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Effect of Microwave Frying on Acrylamide Formation in Potato Chips

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Abstract: The occurrence of acrylamide, a probable carcinogen and a neurotoxin, is currently a global issue. Therefore, the main objective of the present study was to determine the effects of microwave frying on acrylamide formation in potato chips. A simple method using high-performance liquid chromatography has been applied for determination of acrylamide in microwave-fried potato chips. The results showed that microwave frying could form more acrylamide at high microwave power level 800 W compared with low microwave power level 200 W. The highest level was 13230 ppb at 800 W for 120 s. Moreover, the acrylamide content was higher than the levels people might be exposed to in foods 1000 ppb. As a result of this study, it was concluded that microwave frying at high thermal process 180°C, 800 W, 120 s could form high level of acrylamide.

Keywords: Acrylamide, Corn Oil, HPLC (UV), Microwave Frying, Potato Chips, RBD Palm Olein

1. Introduction

In April 2002, the Swedish National Food Administration and the University of Stockholm published data, on the acrylamide content in many foods, such as bread, fried foods, and coffee [1]. Acrylamide is formed during high-temperature processing by the Millard reaction which requires the presence of amino acids, asparagines and reducing sugars, low moisture content [2, 3]. The Swedish National Food Administration reported that fried food products such as chips contain the highest amount of acrylamide [4]. At the laboratory scale, acrylamide causes tumors in animals. World Health Organization (WHO) [5] and the Scientific Committee for Food (SCF) of the European Union (OSCF, 2002) revealed that the concentration of was high in potato chips, and breakfast cereals. This might represent a potential threat to public health [6].

The concentration of acrylamide in potato chips depends on the type of frying oil, and frying temperature [7]. Acrylamide is created by the thermal reaction of natural potato components when moisture levels become low. Moreover, several factors, such as the initial concentration of amino acids, asparagines and reducing sugars, their ratio, heating temperature, processing time, pH, and moisture content of the product, affect the level of acrylamide in heat-processed foods [8]. The average daily food intake of acrylamide is in the range of 0.3 – 0.8 µg / kg body weight / day [5]. Depending on current reports, the daily dietary intake of acrylamide is about 0.4 µg / kg body weight, with a 90th percentile 0f 0.95 µg / kg body weight [9]. In some previous researches, it was indicated that the temperature is required to be higher than 120°C for the development of acrylamide [10]. The effect of microwave frying on acrylamide content of potato strips has also been studied and the results showed that the acrylamide content of microwave fried potatoes was lower compared to those fried in conventional deep fryer because of the shorter frying time [11]. Moreover, Microwave frying resulted in lower acrylamide formation in the coatings prepared by different types of flours as compared to conventional frying [12].

Microwaves offer many advantages in certain food processing operations primarily short processing time, space and energy savings, as it ensures preservation of nutritional value, process control, and selective heating [13-15]. Microwave heating mechanism differs from conventional methods. Volumetric heating is the most important feature of microwave heating. Absorption of microwave energy results in internal heat generation within product. However, in traditional heating methods, the heat is transmitted from the surface to the inside of the food. The popularity of microwave heating increases in heat treatment applications because of increasing preference for high quality products that can be prepared in a short period of time along with the development of technology [11, 12, 16-20] However, the effect of microwave frying on acrylamide content of potato strips has also been studied recently and it was found that the acrylamide content of microwave fried potatoes was lower compared to those fried in conventional deep fryer because of the shorter frying time [11]. There are few studies in literature about the effects of microwave frying on acrylamide formation. However, there is no study in literature about the effect of microwave frying at different conditions on acrylamide level in the potato chips using RBD palm olein and corn oil. Therefore, the aim of this study was to investigate the effect of different microwave frying conditions on the acrylamide formation in microwaved-fried potato chips using RBD palm olein and corn oil.

2. Materials and Methods

2.1. Sample Collection

Russet Potatoes cultivar Goldrush, RBD palm olein (Seri Murni) and corn oil (Daisy) were purchased from a local supermarket. Acrylamide (99%) was obtained from Sigma (Diesenhofen, Germany). HPLC gradient grade acetonitrile was obtained from J. T. Baker (Deventer, Holland). Ultra-pure water was used for the chromatographic analysis (MilliQ system, Millipore, Bedford, MA, USA). A Standard stock solution of 1 mg / mL acrylamide was prepared in ultra-pure water and stored between 2 and 5ºC until use. Aliquots of the above stock solution were diluted with ultra-pure water to get concentrations of 50 - 250 µg / mL and used for HPLC analysis. The established calibration curve had good linearity, with $R^2 > 0.99$.

The fresh potatoes were processed with these process peeled, washed with clean water and cut into disc-shaped slices of 2 mm in thickness and 5.8 cm in diameter. The regularity of the thickness of the slices was checked using a caliper. The potato slices were rinsed with distilled water to eliminate starch material on the surface and then blotted with paper towels before each experiment. The samples were placed in aluminium foil to avoid any moisture loss before further processing.

2.2. Microwave Frying Experiments

Microwave frying was performed in microwave oven (Panasonics, Model NN-GT353M, Panasonic Asia Pacific, Panasonic Malaysia Sdn Bhd). Three power levels (high at 800 W, medium at 400 W, and low at 200 W) were used to obtain initial frying temperatures of 180±1, 170±1 and 160± 1°C, respectively. The temperatures of the oils inside the microwave cavity were checked with an optical fiber temperature sensor from OPSens. Power levels were determined by an IMPI 2-L test [21]. Microwave frying was performed in a container containing 300 mL of oil. Room temperature (25±3.0°C) oil was first heated for 8 min to 180 ± 1.0°C at the high power of the microwave oven. The microwave frying potato/oil ratio was maintained at 1:20 (w / v). Four potato slices with an average weight of 15.0 ± 1.5 g were inserted in hot oil at a specific microwave power and frying time of 30, 60, 90, 120, or 150 s. The power of the microwave oven was turned off, and the potato chips were removed, blotted with paper towels, and allowed to cool to room temperature before samples preparation.

2.3. Determination of Acrylamide Content

For sample preparation, potato chips were first minced, and 4 ± 0.1 g was weighed into a 50 ml polypropylene tube. Hexane (20 mL) was added, and the tube was vortexed for 3 min and centrifuged at 5000 rpm for 5 min to remove fat. Ultra-pure water (10 mL) and acetonitrile (10 mL) were added to the tubes and shaken vigorously for 3 min, followed by centrifugation at 5000 rpm for 5 min. A 3 mL aliquot of the supernatant was cleaned-up by solid phase extraction "SPE". The silica gel cartridges were conditioned with (3 mL) of methanol and (3 mL) of water before loading with (3 mL) of filtered supernatant. The samples were then eluted with (1.0 mL) of ultra-pure water. The samples were further purified by SPE. The purified eluent from was subjected to HPLC analysis.

2.4. Apparatus and Chromatographic Conditions

Chromatographic separation was performed on a module 2695 equipped with a Waters 2489 liquid chromatographic system dual-wavelength UV Vis detector, (with detection at 202 nm) and an injector with a 20 µL loop volume. Empower software was applied for data collecting and processing. A Phenomenex C18 reverse-phase (RP) column (250 mm x 4.6 mm i.d. 5µ) was used for separation. The mobile phase consisted of a mixture of acetonitrile and water (pH 3.5 adjusted with orthophosphoric acid) (20:80 v/v) at a flow rate of 0.8 mL / min with detection at 202 nm. The mobile phase was filtered through a 0.2 µm membrane filter and degassed. The injection volume of 20 µL was performed triplicated [22]. The analysis was performed at ambient temperature.

2.5. Statistical Analysis

All experiments and measurements were performed in triplicate (n=3). Both the means and standard deviations (SD) were calculated using MINITAB (version 14.0, Minitab Inc.) statistical software. A two-way analysis of variance (ANOVA) with Tukey's multiple comparisons at ($P < 0.05$) was performed to assess significance.

3. Results and Discussion

The results in (Table 1) showed that acrylamide formation increased accordingly with time for all temperatures for the microwave-fired potato chips fried in RBD palm olein. When frying potato chips in microwave oven at high temperature (180°C/120 s), acrylamide content was the highest and then the acrylamide formation decreased by ≈89% (from 13230 ppb to 1427 ppb) when temperatures changed from 180 to 170°C at 120 s, and about 90% (from 11423 ppb to 1140 ppb) from 180 to 160°C at 150 s. The European Commission recommendation regarding the acrylamide level in foods set a recommendable level for this toxin in potato chips at 1000 ppb. Of the 30 samples of potato chips analyzed, 40% satisfied this recommendation. The values of acrylamide were higher than those reported in Turkish [23] and Columbian fried food products [24]. Most of the potato chips exhibited very high concentrations of acrylamide compared with concentrations reported in the literature. Ghiasvand and Hajipour observed acrylamide concentration in potato chips of 1592 to 18640 ppb. The acrylamide content differed significantly ($P < 0.05$) as frying temperatures and frying times [25]. Pedreschi found that a reduction of the frying oil temperature from 190 to 170 or 150°C decreased acrylamide formation in potato chips by 61% (≈5300–2050 ppb) and 66% (≈2050–700 ppb), respectively [26]. Haase reported that by lowering the frying temperature from 185 to 165°C and from 190 to 150°C, it was possible to reduce the acrylamide content in potato chips by half and by two-thirds, respectively [27]. Kita also mentioned that a decrease of approximately 75% (3300–1500 ppb) in acrylamide content of potato chips when reducing the frying oil temperature from 185 to 160°C [28].

Table 1. *Acrylamide levels (ppb) in potato chips fried in RBD palm olein.*

Frying time (s)	Frying temperature (°C)		
	160	170	180
	Acrylamide Concentration (ppb)		
30	542±15.6^{Aa}	669.0±70^{Aa}	1139.40±56^{Ab}
60	286.82±47.7^{Ba}	3511.5±78.5^{Db}	1717.17±55^{Aa}
90	785±50.9^{Ca}	1795.5±32^{Cb}	8172.90±48^{Bc}
120	811.60±28.4^{Ca}	1427.5±27.6^{Bb}	13230.30±226^{Dc}
150	895.15±59.9^{Ca}	1739.0±11.3^{Cb}	11423.18±256^{Cc}

Each value in the table represents the mean± standard deviation of triplicate analyses for each frying oil, mean value with rows (a, b, c) and columns (A, B, C), followed by different superscript are significantly different ($P < 0.05$).

Table 2. *Acrylamide levels (ppb) in potato chips fried in corn oil.*

Frying time (s)	Frying temperature (°C)		
	160	170	180
	Acrylamide Concentration (ppb)		
30	380±44.4^{Aa}	648.5±13.8^{Aa}	2005.7±545^{Ab}
60	805.1±16.7^{Ba}	1020.3±61.1^{Bb}	1580.21±37^{Bc}
90	678.7±77.4^{Ba}	442.3±53.2^{Ba}	7037.40±558^{Cb}
120	885.50±5.9^{Ca}	7115.20±149^{Cb}	12301.70±110^{Dc}
150	1040.1±7.9^{Da}	1086.50±127.7^{Ca}	9683.40±444.6^{Dbc}

Each value in the table represents the mean± standard deviation of triplicate analyses for each frying oil, mean value with rows (a, b, c) and columns (A, B, C), followed by different superscript are significantly different ($P < 0.05$).

Gertz and Klostermann found a decrease of 85% (1240–184 ppb) in acrylamide content in French fries when lowering the oil temperature from 185 to 160°C. In addition, there was degradation of acrylamide with a frying time of 60 s at 180°C [7].

In microwave-fired potato chips fried in corn oil, the acrylamide content ranged between 380 and 12301 ppb. The acrylamide level in potato chips fried at 160°C ranged between 380 and 1040 ppb and was lower than the acrylamide levels detected for frying at other temperatures. In addition, there was degradation of acrylamide with a frying time of 60 s at 180°C, as shown in (Table 2). The same behavior was observed by Amrein et al. [29]; Granda et al. [30]. The acrylamide concentration increased significantly with increasing frying temperature and frying time ($P < 0.05$). Similar values ranging from 224 to 3700 ppb have reported by others (Becalski et al. [31]; Roach et al. [32]; Rosen et al. [1]; Tareke et al. [4]. Studies in China have reported a much higher value of acrylamide content in potato crisps of 3,016 ppb [33]. Shamla et al. [34] observed acrylamide concentrations of 1465 ppb in potato chips. Overall, the lowest amount of acrylamide 282 ppb was detected in potato chips fried in RBD palm olein at 160°C, 30 s. The lowest concentration of acrylamide in chips fried in corn oil was 380 ppb. The highest levels (12301 and 13230 ppb) were detected in potato chips fried in corn oil and RBD palm olein, respectively. The results in (Table 2) showed the degradation of acrylamide with time at 180°C/ 150 s. The temperature increase may not be the only effect that needs to be considered. Reactant concentrations (asparagine and reducing sugars) in potato chips may be also being evaluated [30].

The increase in acrylamide formation in potato chips fried in corn oil at 170°C was higher than in those fried in RBD palm olein at the same temperature. The acrylamide content increased from 442.28 ± 53.2 ppb at 170°C during the 90 s of frying to 7115.20 ± 149.5 at 170°C/120 s. The acrylamide content in the potato chips fried in PBD palm olein was slightly increased at 170°C.

These results indicate that acrylamide content in the microwave-fried potato chips fried in RBD palm olein in comparison with the samples for microwave-fried potato chips fried in corn oil may be due to the higher thermo oxidative stability of RBD palm olein in comparison with corn oil [35, 36]. This result was similar to previous finding that the presence of natural antioxidant components in frying oil can reduce the concentration of acrylamide formation in crisps by improving therm-oxidative stability of frying oil [37].

The effect of temperature on the formation of acrylamide in potato chips fried in corn oil presented in (Table 2). Acrylamide increases with temperature increased from 160 to 180°C at 120 s of frying; the acrylamide content reduction in microwave-fried potato chips was about 92% (from 12302 to 885.5 ppb). This decrease in acrylamide content is because of the lower temperature used during microwave frying. In this study, potato chips fried in corn oil showed an increase in acrylamide formation as the temperature frying and frying time increased. The acrylamide formation in potato chips continuously increased with increasing frying time at 120 s. Moreover, the decreasing the temperature from 180 to 160°C caused a decrease in acrylamide content of about 90%. The results in (Table 2) showed that at 30, 60s, the acrylamide content were lower ≈ 1600 ppb. There were significant differences in acrylamide content ($P < 0.05$) between potato chips fried in corn oil at different frying temperature.

4. Conclusion

According to the present study, there was a significant difference in acrylamide contents in the potato chips fried in corn oil and RBD palm olein which ranged between 380 and 12,301; 282 and 13,230 ppb, respectively. Among the potato chips samples, 40% had lower acrylamide levels than the maximum values recommended by the European Commission recommendation. High levels of acrylamide were observed in the remaining 60% of the potato chips samples may be due to high thermal processes during microwave frying. In conclusion, the potato chips fried at (200 W), low temperature (160°C) and low frying time led to minimum acrylamide content. The acrylamide content in microwave-fried potato chips increased significantly as microwave power level, frying temperature and duration increased. The results showed that microwave frying at 800 W, and 180°C might be more favorable to the formation of acrylamide compared with low microwave power level and low temperature. Therefore, it is recommended to use lower frying temperatures and low frying time, which will lead to a reduction of acrylamide formation. In addition, we found that the formation of acrylamide had a relationship with the increase in temperatures and frying time. This study confirmed that, to control the level of acrylamide in fried foods, it is important to control the microwave power, frying temperature and frying time during the microwave frying process.

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