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Preventive Action of Acrylamide Formation as A Chemical Hazard During Deep Fat Frying of Potato Strips

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Abstract

Acrylamide is a chemical contaminant that is driven from heat induced reaction between asparagine and reducing sugars during process. This study is aimed to investigate the most effective pre-frying heat treatment as a preventive action on acrylamide formation during frying of potato strips. Acrylamide was determined in potato strips samples using High Performance Liquid Chromatography with UV detector (HPLC-UV) technique. Immersing samples in boiled water (BW) treatment was carried out for 30, 60 and 90 Sec. Also, exposing samples to water vapor (WV) treatment was carried out for 30, 60 and 90 Sec. Exposing samples to microwave treatment was occurred by exposing potato strips to different microwave powers P_1 (385 W), P_2 (540 W) and P_3 (700 W) for 30, 60 and 90 sec. of each power level. Results showed significant differences ($p<0.05$) in acrylamide levels between exposure times in each individual treatment. Comparing the results among all the treatments and times showed that no significant differences ($p<0.05$) between each following pair of treatments: WV/30 sec. and P_2/30 sec.; P_2/30 sec. and BW/60 sec.; P_1/90 sec. and WV/60 sec. and P_2/90 sec. and BW/90 sec. Microwave is the most effective heat treatment to produce safe fried potato strips.

Keywords: Potato strips; Acrylamide; Asparagine; Reducing sugars; Boiled water; Water Vapor. Microwave; HPLC-UV.

1. Introduction

Acrylamide is a chemical compound has no color, non-volatile, crystal-like solid, solvable in water and has a molecular weight of 71.08 kDa [1]. Polyacrylamide was produced commercially and used for many industries i.e. waste water treatment, paper making and as monomers for production of many other products [2]. Acrylamide is often formed during processing, catering, homemade potato products and many other foods such as coffee, bakeries and chocolate [3]. There is no doubt that acrylamide is considered to has toxic effects on many body systems comprise genitourinary, generative, nervous system, along with being a cancer-causing substance [4,5].

It had been stated that confident foods that are treated or heated at high temperature contain relatively high level of acrylamide. The incidence of acrylamide is motivated from heat brought reaction between the amino group of asparagine (an amide resulting from aspartic acid) and the group of carbonyls in reducing sugars during baking and frying [6]. This decomposed product is engendered during Maillard reactions, linking free reducing sugars and an exact amino acid, *i.e.*, asparagine (an amide resulting from aspartic amino acid) when temperatures typically exceed 120 °C that converted to amide [7].

Although, asparagine individually may issue acrylamide by thermally started decarboxylation and deamination, in the existence of reducing sugars [8], the major mechanism of acrylamide formation therefore involves the reaction of a carbonyl compound in reducing sugar with amino group in asparagine, resulting in the formation of N-glycosylasparagine and the formation of a decarboxylated Schiff base (after dehydration under high temperatures) [9,10]. This reaction includes a

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force of reactions with different highly responsive intermediates resulting in acrylamide formation in food. These intermediates have been proposed in Figure 1 [7,11,12] as following: a) Decarboxylation of the Schiff base which may prime after breakdown directly to acrylamide and an imine or followed by hydrolysis to 3-aminopropamide (3-APA) and carbonyl compounds. In this respect, it should be distinguished that 3-APA may as well occur in potatoes as such, b) consequent removal of ammonia from 3-APA can produce acrylamide and c) on the other hand, acrylamide may also be produced by the hydrolysis of the imine which provides the Strecker aldehyde of asparagine (3-oxopropanamide), although to a limited extent [10,13].

Blanching is used in industrial production of potato products, as a common pre-treatment to extract reducing sugar in direction to decrease browning, to deactivate enzymes *i.e.*, polyphenol oxidase and to decrease the oil acceptance by gelatinization of surface starch. There are many studies that privilege acrylamide formation reduction in potato products by shifting to blanching conditions [14]. Besides, immersed potato strips in water for 2 hours at ambient temperature presented a decrease the rate of acrylamide creation by 33%, 27% and 21% at frying temperature of 150, 170 and 190 °C respectively, as compared contrary to the control. Also, immersing potato strips on hot water at 50 °C for 80 min lowered acrylamide level after frying at the previous temperature. Also, the immersed potato strip in citric acid solution (10 g/L) reduced much more the acrylamide development after frying than the strips immersion in sodium pyrophosphate solution at the same concentration. Acrylamide development decreased dramatically as the frying temperature decreased from 190 to 150 °C for all the pre-treatments used [15].

Microwave pre-cooking of potato strips effect on acrylamide levels in French fries was also examined.

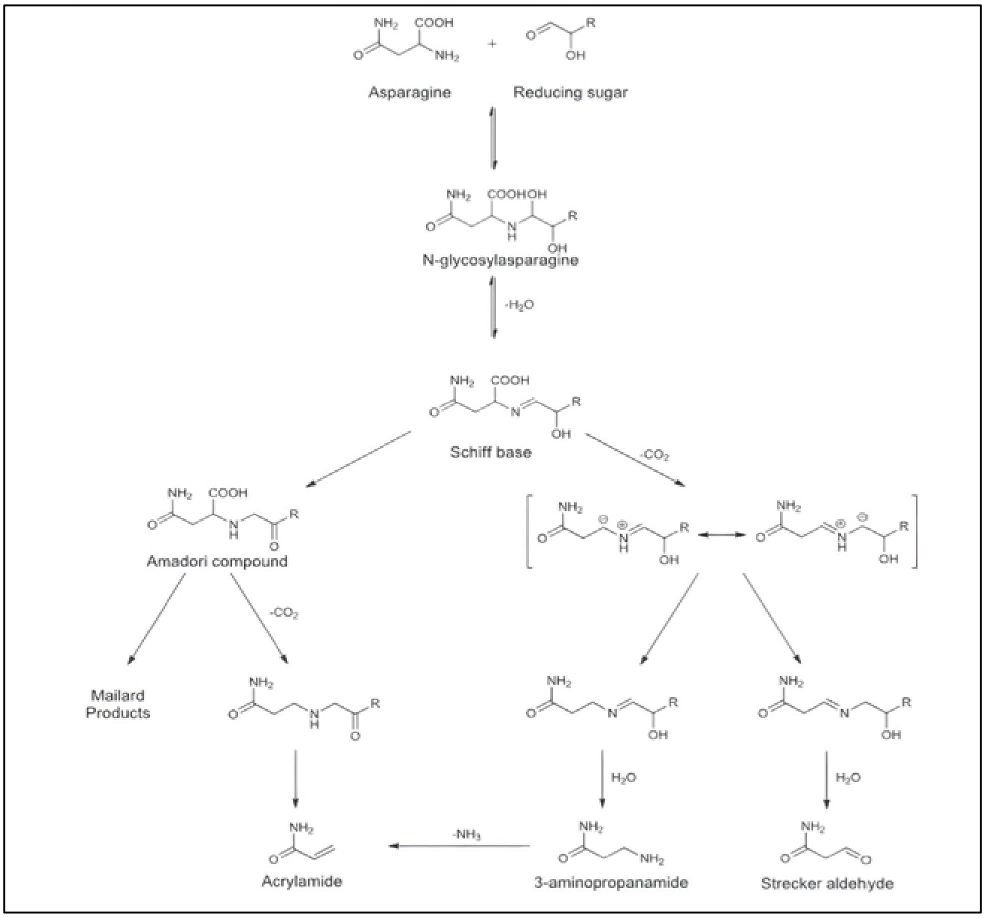

Figure 1. Proposed mechanism for acrylamide formation as a side reaction of the Maillard reaction

The results showed that microwave submission prior to frying caused a marked reduction of acrylamide content in the surface layer, whereas an insignificant increase was noticed for the central region [16]. Microwave power and time should be controlled because it was reviewed that microwave frying at high thermal process could form high level of acrylamide [17].

Commission regulation of European Union (EU) identified benchmark levels for presence of acrylamide in foodstuffs which were 500, 750, 50-100, 150-300, 400, 850, 500, 40 and 150 µg/Kg in ready to eat French fries, soft bread, breakfast cereals, roasted coffee, instant coffee, coffee substitute, processed cereal based baby food and biscuits for infants and young children respectively [18].

One of the most important challenges is to minimize the formation of acrylamide both during industrial food-processing as well as food preparation by consumers. Home-cooking choices could have a substantial impact on the acrylamide content in food [17].

The aim of this study is to investigate the effect of pre-frying heat treatment (*i.e.*, immersing in boiling water, espousing to water vapor and microwave treatment) as a preventive action of acrylamide formation during deep fat frying of potato strips.

2. Experimental

2.1. Materials

Potatoes (*Solanum tuberosum L.*) Diamond variety was obtained from Horticulture institute, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Giza, Egypt. Palm stearin was obtained from Arma for Food Industry Company, 10th of Ramadan city, Sharkia governorate, Egypt. Acrylamide (>99%) was obtained from Aldrich, USA.

2.2. Methods:

2.2.1. Frying process:

Frying process was carried out by deep-fat frying [19] with some modifications. Where's treated potato strips were fried in palm stearin with a ratio of 1 Kg potato strips / 7 Kg palm stearin at 170 °C for 12 min. using Moulinex fryer, model: SERIE F30, China.

2.2.2. Boiling water (BW) blanching treatment:

Potato strips (1.5 Kg) were divided into equal 3 parts, each one was immersed in boiling water using Stainless steel pan for 30, 60 and 90 sec. then decanted and fried.

2.2.3. Water vapor blanching treatment:

Potato strips (1.5 Kg) were divided into equal 3 parts, each part was exposed to water vapor using electric CAMPOMATIC vapor pan model: CS 180SS, China, for 30, 60 and 90 sec. then fried.

2.2.4. Microwave treatment:

Potato strips (500 g for each treatment) were exposed to different microwave power levels (P_1=385 W, P_2=540 W and P_3=700 W) using FIRST Microwave model: KOR – 6L 15, China, with capacity of 6 Liters for different exposure times for each level of power (30, 60 and 90 sec.) then fried.

2.2.5. Acrylamide Determination:

Acrylamide content in fried potato strips was determined by Hewlett Packard (hp) High Performance Liquid Chromatography with UV detector (HPLC-UV) [20]. One g of each solid potato strips samples was weighed into 50 mL Teflon centrifuge tubes. To each one of centrifuge tube 10 mL of water was added. All the caped tubes were clamped in a rotating shaker and shaken for 30 min. The tubes were centrifuged at 6700 ×g for 10 min. A pipette was put in through the oil layer in the top to the bottom aqueous layer, avoiding solids in the bottom with the pipette tips when 3.0 mL of aqueous phase was reserved. The aqueous sample solution was then centrifuged by a cyclone centrifuge with freezing at 14,500 ×g and at 0 °C for 15 min to solidify and precipitate the oil residue in the aqueous sample solution. Then 2.0-mL aliquot of clarified aqueous layer was promptly removed and filtered through a 0.45 µm Polyvinyl Difluoride (PVDF) syringe filter to a vial.

Oasis Hydrophilic-Lipophilic-Balanced Solid Phase Extraction (HLB-SPE) cartridges and Varian Bond Elut-Accucat SPE cartridges were used to remove a number of early eluting co-extractives (*i.e.*, the interferents) in the aqueous sample extract. Oasis and Elut-Accucat SPE cartridges were initially conditioned with 3.5 mL of methanol shadowed by 3.5 mL of water; the methanol and water percentages were wasted. The filtered extract was allowed to continually pass through both SPE cartridges then collection of all elutant from the Oasis and Elut-Accucat SPE cartridges was created. The extract was then evaporated to just about dryness by a kind stream of compressed air at room temperature. The resulting residue was dissolved again in water and adjusted to 1.0 mL in a 1.5-mL tawny glass vial. All clean sample extracts were kept at 4 °C until future use. Additional filtrations of the clean sample extracts were performed through 0.2 µm PVDF syringe filters prior to all HPLC–UV analyses.

HPLC–UV analysis was created on an HP 1010 series HPLC instrument equipped with a vacuum degasser, a dual pump and a DAD (Hewlett Packard, Wilmington, DE, USA). The calibration standards and sample extracts were injected by a 20 µL sample loop, and detected at the same time at UV wavelengths of 210 nm. A rise elution program was used at a flow rate of 0.10 mL/min, in which mobile phase A (acetonitrile and water 1:24 (v/v)), and mobile phase B (pure acetonitrile). The elution program was applied as follows:

- 100% A (0% B) for 10 min;
- 20% A (80% B) from 10 to 12 min; and kept at 20% A for 5 min;
- Increased to 100% A from 17 to 19 min; and kept at 100% A for 21 min.

So, the total run time was 40 min. Under these chromatographic situations, acrylamide and the food components in the established samples were all baseline separated and eluted.

2.2.6. Statistical analysis:

All experiments and measurements were performed in triplicate (n=3). Means and standard deviations (SD) were calculated using IBM SPSS program ver. 26 statistical software. ANOVA analysis of variance with Duncan's multiple comparisons at ($P < 0.05$) was performed to assess significance.

3. Results and discussion

3.1. Blanching using boiled water (BW) treatment

The acrylamide content in potato strips as affected by blanching using boiled water were given in table 1. The results showed that acrylamide contents were 2223, 1238, 949 and 530 µg/kg at exposure time 0, 30, 60 and 90 Sec. respectively. The decreasing percentages reached 44%, 57% and 76% respectively. A significant decreases of acrylamide contents ($p<0.05$) were found by increasing exposer time, but the lowest level of acrylamide was not reached the acceptable amount in French fries which identified by commission regulation (EU) 2017/2158 (500 µg/Kg) (EU, 2017). Where's, the acrylamide level was slightly increased by 30 µg/Kg of that recommended by the EU regulation at BW/90 sec.

A previous study on potato chips revealed that blanching at 86 °C for 6 min. decreased the acrylamide content from 3100 µg/Kg to 1100 µg/Kg. The reduction percentage reached 64.5% [21].

3.2. Blanching using water vapor (WV) treatment

Table 1. Effect of blanching by boiled water (BW) on acrylamide content of deep fat fried potato strips.

	Time (Sec.)			
	Control	30	60	90
Acrylamide content (µg/Kg) [1]	2223±99^{a}	1238±25^{b}	949±23^{c}	530±14^{d}
Decomposition rate (%)	--	44%	57%	76%

[1] The values are expressed as mean±SD and cells superscript with different letters are significantly different ($p < 0.05$).

The results of blanching potato strips by exposing to WV are shown in table 2. The obtained results showed that acrylamide contents were 2223, 1023, 723 and 321 µg/kg at exposure times 0, 30, 60 and 90 Sec. respectively. The decreasing percentages were 54%, 68% and 85% respectively. A significant decreases of acrylamide contents ($p<0.05$) were found by increasing exposure time.

The acrylamide content of potato strips exposing to WV for 90 sec. (321 µg/Kg) was less than that recommended by commission regulation (EU) 2017/2158 (500 µg/Kg) [18].

Table 2. Effect of blanching by water vapor (WV) on acrylamide content of deep fat fried potato strips.

	Time (Sec.)			
	Control	30	60	90
Acrylamide content (µg/Kg) [1]	2223±99^{a}	1023±11^{b}	723±13^{c}	321±8^{d}
Decomposition rate (%)	--	54%	68%	85%

[1] The values are expressed as mean±SD and cells superscript with different letters are significantly different ($p <0.05$).

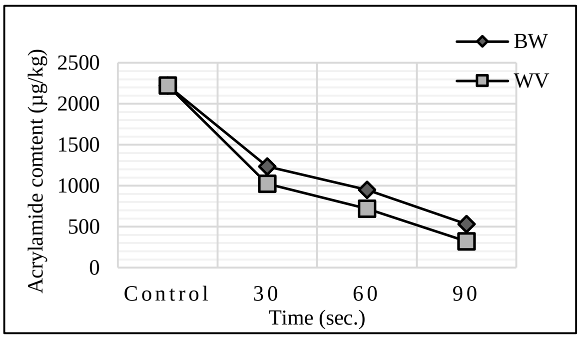

Figure 2. Effect of BW and WV pre-frying treatments on Acrylamide content of deep fat fried potato strips

The same results showed that WV treatment was more effective than treatment using BW in reduction rate of acrylamide formation in potato strips as shown in figure 2.

3.3. Microwave treatment

Table 3 showed the acrylamide contents of fried potato strips as affected by exposure to microwave powers (P_1=385W, P_2=540W and P_3=700W) at exposure times 30, 60 and 90 sec. for each power used. The results showed that acrylamide contents in P_1 were 1432, 1162 and 739 µg/kg with decreasing percentages 36%, 48% and 67% at exposure times of 30, 60 and 90 Sec., respectively. Meanwhile, results showed that acrylamide contents in P_2 treatment were 990, 801and 530 µg/kg with decreasing percentages 55%, 64% and 76% at exposure times of 30, 60 and 90 Sec., respectively. Furthermore, the same results showed that acrylamide contents of P_3 treatment were 631, 381 and 253 µg/kg with decreasing percentages 72%, 83% and 89% at 30, 60 and 90 Sec. respectively. The tabulated results showed significant differences ($p<0.05$) among all microwave powers at different exposure times. Also, data showed that acrylamide contents in both P_3/60 sec. and P_3/90 sec. were less than acceptable limit recommended by commission regulation (EU) 2017/2158 in potato strips (500 µg/Kg) [18]. A previous study concluded that microwave-fried samples of French fries exhibited a reduction of acrylamide content, obtaining lower amount of acrylamide when increasing the applied power. Meanwhile, increasing microwave exposure time for any power increased the acrylamide content [22]. Furthermore, thawing French fries in microwave before frying by 30% power/5 min then deep fried at 180°C/3.5 min., led to reduction of acrylamide content [23]. It was concluded that microwave frying at high thermal process (180°C, 800 W, 120 sec.) led to higher content of acrylamide [24].

Table 3. Effect of different microwave powers pre-frying treatment on acrylamide content of deep fat fried potato strips

Time (Sec.)	Microwave powers					
	P_1 (385 W)		P_2 (540 W)		P_3 (700 W)	
	Acrylamide content (µg/Kg)	Decomposition rate (%)	Acrylamide content (µg/Kg)	Decomposition rate (%)	Acrylamide content (µg/Kg)	Decomposition rate (%)
Control	2223±99[a]	---	2223±99[a]	---	2223±99[a]	---
30	1432±27[b]	36%	990±6[d]	55%	631±6[g]	72%
60	1162±13[c]	48%	801±6[e]	64%	381±10[i]	83%
90	739±4[f]	67%	530±7[h]	76%	253±9[j]	89%

[1] The values are expressed as mean±SD and cells superscript with different letters are significantly different ($p < 0.05$).

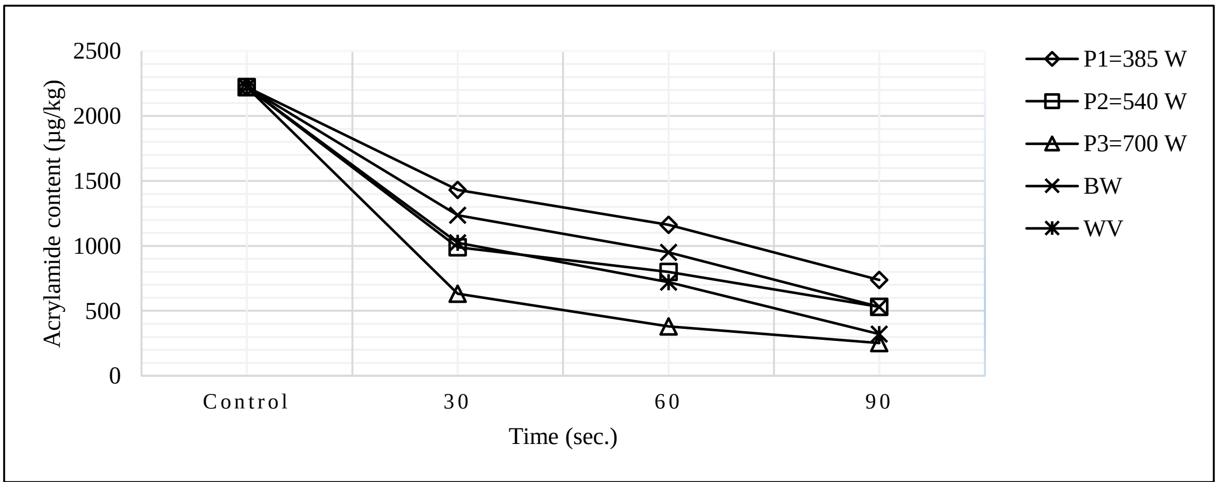

Figure 3. Effect of all pre-frying heat treatments on Acrylamide content of deep fat fried potato strips

Table 4. Statistical analysis of BW, WV and microwave powers heat treatments.

Time (Sec.)	Acrylamide level [1] (µg/Kg)				
	Microwave powers			WV	BW
	P_1 (385 W)	P_2 (540 W)	P_3 (700 W)		
Control	2223±99[a]	2223±99[a]	2223±99[a]	2223±99[a]	2223±99[a]
30	1432±27[b]	990±6[e,f]	631±6[i]	1023±11[e]	1238±25[c]
60	1162±13[d]	801±6[g]	381±10[k]	723±13[h]	949±23[f]
90	739±4[h]	530±7[j]	253±9[m]	321±8[l]	530±14[j]

[1] The values are expressed as mean±SD and cells superscript with different letters are significantly different ($p < 0.05$).

Table 4 showed that no significant differences ($p<0.05$) between each following pair of treatments: WV/30 sec. and P_2/30 sec.; P_2/30 sec. and BW/60 sec.; P_1/90 sec. and WV/60 sec. and P_2/90 sec. and BW/90 sec.

Figure 3 showed the effect of all pre-frying heat treatments on Acrylamide content of potato strips. The most effective treatment was microwave power (P_3) at 60 and 90 sec. Furthermore, both treatments of WV and P_2 at first 30 Sec of time had the same effect on acrylamide content. Meanwhile, at 60 sec. the obtained results showed a very slight difference between the same two treatments. The least effective treatment was microwave power (P_1) at all tested times.

4. Conclusion

We concluded that heat treatment *i.e*., BW, WV and microwave prior to deep fat frying of potato strips could be used successfully as a preventive action for reducing acrylamide formation. The most effective pre-heat treatment found was microwave at power 700 W for 60 and 90 sec.

Although, microwave treatment only affects asparagine (amide) without any effect on reducing sugars content of potato strips and BW treatment affect both asparagine and reducing sugars, microwave treatment at specific powers was more effective than BW treatment as a preventive action of acrylamide formation during deep fat frying of potato strips. This finding ensures that asparagine (amide) was a main precursor of acrylamide formation during deep fat frying of potato strips.

5. Acknowledgments

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