0.40	2.30±0.40	2.30±0.40	2.30±0.40	2.30±0.40
	4	5.50±1.10	5.45±1.01	5.90±1.80	5.85±1.40	5.50±1.11	5.70±1.35
	8	10.00±2.13	10.30±3.30	11.50±2.57	11.20±2.41	10.20±2.29	11.00±2.50
	12	11.90±3.01	12.00±3.20	12.60±3.60	12.45±3.35	11.30±3.80	12.30±3.25
	16	13.50±3.02	13.60±3.10	13.80±3.30	13.70±3.25	14.10±3.60	13.50±3.10
	20	16.80±3.71	17.00±3.79	17.66±3.00	17.30±3.10	17.18±3.02	17.10±3.00
Viscosity (min)	0	5.00±1.01	500±1.01	5.00±1.01	500±1.01	5.00±1.01	5.00±1.01
	4	6.80±1.50	6.95±1.70	7.20±1.81	6.90±1.75	6.90±1.73	6.90±1.71
	8	8.50±2.10	8.80±2.30	9.00±2.00	8.90±2.36	8.66±2.25	8.89±2.35
	12	9.30±2.71	9.50±2.82	10.01±2.00	9.60±2.91	9.35±2.75	9.55±2.86
	16	10.90±3.83	11.20±3.01	11.60±3.33	11.30±3.15	11.00±3.90	11.40±3.17
	20	13.11±3.80	13.50±3.11	14.11±3.34	13.35±3.31	13.20±3.0	13.35±3.13

Mean value ± standard deviation (SD)

Smoke Point: The intermittent frying of sunflower oil led to a gradual and significant decrease ($P \geq 0.05$) in the smoke point values. Frying potato varieties Osina, Sponta and Glactica at 180 ± 5°C for 20 hrs also caused significant decreases in smoke point but other varieties more decreases in smoke point.

Clour: In the present study, the values of yellow glass slides were fixed at 35 and variable values were recorded for the red glass slides. The initial red glasses value for the non-fried sunflower oil was 2.30. During the intermittent frying, the values of red glasses for sunflower ($P \geq 0.05$) oil were gradually and significantly increased (Table 3). Increasing in colour values sunflower oil during frying potato varieties Valour, Ledy valour and Hana more than varieties Osina, Sponta and Glactica.

Viscosity: Changes in the viscosity of sunflower oil during frying different potato varieties at 180 ± 5°C for 4hr for five consecutive days are shown in Table 3. The viscosity of sunflower oil was gradually and significantly ($P \geq 0.05$) increased during the frying process. The viscosity values during frying potato varieties (Osina, Sponta and Glactica) in sunflower oil lower than values of other varieties.

Acid Value: Data illustrated in Table 3 indicate that the acid value of sunflower oil increased significantly ($P \geq 0.05$) during frying and was strongly correlated with prolonging the frying period. Frying potato varieties Osina, Sponta and Glactica caused light increased in acid values compared with other varieties.

Peroxide Value: The results demonstrate the occurrence of gradual increases in the peroxide value of the fried sunflower oil (Table 4). In fact, the peroxide value of sunflower oil during Osina, Sponta and Glactica varieties lower than that of sunflower oil during frying valour, Valour, Ledy valour and Hana varieties.

Thiobarbituric Acid Value (TBA): The results of TBA test indicate the incidence of gradual and significant ($P \geq 0.05$) increases on the TBA values for the fried sunflower oil. The data for TBA values of sunflower oil during frying potato chips (Osina, Sponta and Glactica) lower than that during frying other varieties (Table 4).

Polar Compounds: Table 5 indicates that the levels of polar compounds of fried sunflower oil were gradually and significantly ($P \geq 0.05$) increased towards the end of the frying process. The value of polar compounds at the end of the frying period of sunflower oil during frying Valour, Ledy valour and Hana potato varieties higher than that of sunflower oil during frying other varieties.

Polymer Content: The initial polymer content of fresh sunflower oil was 0.00 % and this value was increased progressively with the frying period (Table 4). The changes in polymer content of sunflower oil during frying different potato varieties showed increase with time (Table 5). Frying Osina, Sponta and Glactica potato varieties led to decreased the formation of polymers compared with other varieties.

Table 4: Changes in some chemical properties of sunflower oil during frying for different potato varieties

		Fried potato variety					
Frying time (hr)		Osina	Glactica	Valour	Ledy valour	Sponta	Hana
Acid value (mg KOH/g oil)	0	0.09±0.01	0.09±0.01	0.09±0.01	0.09±0.01	0.09±0.01	0.09±0.01
	4	0.21±0.01	0.30±0.03	0.40±0.05	0.35±0.40	0.25±0.01	0.35±0.04
	8	0.50±0.11	0.60±0.15	0.75±0.19	0.70±0.16	0.56±0.12	0.66±0.17
	12	0.90±0.20	0.95±0.22	1.15±0.30	1.00±0.25	0.95±0.23	1.01±0.28
	16	1.90±0.40	1.95±0.41	2.20±0.50	2.01±0.48	1.94±0.40	2.00±0.46
	20	3.50±0.61	3.61±0.62	4.00±0.65	3.60±0.63	3.60±0.62	3.75±0.61
Peroxide value (meq./kg oil)	0	0.50±0.12	0.50±0.12	0.50±0.12	0.50±0.12	0.50±0.12	0.50±0.12
	4	4.10±0.70	4.25±0.75	5.00±0.80	4.90±0.79	4.20±0.74	4.85±0.76
	8	10.60±2.00	10.70±2.10	11.00±2.10	11.00±2.10	10.70±2.01	10.90±2.11
	12	16.10±2.50	16.20±2.55	16.90±2.60	16.85±2.58	16.15±2.51	16.90±2.60
	16	25.13±3.10	25.20±3.20	26.00±3.30	25.91±3.24	25.15±3.11	25.85±3.23
	20	39.50±4.20	39.65±4.30	41.00±4.50	40.80±4.41	39.60±4.26	40.70±4.35
Thiobarbituric acid	0	0.001±0.001	0.001±0.001	0.001±0.001	0.001±0.001	0.001±0.001	0.001±0.001
(absorbance at 530 nm)	4	0.20±0.01	0.23±0.11	0.30±0.13	0.28±0.12	0.20±0.01	0.27±0.03
	8	0.80±0.18	0.85±0.19	0.91±0.21	0.90±0.20	0.83±0.18	0.88±0.20
	12	1.55±0.30	1.60±0.32	1.80±0.35	1.78±0.30	1.59±0.30	1.75±0.29
	16	1.90±0.41	2.01±0.42	2.20±0.45	2.15±0.40	2.00±0.40	2.11±0.40
	20	2.11±0.40	2.16±0.43	2.50±0.44	2.45±0.42	2.15±0.41	2.43±0.42

Mean value ± standard deviation (SD)

Table 5: Changes in some chemical properties of sunflower oil during frying different potato varieties

		Fried potato variety					
Frying Time (hr)		Osina	Glactica	Valour	Ledy valour	Sponta	Hana
Polar content (%)	0	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	4	0.61±0.20	0.65±0.21	0.75±0.25	0.70±0.23	0.62±0.22	0.71±0.23
	8	4.20±0.80	4.30±0.81	4.80±0.85	4.45±0.82	4.25±0.80	4.40±0.81
	12	10.20±2.00	10.35±2.01	10.50±2.10	10.49±2.09	10.30±2.01	10.45±2.08
	16	20.11±3.90	20.20±3.92	20.90±3.95	20.86±3.94	20.15±3.90	20.85±3.94
	20	25.50±4.20	25.59±4.25	26.00±4.30	26.00±4.31	25.55±4.22	25.90±4.25
Polymer content (%)	0	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	4	0.30±0.01	0.32±0.01	0.40±0.02	0.36±0.01	0.31±0.01	0.35±0.02
	8	1.20±0.50	1.23±0.51	1.50±0.55	1.45±0.45	1.22±0.50	1.43±0.45
	12	2.10±0.65	2.16±0.66	2.60±0.68	2.50±0.67	2.15±0.65	2.42±0.67
	16	2.45±0.70	2.52±.71	3.01±0.75	2.85±0.74	2.50±0.71	2.80±0.73
	20	5.90±1.00	5.95±1.01	6.50±1.20	6.40±1.15	5.92±1.02	6.35±1.25
Oxidised Fatty acids (%)	0	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	4	0.09±0.001	0.10±0.01	0.40±0.01	0.35±0.02	0.10±0.01	0.30±0.02
	8	0.25±0.01	0.27±0.02	0.60±0.10	0.55±0.10	0.26±0.02	0.50±0.10
	12	0.82±0.20	0.85±0.21	1.00±0.30	0.90±0.25	0.83±0.23	0.90±0.25
	16	1.00±0.30	1.03±0.31	1.20±0.32	1.18±0.30	1.02±0.30	1.15±0.32
	20	1.15±0.32	1.20±0.32	1.50±0.33	1.40±0.34	1.29±0.32	1.30±0.35

Mean value ± standard deviation (SD)

Table 6: Moisture loss and oil uptake of fried potato chips for different varieties potato tubers

		Fried potato variety					
Frying Time (hr)		Osina	Glactica	Valour	Ledy valour	Sponta	Hana
Moisture loss (%)	4	0.23±0.01	0.26±0.02	0.40±0.15	0.38±0.14	0.24±0.01	0.36±0.13
	8	0.24±0.01	0.26±0.02	0.39±0.14	0.39±0.14	0.24±0.01	0.36±0.13
	12	0.23±0.01	0.25±0.02	0.41±0.16	0.40±0.14	0.25±0.02	0.37±0.14
	16	0.25±0.02	0.26±0.02	0.40±0.15	0.40±0.15	0.24±0.02	0.37±0.13
	20	0.26±0.03	0.27±0.03	0.41±0.15	0.40±0.15	0.25±0.02	0.36±0.13
Oil uptake (%)	4	38.43±3.50	43.51±3.60	50.23±4.11	48.81±3.90	41.03±3.20	47.59±3.80
	8	38.53±3.51	43.50±3.60	50.31±4.15	48.85±3.95	41.05±3.21	47.60±3.75
	12	38.49±3.40	43.52±3.61	50.45±4.16	48.90±3.92	41.11±3.22	47.62±3.76
	16	38.50±3.50	43.55±3.62	50.40±4.18	48.93±3.93	41.15±3.25	47.65±3.74
	20	38.52±3.51	43.61±3.65	50.40±4.16	48..92±3.92	41.09±3.30	47.70±3.75

Mean value ± standard deviation (SD)

Oxidised Fatty Acids: The initial value of oxidised fatty acids in fresh sunflower oil was 0.00 %. On frying process under the aforementioned conditions, the levels of oxidised fatty acids were gradually and significantly ($P \geq 0.05$) increased throughout the frying period (Table 5). However, the levels of oxidized fatty acids content in this case (frying potato varieties Osina, Sponta and Glactica) were lower than that of the oxidised fatty acids content of sunflower oil during frying potato varieties Valour, Ledy valour and Hana.

In general, the results for physico-chemical properties of fried sunflower oil were lower during frying Osina, Sponta and Glactica potato varieties than the other varieties. This results may be due to oxidation of fried oil increased with increase moisture content and reducing sugar [17].

Moisture Loss and Oil Uptake: Moisture loss profiles for different potato varieties during frying in sunflower oil at 180 ± 5°C for 20 hr for 5 days are shown in Table 6. There was significant difference ($P \geq 0.05$) between the fried potato chips. Water loss increased with increase moisture content in potato variety.

Oil uptake, in the examined chips differed (Table 6). The highest oil uptake content was in chips made of the Valour, Ledy valour and Hana potato varieties, while those produced from Osina, Sponta and Glactica potato varieties had lowest oil uptake. The amount of oil uptake has generally been related to the amount of moisture lost. In fact, several studies claim that higher initial moisture content results in an increased oil uptake, since water evaporation defines the volume of the oil reservoir, through the empty spaces, as it leaves the structure [28]. Also, oil uptake is related to starch and dry matter content of raw material [15]. Potatoes of higher dry mass content produce chips with lower oil uptake than those with lower dry matter values. That relationship was confirmed by the results obtained. The highest oil uptake was in the chips made from the Valour variety, characterized by the lowest dry matter, while the lowest uptake values were recorded for the potatoes of the Osina variety with a high dry matter content.

In conclusion, chips produced from six varieties were of appropriate colour, floavour, odour and texture. The best texture was in the chips made from Osina, Sponta and Glactica potato varieties, while Valour, Ledy valour and Hana were the worst in that respect. Chips texture depended mainly on chemical composition of the potato tubers. On the other hand, the outcome of the present study suggests that Osina, Sponta and Glactica potato varieties can be used to extend the frying life of frying oil.

REFERENCES

1. Troncoso, E., F. Pedresch and R.N. Zuniga, 2009. Comparative study of physical and sensory properties of pre-treated potato slices during vacuum and atmospheric frying. Food Science and Technology, 42: 187-195.
2. Moreira, R., M.E. Castell-perey and M.A. Barrufet, 1999. Deep- fat frying Fundamentals and applications. MD. Aspen Publishers, Inc.
3. Thygesen, L.G., A.K. Thbo, S.B. Engelsen, 2001. Predication of sensory texture quality of boiled potatoes from low-fried HNMR of raw potatoes. Lebensmittel Wissenschaft and Technologie, 34: 469-477.
4. Ross, K.A. and M.G. Scanlon, 2004. Fracture mechanics analysis of the texture of fried potato crust, Journal Food Engineering, 62: 217-423.
5. Hubbard, L.J. and B.E. Farkas, 1999. A method for determining the convective heat transfer coefficient during immersion frying. Journal Food Process Engineering, 22: 201-214.
6. Garaya, J. and R. Moreira, 2002. Vacuum frying of potato chips. Journal Food Engineering, 55: 181-191.
7. Rao, V.N.M. and A.M. Delaney, 1995. An engineering perspective on deep-fat frying of breaded chicken pieces. Food Technology, 49: 138-141.
8. Ballard, T.S. and P. Mallikarjunan, 2006. The effect of edible coatings and pressure frying using nitrogen gas on the quality of bread chicken nuggets. Journal Food Scince, 71: 259-264.
9. Innawong, B., P. Mallikarjunan, J. Marcy and J. Cundiff, 2006. Pressure conditions and quality of chicken nuggets fried under gaseous nitrogen atmosphere. Journal Food Processing & Preservation, 30: 231-245.
10. Oreopoulou, V., M. Krokida and D. Marinos-kouris, 2006. Frying of foods. In: A.S. Mujumdar, (eds.), Handbook of Industrial drying, Third ed. (RC Press, Boca Raton, F.L. (Chapter 52).
11. Costa, R.M., F.A.R. Oliveira, C.O. Delaney and V. Gekas, 1999. Analysis of heattransfer coefficient during potato frying. Journal Food Engineering, 39: 293-299.
12. Farkas, B.E., R.P. Singh and T.R. Rumesy, 1996. Modeling heat and mass transfer in immersion frying. 1. Model development. Journal Food Engineering, 29: 211-226.
13. Mayano, P.C., E. Troncoso and F. Pedreschi, 2007. Modeling texture kinetics during thermal processing of potato products. Journal Food Science, 72:102-107.

14. Troncoso, E. and F. Pedresch, 2007. Modeling of textural changes during of potato slices. Journal Food Engineering, 82: 577-584.
15. Kita, A., 2002. The influence of potato chemical composition on crisp texture. Food Chemistry, 76: 173-179.
16. Troncoso, E. and F. Pedresch:, 2009. Modeling water loss and oil uptake during vacuum frying of pre-treated potato slices. Food Science & Technology, 42: 1-10.
17. Erdogdu, F. and P. Dejemek, 2010. Determination of heat transfer coefficient during high pressure frying of potatoes. Journal Food Engineering, 96: 528-532.
18. Doran, M., F. Pedresch:, P.C. Moyano and E. Troncoso, 2007. Oil partition in pre-treated potato slices during frying and cooling. Journal Food Engineering, 81: 257-265.
19. A.O.A.C., 2005. Official Methods of Association of Agricultural Chemicals, 18th edn. Washington: AOAC.
20. Nielsen, S.S., 1998. Food Analysis, 2nd edn. Gaithersburg, Maryland: Aspen Inc., pp: 222-223.
21. Joslyin, M.A., 1950. Methods of Food Analysis. New York. Academic Press, Inc.
22. Sidwell, G.G., S. Harold, B. Milado and J.H. Mitchell, 1954. The use of thiobarbituric acids as a measure of fat oxidation. Journal The American Oil Chemical Society, 63: 1363-1367.
23. Billek, G., G. Guhr and J. Waible, 1978. Quality assessment of used frying fats: a comparison of four methods. Journal The American Oil Chemical Society, 55: 778-783.
24. Wu, P.F. and W.W. Nawar, 1986. A technique for monitoring he quality of used frying oils. Journal The American Oil Chemical Society, 63: 1363-1367.
25. Waltking, A.E. and H. Wessels, 1981. Chromatographic separation of polar and non polar components of frying oils. Journal The Association of Official Analytical Chemistry, 64: 1329-1330.
26. Carpenter, R.P., D.H. Lyon and T.A. Hasdell, 2000. Guidelines for Sensory Analysis in Food Product Development and Quality Control., pp: 71-91. Gaithersburg: Aspen Publishers, Inc.
27. Donouqe, O. and E.P. Marangoni, 1996. The relationship of crisps color with structural parameters of starch. American Potato Journal, 73: 545-558.
28. Gazmuri, A.M. and P. Bouchon, 2009. Analysis of wheat gluten and starch metrics during deep-fat frying. Food Chemistry, 108: 500-510.