J. Agric. Sci. Mansoura Univ., 34 (4): 3049 - 3063, 2009

STUDIES ON ACRYLAMIDE FORMATION IN SOME EGYPTIAN POPULAR FRIED-FOODS

Osman, M. F.; M. A. Abd El-Galeel and A. K. Ammar
Food Technology Dept., Fac. of Agric., Kafrelsheikh Univ., Kafrelsheikh, Egypt.

ABSTRACT

The aim of this work is to investigate the effect of frying conditions on acrylamide formation in some popular Egyptian fried- foods. Prepared potato chips and bean balls (falafel) were obtained from three different restaurants in Kafrelsheikh City. After preparing falafel balls and potato slices, they were fried under laboratory conditions using palm oil or blend of cottonseed and sunflower oils (1:1). The obtained results revealed that frying conditions especially; reusing of oil lowered the quality of physical and chemical properties of restaurant oils. The deterioration of oil had a great effect on acrylamide formation, where the samples fried in restaurants had significantly higher acrylamide levels than those of samples fried in laboratory. Also, potato chips had acrylamide content higher than that of falafel either in restaurants or in laboratory. Reducing sugars and asparagine contents of samples before frying played an important role in acrylamide formation. The highest level was found in samples contained the highest reducing sugars; followed by those contained the moderate level of reducing sugars and the highest level of asparagine. But the lowest acrylamide content was found in samples contained the moderate level of reducing sugars and the lowest content of asparagine. Samples fried using palm oil in lab had acrylamide content lower than those fried using mixed oil from cottonseed and sunflower. Sensory characteristics could not be used as an indicator for acrylamide content, where potato chips or falafel with similar sensory characteristics had different acrylamide concentrations. The results of the present study suggest that acrylamide formation depended strongly on frying conditions (especially reusing of oil) and chemical composition of samples (especially reducing sugars and asparagine content). From these results, it can be recommended that frying using fresh oil at low temperature for a short time (as possible as) and lowering reducing sugars and asparagine of samples are important to reduce the acrylamide formation in fried foods.

Keywords: Acrylamide, potato chips, falafel, frying, cottonseed oil, palm oil, sunflower oil.

INTRODUCTION

Acrylamide is a low molecular weight vinylic compound. This colorless and odorless crystalline substance is highly water soluble, easily reactive in air and rapidly polymerizable, i.e. single molecules of acrylamide (monomers) can bind together and form a larger molecule (polymer) with new properties (Besaratinia and Pfeifer, 2007). It was first reported in cooked foods in 2002 (Tareke *et al.*, 2002).

Acrylamide is known to be carcinogenic to laboratory rodents and has been classified as a probable human carcinogen and neurotoxin according to the IARC (1994). Acrylamide is a potential health hazardous compound, occurring during preparation and/or processing of foods, although studies to date have not demonstrated carcinogenicity in humans. It is also a known neurotoxin. The toxicological studies on acrylamide revealed that, it causes DNA damage and at high doses, neurological and reproductive effects have been observed. The no observed effect level for acrylamide was reported to be up to 2 mg/kg rat body weight per day (FAO/WHO, 2002). Allan, (2002) reported that acrylamide is considered to be genotoxic *in-vivo* and carcinogenic in experimental animals. The acute oral LD_{50} for acrylamide in rats is 107-203 mg/kg body weight (Lindsay, 2002).

The Maillard reaction has been shown to generate acrylamide (Mottram *et al.*, 2002, Stadler *et al.*, 2002), it is generally agreed that the main precursors are sugars and the amino acid asparagine (Amrein *et al.*, 2003) and it is favored by conditions of high temperature and low moisture content (Taeymans *et al.*, 2004). Potatoes contain relatively high amounts of sugars (glucose, fructose and sucrose) and asparagine. These components are varied with potato variety and storage conditions (Olsson *et al.*, 2004, Wicklund *et al.*, 2006).

Acrylamide was shown to be present in a wide range, from low levels in bread and meat products, to much higher levels in potato chips. Even this preliminary study showed that temperature and moisture content were key factors in the levels of acrylamide formation (Burch, 2007). The excessive use of frying oil in food preparation caused significant increases in acrylamide content, especially in falafel (Al-Dmoor *et al.*, 2004).

Acrylamide has been found mainly in carbohydrate-rich foods. Surveys of commercially available foods showed that levels could vary widely from manufacturer to manufacturer, and that in general the highest levels were found in potato crisps and chips (Becalski *et al.*, 2003, Yusa *et al.*, 2006). Chemical analysis has shown that acrylamide is presented in a large number of foods and its level differ widely within each food group analyzed, despite it has so far not been detected in raw foods. For example, raw potato has negligible levels of acrylamide (< 0.030 mg/kg of potato) but, if you make potato chips, the level of acrylamide can skyrocket to 1.2 mg/kg (Swedish National Food Administration, 2002). Acrylamide does not only form in industrially manufactured foods, but also foods prepared at home are concerned (Glese 2002). Mottram *et al.*, (2002) found that the acrylamide formed in significant quantities when the food was heated at about 180°C. Potatoes contain high levels of amino acid asparagine and starch, this may explain why they have the highest acrylamide levels when compared to other chips such as corn (Stadler *et al.*, 2002).

The formation of acrylamide in fried foods was found to depend on the composition of raw materials and frying conditions. In potato chips, acrylamide was rapidly formed at over 160 °C, the amount proportional to the heating duration and temperature (Kim *et al.*, 2005).

In Egypt, considerable amounts of fried traditional foodstuffs such as potato chips and falafel, which are expected to contain acrylamide are consumed. The objectives of this study were to investigate the acrylamide formation in potato chips and falafel processed either in home or in restaurants as well as to compare the effect of different processing factors on acrylamide formation.

MATERIALS AND METHODS

Materials:

Fried and paste falafel (bean balls) and potato chips were collected from three common restaurants at Kafrelsheikh City. Also, palm oil used in frying process was collected from the same restaurants. Potato tubers, diamond variety and mixed of cottonseed and sunflower oils (1:1) were purchased from the local market, Kafrelsheikh City, Egypt.

Methods:

Preparation of food samples in laboratory:

Potato chips:

Potato tubers were washed and hand peeled, then sliced using slicer machine at 2.0 mm thickness and 6.0 cm diameter. Potato slices were washed again with water. Frying process was performed at two net cages; each containing 10 – 12 chips using tested oils at 180 $\pm$ 5 C^o for 6-7 min.

Falafel (beans balls):

Falafel paste, previously prepared at restaurant was formed to small balls. Frying was performed using two net cages; each containing 10 – 12 balls using tested oils at 180 $\pm$ 5 C^o for 4-5 min. All samples were divided to two parts, the first one was directly asked for sensory evaluation and the second was kept in polyethylene bags in freezer (-18^{0}C) until further analysis.

Analysis:

Chemical composition:

Gross chemical composition of fried samples was studied. Moisture, crude protein, ether extract, ash and crude fibers were determined according to the methods described in A. O. A. C. (2000).

Total carbohydrates were determined by phenol- sulphuric acid according to the method outlined by Dubois *et al.* (1956). The available carbohydrates were calculated by subtracting the percentage of crude fibers from the percentage of total carbohydrates content.

Physical and chemical properties of the used oils:

Specific gravity and refractive index were determined according to the methods of A. O. A. C. (2000). Color was measured using Lovebond Tintometer Model F serial number F 791, Wills, England (Alex. Co. for Oils and Soaps at Kafrelsheikh City) according to the method described by A. O. C. S. (1981).

Acid and saponification values of oils were determined according to the A. O. A. C. (2000) method. Peroxide and iodine values were tested using the method outlined by Leonard *et al.* (1987).

Reducing sugars determination:

Dinitrosalycilic acid reagent (DNS) was used to determine the concentration of reducing sugars in the potato and falafel paste samples before frying (Miller, 1959). The absorbance of samples was recorded with a spectrophotometer (Model JENWAY 6100, U.K.) at 575 nm.

Asparagine (Asn) determination:

Asparagine was determined by a High Performance Liquid Chromatography analysis ((Shinadzu HPLC) according to the method described by Tcherkas *et al.* (2001) and Paramás *et al.* (2006) in the National Research Center, Giza, Egypt.

Acrylamide determination:

Preparation of samples and extraction of acrylamide were performed in laboratory and determination was determined using HPLC in the National Research Center, Giza, Egypt.

Extraction:

Fifteen grams of samples (potato chips or falafel) were crushed in a Warring Blender. Five grams of the crushed sample were mixed with 50 ml of distilled water. After shaking at 100rpm for 30 min, the sample was centrifuged at 9000 rpm at 4^{0}C for 30 min. The supernatant was transferred into a 100 ml separating funnel and allowed to stand for 20 min to allow the aqueous and lipid layer to separate. The aqueous layer was removed and used for determination of acrylamide (Vattem and Shetty, 2003).

HPLC conditions:

High Performance Liquid Chromatography (HPLC) with spectrophotometric detector (Shinadzu HPLC) was used for quantitative determination of acrylamide levels in the experimental foods under the following conditions: Column flow rate: 1 ml/min. Wavelength: 230 nm. Column temp: 25 °C. Iso cartic elution.

Sensory analysis:

Organoleptic evaluation of fried samples was performed by a semi-trained panel of judges using ten-point hedonic-scale ratings for color, taste, odor, texture and overall acceptability with 10 being the highest score, extremely liked, and 1 being the lowest score, extremely disliked, (Watts *et al.*, 1989).

Statistical analysis

The obtained data were statistically analyzed using General Linear Models Procedure Adapted by Statistical Package for the Social Sciences (SPSS, 1997).

RESULTS AND DISCUSSION

Chemical composition of potato chips:

The results in Table (1) show the chemical composition of potato chips fried either in restaurants or in laboratory (lab). The data cleared that no significant differences were found in protein contents among all samples. Ether extract of samples fried in lab either in palm oil or in mixed oil was approximately similar; both of them contained the lowest value. For the samples fried in restaurants, the samples fried in R2 had significantly the highest ether extract content. Samples fried in R1 had ether extract similar to that of R3; both of them had the second order. The differences between the chips samples in ether extract content may be due to the differences of frying conditions or treatments after frying process. These results are similar with those reported by Kita (2002), who found that oil contents of some potato crisps varieties ranged between 35.77 to 39.44%. The results in the same table indicate that no significant differences in ash and crude fiber contents were found among samples either in lab or restaurants. Total and available carbohydrates of samples fried in lab were the highest followed by R1 and R3 which had no significant differences between both of them. While, the samples fried in R2 were the lowest.

Table (1): Chemical composition of potato chips fried in laboratory and restaurants (% on dry weight basis).

Samples / Constituents	laboratory		Restaurants		
	Palm oil	C+S	R1	R2	R3
-Moisture	23.21**b**	24.99 **a**	22.50 **c**	21.52 **d**	22.39 **c**
-Dry matter	76.79 **c**	75.01 **d**	77.50 **b**	78.48 **a**	77.61 **b**
-Crude protein	6.67 **n.s**	6.63	6.58	6.43	6.47
-Ether extract	39.33 **c**	39.20 **c**	40.80 **b**	43.50 **a**	40.40 **b**
-Ash	3.40 **n.s**	3.52	3.36	3.21	3.54
-Total carbohydrates	51.23 **a**	51.42 **a**	50.12 **b**	47.46 **c**	50.11 **b**
Available carbohydrates	48.07 **a**	48.30 **a**	47.05 **b**	44.11 **c**	46.86 **b**
Crude fibers	3.16 **n.s**	3.12	3.07	3.35	3.25

Values are means of three replicates. Values having the same letter(s) within a row are not significantly different (P > 0.05). C+S = chips fried using mixed oil (cotton seed: sunflower, 1:1) in lab, R1, R2, R3 are chips from different restaurants.

Chemical composition of falafel:

The results in Table (2) show the chemical composition of falafel fried in laboratory or in restaurants. It should be noted that protein content was not differed significantly among samples obtained from the same restaurants either fried in laboratory or in restaurant. There are significant differences among the protein content of samples obtained from different restaurants either fried in laboratory or in restaurant. This may be due to the difference in mixture content of falafel paste. Ether extract of samples fried in Lab using palm oil was somewhat higher than those of samples fried using mixed oil. Ether extract of samples fried in restaurants was higher than those fried in lab. This may be related to the frying conditions and/or treatments after frying. Ash contents of samples fried in R2 were significantly the highest either fried in lab or in restaurant.

No significant difference was found between the samples from R1 and R3; both of them were come in the second order. As for available carbohydrates, the results referred that samples from R2 had significantly the highest followed by samples from R1, then from R3. This may be related to that some restaurants add bread to the paste mixture instead of bean led to reduce the price cost. This may explain why the samples contained high protein content had low carbohydrates content.

Crude fibers content of samples obtained from R2 was slightly higher than that of samples obtained from other restaurants which had similar crude fibers content. From the same results in Table (2), it could be observed that with exception ether extract, the type of oil had no clear effect on chemical composition of falafel.

Table (2): Chemical composition of falafel fried in laboratory and restaurants (% on dry weight basis).

Samples / Constituents	Laboratory						Restaurants		
	R1		R2		R3		R1	R2	R3
	P	C+S	P	C+S	P	C+S			
-Moisture	35.65b	36.35a	34.32c	34.81c	32.14e	33.21d	35.15b	34.38c	32.29e
-Dry matter	64.35d	63.65e	65.68c	65.19c	67.86a	66.79b	64.85d	65.62c	67.71a
-Crude protein	15.45b	15.43b	13.27c	13.25c	16.13a	16.23a	15.56b	13.30c	16.43a
-Ether extract	37.12c	36.23d	38.10b	37.52c	39.33a	38.51b	38.15b	37.86c	39.91a
-Ash	5.33b	5.35b	5.68a	5.73a	5.25b	5.31b	5.24b	5.74a	5.23b
-Total carbohy.	42.04b	42.24b	43.38a	43.49a	40.29c	40.23c	41.83b	43.42a	40.04c
-Avail. carbohy.	22.93b	23.09b	23.84a	24.00a	21.28c	21.23c	22.78b	23.81a	21.04c
-Crude fibers	19.11b	19.15b	19.54a	19.49a	19.01b	19.00b	19.05b	19.61a	19.00b

Values are means of three replicates. Values having the same letter(s) within a row are not significantly different (P > 0.05). P = Flafel fried in palm oil, C+S = Falafel fried using mixed oil (cotton seed: sunflower, 1:1), R1, R2, R3 falafel from different restaurants before and after frying.

Asparagine, reducing sugar and acrylamide contents of potato chips:

Table (3) show the influence of reducing sugars and asparagine concentrations (%) of potato before frying on the formation of acrylamide (µg/kg) in potato chips during deep- fat frying. The data cleared that reducing sugars of samples prepared in lab were significantly the lowest, while the samples obtained from R2 had the highest amount of reducing sugars. No significant difference was found between samples from R1 and R3; both of them come in the second order. These values are higher than those reported by Kita (2002), who found that reducing sugars of some potato tuber varieties ranged between 0.040 to 0.127%. This may be due to potato varieties and/or conditions of storage.

Table (3): Reducing sugars, asparagine and acrylamide contents of potato chips.

Samples		Reducing* sugars%	Asparagine* %	Acrylamide** (µg/kg)
Laboratory	Palm oil	0.22 c	0.177 b	213 e
	C+S	0.22 c	0.177 b	235 d
Restaurants	R1	0.38 b	0.188 a	843 b
	R2	0.43 a	0.175 b	889 a
	R3	0.34 b	0.135 c	814 c

***Analyzed before frying, **Analyzed after frying, Frying conditions (180 ± 5°C for 8 min). Values are means of treatments. Values having the same letter(s) within a column are not significantly different (P > 0.05). C+S = mixed oil from cottonseed and sunflower (1:1). R1, R2, R3 are chips obtained from different restaurants**

As for asparagine contents, samples from R1 had the highest concentrations. No significant differences were found among samples prepared in lab and R2, content of asparagines in both of them come in the second order; while, the samples from R3 had the lowest asparagine content. This may be due to variation of preparation or cultivation.

As regard to acrylamide content, it can be seen that chips samples purchased from restaurants contained very high acrylamide content (814-889**µg/kg)** compared with those fried in lab (213-235**µg/kg**). This may be due to preparing or frying conditions (type of oil, temperature and time). It could be noted that the type of oil has lower effect on acrylamide formation compared with the effect of frying conditions. Where the variation between the acrylamide level of chips fried in palm oil (213µg/kg) and chips that fried in mixed oil (235µg/kg) is little but the variation between the acrylamide content of chips fried in lab (using palm oil) and chips that fried in restaurants (using the same oil) was high. Such results indicate that the conditions of frying process are very effective on acrylamide formation. These results are in agreement with those found by Bessar, (2006), who found that the rate of acrylamide formation increased markedly after the reuse of the frying oil for third process.

It could be also observed that, there is relationship between reducing sugars in potato before frying and the level of acrylamide formed during frying. Acrylamide formation in chips increased as a function of increasing reducing sugars. The obtained results also, are in harmony with those reported by Biedermann *et al.* (2002) and Gökmen *et al.* (2007), who found that sugar concentration has a strong correlation with the amount of acrylamide formation upon frying potatoes. The results in the same Table (3) show that sample contained high level of reducing sugars and medium level of asparagine (treatment R2) had the higher acrylamide content than that of samples contained medium level of reducing sugars and high level of asparagine (R1). These results are in agreement with those found by Granda *et al.* (2005).

Tareke *et al.*, (2000) cleared that among the different food products analyzed, the highest levels of acrylamide have been found in French fries, potato chips, and other deep-fat fried products. Overcooked French fries showed a very high level of acrylamide (>10 ppm), indicating that frying temperature and frying time influence acrylamide formation. Acorrding to FAO/WHO (2002), within each food group evaluated so far, suggesting that heat processing has a marked effect on the level of acrylamide in the products. Modifying the cooking process could probably reduce the amount of acrylamide in foods.

During frying, all the heat transferred from the hot oil is utilized to increase the internal energy of potato strip until the surface reaches slightly above the boiling point of water (103–104°C). After this point, moisture evaporation starts extracting a large amount of the incoming energy. At lower temperatures (≤150°C), the energy input to potato strip is limited preventing the surface from reaching temperatures above 120°C within 10 min of frying. However, when the oil temperature is high enough (≥170°C), the energy input is sufficient for both moisture evaporation and temperature increase to take place in the same duration, which favors the formation of acrylamide (Gökmen *et al.*, 2006). In addition, Gökmen and Palazoğlu (2008) cleared that, formation of acrylamide takes place mainly at the surface and in the near-surface regions because the conditions in this part of the potato strip become favorable for acrylamide formation as a result of simultaneous drying. As a consequence, any treatment like washing of the cut surface of potato strips may decrease concentrations of precursors on the surface where the chemical reactions responsible for the acrylamide formation take place. Asparagine, reducing sugar and acrylamide contents of falafel:

Reducing sugars and asparagine of falafel paste obtained from three different restaurants as well as acrylamide content of these samples after frying were recorded in Table (4). The presented data clear that reducing sugars and asparagine in falafel paste before frying varied according to resources. This may be due to the raw materials which used in preparing the paste. Reducing sugars of falafel paste ranged between 0.15 to 0.22%, while asparagines content ranged from 0.077 to 0.088%.

Concerning acrylamide contents, generally acrylamide content of falafel fried in restaurants (427 to 518µg/kg) was markedly higher than that of falafel fried in lab (74 to 92µg/kg). This may be related to frying conditions, where the restaurants in general used the oil for frying more than one time under high temperature for long time which led to presence of foreign by-products and food residues. These conditions play a key role in acrylamide formation. Al-Dmoor *et al.* (2004) reported that the excessive use of frying oil in food preparation caused significant increases in acrylamide content, especially in falafel. Bessar (2006) found that the acrylamide content of falafel (bean balls) fried in palm oil for one time were 76µg/kg, while increased to 203µg/kg when oil used for three times. This result can be explained by the assumption of presence of acrolein in old oil. Acrolein was proposed as a precursor for acrylamide formation (Stadler *et al.*, 2002).

Table (4): Reducing sugars, asparagine and acrylamide contents of falafel.

Samples			Reducing sugars* %	Asparagine* %	Acrylamide** (µg/kg)
Frying place	Paste source	Oil type			
Laboratory	R1	Palm	0.18b	0.077b	77e
		C+S	0.18b	0.077b	88d
	R2	Palm	0.22a	0.088a	89d
		C+S	0.22a	0.088a	92d
	R3	Palm	0.15c	0.079b	74e
		C+S	0.15c	0.079b	76e
Restaurants	R1	Palm	0.18b	0.077b	488b
	R2	Palm	0.22a	0.088a	518a
	R3	Palm	0.15c	0.079	427c

*Analyzed before frying, **Analyzed after frying. Frying conditions (180 ± 5 °C for 4 min). Values having the same letter(s) within a column are not significantly different ($P > 0.05$). C+S = mixed oil from cottonseed and sunflower (1:1). R1, R2, R3 are falafel obtained from different restaurants

The variation between acrylamide content of falafel fried in lab using palm oil and that fried in mixed oil is small. These results are in agreement with those reported by Bessar, (2006). This may be due to the nature of oil. The results show also that the effect of reducing sugars and asparagine contents of falafel paste before frying on acrylamide formation is strong, where its level increased significantly with increasing the reducing sugars and asparagine contents (518µg/kg in case of falafel fried in R2). When the reducing sugar content was medium and asparagine content was low, the acrylamide formed in medium level (488µg/kg as shown in sample fried in R1). But when the reducing sugars content was low and asparagine was medium, the acrylamide content was significantly low (427µg/kg as shown in case of R3). Gökmen and Palazoğlu (2008) cleared that the composition in terms of the concentrations of reducing sugars and asparagine and frying conditions in terms of temperature and duration significantly influence acrylamide formation. The acrylamide level increases substantially with an increase of frying oil temperature. As higher oil temperatures result in an increased rate of dehydration, which in turn leads to the favorable conditions for the Maillard reaction to develop earlier during the frying process.

For comparing the acrylamide formed in potato chips (Table 3) with that in falafel (Table 4), it could be observed that potato chips had greatly higher amounts than those of falafel either fried in lab or in restaurants. This may be related to the highest levels of reducing sugars in potato comparing with of falafel as well as, the frying time used in case of potato was longer than that in case of falafel. Al-Dmoor *et al.* (2004) reported that acrylamide content of fried potato was significantly higher than that of falafel. In addition, Bessar (2006) obtained similar results.

Physical and chemical properties of used oils before and after frying process:

Some physical and chemical properties of oils used for frying process either in lab or in restaurants were tabulated in Table (5). Specific gravity (SG) and refractive index (RI) for palm oil used in restaurants were higher than those used in Lab. It may be due to the increment of viscosity during multiple frying and polymers formation.

Table (5): Some physical and chemical properties of oils used in frying process before and after frying.

Properties		Laboratory		Restaurants		
		Palm oil	C+S	R1	R2	R3
Specific gravity (50 °C), water at 25 °C	B	n.s 0.91	n.s 0.78	b 0.91	b 0.91	b 0.91
	A	0.91	0.78	a 0.93	a 0.95	a 0.93
Refractive index (40 °C)	B	n.s1.488	n.s1.467	b 1.488	b 1.488	b 1.488
	A	1.488	1.467	a 1.492	a 1.495	a 1.490
Color	B	5 R	20Y + 3R	5 R	5 R	5 R
	A	5.4Y + 1R	20Y + 3.4R	13Y+6.5R	14Y+7.3R	14Y + 5.5R
Acid value	B	n.s 0.65	n.s 0.35	b 0.65	b 0.65	b 0.65
	A	0.68	0.37	a 1.43	a 1.88	a 1..17
Peroxide value (meq. O_2/kg oil)	B	n.s 0.53	n.s 0.77	b 0.53	b 0.53	b 0.53
	A	0.88	0.93	a 18.11	a 22.56	a 15.85
Iodine value (g I/100g oil)	B	n.s57.48	n.s90.42	a 57.48	a 57.48	a 57.48
	A	56.88	90.00	b 46.60	b 38.82	b 49.80
Saponification value (mg KOH/g oil)	B	n.s195.0	n.s192.0	a 195.0	a 195.0	a 195.0
	A	195.5	192.0	b 193.2	b 192.3	b 190.7

*C+S= Cottonseed + sunflower oils blend (1: 1), B = before frying and A = after frying. R1, R2, R3 are oils obtained from different restaurants

The color of frying oils used in restaurants darkened swiftly. Both yellow and red increased significantly compared to oils used in lab. As for acid and peroxide values, the results cleared that no significant differences were found between frying oils used in lab before and after frying process; while it was increased significantly as a function of multiple frying process in oils from restaurants.

Frying process did not affect significantly on iodine value for oils used in Lab. It may be due to the relationship between peroxide and iodine values which was not increased during the first time of frying. Iodine values of oils from restaurants were significantly decreased as a resulting of frying process. These changes related to the oxidation of double bonds of unsaturated fatty acids which decreased iodine values. Saponification value of oils in Lab not significantly changed as a function of frying process; while it was decreased significantly as a result of frying process in restaurant oils.

Variations of acrylamide levels in oils used several times of frying may be due to reconstruction of used oil as, presence of foreign by-products, salt, food residues, and high temperature for long time, which play a key role in changing the physical and chemical properties of frying oil. These results are in harmony with those found by Glese, (2002) and Konings *et al.* (2003).

From the resultes presented in Tables (3, 4 and 5), it could be noted that, there was relationship between changes in physical and chemical properties of frying oil and acrylamide formation in fried samples. This may be due to reusing of oils at high temperature for long time (usually in restaurants) lead to oil deterioration and increase its carbonyl compounds (secondary products of oil oxidation) which help in acrylamide formation. Becalski *et al.*, (2003) reported that heating asparagine with octanal, 2-octanone, or 2, 3-butanedione formed various amounts of acrylamide. Yaylayan *et al.*, (2003) also, found that glycolaldehyde and glyceraldehyde produced about 2 times and 1.75 times more acrylamide than glucose with asparagine, respectively. In addition, Yasuhara *et al.*, (2003) found that acrolein formed from lipids upon oxidation yielded 114µg acrylamide/g asparagine. Acrylic acid, which is an oxidative product of acrolein, produced significant amount of acrylamide.

Organoleptic evaluation of potato chips

The organoleptic evaluation of potato chips either prepared in lab or purchased from restaurants was performed and the means of results were recorded in Table (6).

Table (6): Organoleptic evaluation of potato chips from different sources.

Samples		Color	Taste	Odor	Texture	Overall acceptability
Laboratory	Palm oil	8.3 a	8.0 a	8.3 a	8.6 a	8.3 a
	C+S	7.8 b	7.9 ab	7.8 b	7.9 b	7.8 b
Restaurants	R1	7.3 c	6.7 c	6.8 c	7.0 c	7.0 c
	R2	4.8 d	4.8 d	4.6 d	4.8 e	4.8 d
	R3	8.1 ab	7.5 b	7.1 c	6.5 d	7.3 c

Values are means of evaluations. Means of evaluations having the same letter(s) within a column are not significantly different ($P > 0.05$). C+S = mixed oil from cottonseed and sunflower (1:1). R1, R2, R3 are chips obtained from different restaurants

The data show that the chips prepared in lab had high scores for all characteristics compared with these purchased from restaurants. This may be attributed to the exposure to high temperature and frying time in the restaurants, in general, longer than that used in lab, which play a key role in changing the nature of oil.

The characteristics of chips fried in lab using palm oil had highest scores. This may be attributed to chemical properties of fresh palm oil especially, the low levels of peroxide and iodine values. This means, it contains low amounts of unsaturated fatty acids that make it more constant during frying process. The results show also that the characterestics of chips prepared in restaurant (R2) had the lowest scores. This may be due to the conditions of frying process in such restaurant.

The relation of the results in Table (3) and these of Table (6), it can be seen that the effect of sensory characteristics on acrylamide formation is very slight comparing with frying conditions such as time, temperature, reusing the oil which have important role in acrylamide formation. Obtained results are in agreement with those reported by Granda *et al.* (2005), who reported that color could not be used as an indication of acrylamide content because potato chips with similar color had very different acrylamide concentrations. In addition, Taubert *et al.* (2004) found that at a level of browning 2 "golden brown", acrylamide content varied from 2.5 to 13 ppm in 3-mm slices potatoes and ranged from 4 to 18 ppm in grated potatoes. They reported that because color continues to develop during the Maillard reaction, and acrylamide may start degrading, browning alone should not be used as the sole predictor of acrylamide formation. In contrast, Stadler *et al.* (2002), Zyzak *et al.* (2003) and Becalski *et al.* (2003) reported that the formation of acrylamide in foods is closely linked to the formation of desirable characteristics such as flavor and color. Because the Maillard reaction is favored by conditions of high temperature, resulting in the flavors and brown color in roasted, baked and fried foods. Al-Dmoor *et al.* (2004) reported that the heat intensity (time and temperature) and all factors enhancing browning and crust formation are the major cause of acrylamide formation.

Organoleptic evaluation of falafel

The organoleptic evaluation of falafel either purchased from restaurants and fried in laboratory or fried in restaurants was performed and the means of results were recorded in Table (7). From overall acceptability, the results show that falafel fried in lab using palm oil had higher scores for all characteristics as compared with those fried using mixed oil. Falafel obtained from R1 and R3 that fried in palm oil at lab had the highest acceptability from judges' view followed by R2. No significant differences were found between samples obtained from R2 fried in lab, R1 and R3 fried in restaurants; both of them were come in the second order. While, samples fried at restaurant R2 had the lowest score.

The results in Tables (4) and (7) indicate that sensory properties had a little effect on acrylamide formation in falafel where some samples have similar score for color and the acrylamide content is very different (sample obtained from R1 and fried in lab has score 8.6 for color and contained 79µg acrylamide/kg but sample collected from the same restaurant and fried in restaurant has nearly similar score for color and contained 488µg acrylamide/kg). This indicate that frying conditions, reusing the frying oil and reducing sugars content of samples have the great effect on acrylamide content, but their sensory characterestics are not indicator for acrylamide content. Granda *et al.* (2005) reported that color could not be used as an indication of acrylamide content because potato chips with similar color had very different acrylamide concentrations.

Table (7): Organoleptic evaluation of falafel from different sources.

Samples			Color	Taste	Odor	Texture	Overall acceptability
Frying place	Paste source	Oil type					
Laboratory	R1	Palm	8.6 a	8.1 a	8.1 a	8.4 a	8.3a
		C+S	8.0 b	7.7 abc	7.6 c	7.7 bc	7.7 b
	R2	Palm	7.9 b	7.6 bc	7.8 bc	8.0 abc	7.8 b
		C+S	7.8 b	7.4 cd	7.6 c	7.5 de	7.6 b
	R3	Palm	8.5 a	8.1 a	8.3 a	8.1 ab	8.3 a
		C+S	8.2 ab	7.9 a	7.8 bc	8.1 ab	8.0 ab
Restaurant	R1	Palm	8.2 ab	7.6 bc	7.6 c	7.7 bc	7.8 b
	R2	Palm	7.2 c	7.1 d	7.0 d	7.1 e	7.1 c
	R3	Palm	8.2 ab	7.7 abc	7.5 c	7.6 cd	7.8 b

Values are means of evaluations. Means of evaluations having the same letter(s) within a column are not significantly different ($P > 0.05$). C+S = mixed oil from cottonseed and sunflower (1:1). R1, R2, R3 are falafel obtained from different restaurants

CONCLUSION

From the obtained results, it can be concluded that frying conditions especially reusing of oil had a great effect on acrylamide formation, where the samples fried in restaurants had significantly higher acrylamide levels than those of samples fried in laboratory. The acrylamide concentration of studied samples differed from restaurant to other. Reducing sugars and asparagine contents played an important role in acrylamide formation. The highest level of acrylamide was found in samples contained the highest reducing sugars; followed by those contained the moderate level of reducing sugars and the highest level of asparagine. The results cleared that potato chips had acrylamide content higher than that of falafel. Samples fried using palm oil in laboratory had acrylamide content somewhat lower than that of samples fried using mixed oils. Sensory characteristics could not be used as an indicator for acrylamide content; where potato chips or falafel with similar sensory characteristics had different acrylamide content. It recommended that the frying in fresh oil at low temperature and short time (as possible as) are important to reduce acrylamide formation during frying. Before frying, reducing sugars and asparagine content of samples must be reduced for lowering of acrylamide formation during frying.

REFERENCES

Al-Dmoor, H. M., Humeid, M. A. and Alawi, M. A. (2004). Investigation of acrylamide levels in selected fried and baked foods in Jordan. Food Agriculture & Environment, 2(2):157-165.

Allan, S. (2002). Acrylamide angst, another annoying distraction about food safety. (Electronic version). Agrochemical and Environmental News Issue, October, No. 198. from http:/www. envirofacs. org/Acrylamide % 20 Angst.pdf.

Amrein, T., Bachmann, S., Noti, A., Biedermann, M., Ferraz, M., Biedermann, S., Grob, K., Keiser, A., Realini, P., Escher, F., Amado, R. (2003). Potential of acrylamide formation, sugars and free asparagine in potatoes: a comparison of cultivars and farming systems. J Agric Food Chem 51:5556–5560.

A. O. A. C., (2000). Association of Official Method of Analysis. Official Analytical Chemists. 17th Ed., Gaithersburg, MD: AOAC International. (Official Method 925.10, 920.87).

A. O. C. S. (1981). Official and Tentative Methods of Analysis, Published by American Oil Chemists Society. 2nd ed. Chicago Illinois, USA.

Becalski, A., Lau, B. P., Lewis, D. and Seaman, S.W., (2003). Acrylamide in foods: occurrence, sources and modeling, J. Agric. Food Chem., 51:802-808.

Besaratinia, A. and Pfeifer, G. (2007). A review of mechanisms of acrylamide carcinogenicity. Carcinogenesis, 28(3):519-528.

Bessar, B. A. (2006). Effect of using different cooking oils on acrylamide formation on some Egyptian fried foods. J. Agric. Res., Tanta Univ., 32(4):845-857.

Biedermann, M., Noti, A., Biedermann-Brem, S., Mozzetti, V., Grob, K. (2002). Experiments on acrylamide formation and possibilities to decrease the potential of acrylamide formation in potatoes. Mitt. Geb. Lebensm Unters Hyg; 93:668–687.

Burch, R. (2007). Examination of the effect of domestic cooking on acrylamide levels in food. Final Report for Food Standards Agency. Pp.4.

Dubois, M., Gilles, K.A., Rober, J.K. and Smith, P.A. (1956). Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350–356.

FAO/WHO, (2002). Health Implications of Acrylamide in Food. Report of a Joint FAO/WHO Consultation, 25–27 June 2002 (Geneva: WHO).

Glese, J. (2002). Acrylamide in foods. Food technol., 56(10):71-72.

Gökmen, V., Palazoğlu, T. and Şenyuva, H. (2006). Relation between the acrylamide formation and time–temperature history of surface and core regions of French fries. J Food Eng; 77:972–976.

Gökmen, V. and Palazoğlu, T. (2008). Acrylamide Formation in Foods during Thermal Processing with a Focus on Frying. Food Bioprocess Technol., 1:35–42.

Gökmen, V., Akbudak, B., Serpen, A., Acar, J., Turan, Z. and Eri°, A. (2007). Effects of controlled atmosphere storage and low-dose irradiation on potato tuber components affecting acrylamide and color formations upon frying. Eur. Food Res. Technol; 224:681-7.

Granda, C., Moreira, R. G. and Castell-Perez, E. (2005). Effect of raw potato composition on acrylamide formation in potato chips. J of Food Sci., 70(9):519-525.

(IARC) International Agency for Research on Cancer, (1994). Some industrial chemicals. Monographs on the evaluation of the carcinogenic risk of chemicals to humans, Vol. 60 (Lyon: IARC), pp. 389–433.

Kim, C. T., Hwang, E. S. and Lee, H. J. (2005). Reducing acrylamide in fried snack products by adding amino acids. J. of Food Sci., 70(5):354-358.

Konings, E. J., Baars, A. J., van Klaveren, J. D., Spanjer, M. C., Rensen, P. M., and Hiemstra, M., (2003). Acrylamide exposure from foods of the Dutch population and an assessment of the consequent risks. Food Chem Toxicol; 41(11):1569–1579.

Kita, A. (2002). The influence of potato chemical composition on crisp texture. Food Chemistry, 76:173-179.

Leonard, W. A., Woods, A. E. and Wells, M. K. (1987). Food composition and analysis. Published by van nostrand Reinhold Company, New York.

Lindsay, R. (2002). Acrylamide review. (Electronic version) from http://www.inchem.org/documents/pims/chemical/pim652.htm.

Miller, G. L. (1959). Use of dinitrosalicylic acid reagent for the determination of reducing sugars. Anal Chem., 31:426–428.

Mottram, D. S., Wedzicha, B. L., Dodson, A. T. (2002). Acrylamide is formed in the Maillard reaction. Nature 419:448–449.

Olsson, K., Svensson, R. and Roslund, C. (2004). Tuber components affecting acrylamide formation and color in fried potato: variation by variety, year, storage temperature and storage time. J Sci Food Agric 84:447–458.

Paramás, A. M. G., Bárez, J. A. G. and Marcos, C. C. (2006). Food Chem., 95:148–156

Stadler, R., Blank, I., Varga, N., Robert, F., Hau, J., Guy, P., Robert, P. and Riediker, S. (2002). Acrylamide from Maillard reaction products. Nature 419:449.

Statistical Package for the Social Sciences, SPSS (1997). SPSS based 7.5 for windows, User's Guide; SPSS inc.

Swedish National Food Administration (2002). Information about acrylamide in food [http://www.slv.se/engdefault.asp].

Taeymans, D., Wood, J., Ashby, P., Blank, I., Studer, A., Stadler, R. H., Gonde, P., Van Eijck, P., Lalljie, S., Lingnert, H., Lindblom, M., Matissek, R., Muller, D., Tallmadge, D., O'Brien, J., Thompson, S., Silvani, D. and Whitmore, T. (2004). A review of acrylamide: an industry perspective on research, analysis, formation, and control. Crit. Rev. Food Sci. Nutr., 44:323–347.

Tareke, E., Rydberg, P., Karlsson P., Eriksson, S. and Törnqvist, M. (2000). Acrylamide: a cooking carcinogen? Chem. Res. Toxicol. 13:517–22.

Tareke, E., Rydberg, P., Karlsson, S., Eriksson, S. and Törnqvist, M. (2002). Analysis of acrylamide, a carcinogen formed in heated foodstuffs. J Agric Food Chem; 50:4998–5006.

Taubert, D., Harlfinger, S., Henkes, L., Berkels, R., and Schoemig, E. (2004). Influence of processing parameters on acrylamide formation during frying of potatoes. Journal of Agricultural and Food Chemistry, 52, 2735–2739.

Tcherkas, Y. V., Kartsova, L. A. and Krasnova, I. N. (2001). J Chromatog. A 913:303–308

Vattem, D. A. and Shetty, K. (2003). Acrylamide in food: a model for mechanism of formation and its reduction. Innovative Food Science and Emerging Technologies 4, 331-338.

Watts, B. M., Ylimaki, G. L., Jeffery, L. E., and Elias, L. G. (1989) Basic Sensory Methods for Food Evaluation. IDRC, Ottawa, Ontario, Canada, pp 66-78.

Wicklund, T., Ostlie, H. Lothe, O., Knutsen, S., Brathen, E. and Kita, A. (2006). Acrylamide in potato crisp – the effect of raw material and processing, *Lebensmittel-Wissenschaft-und-Technologie* 39:571-575.

Yasuhara, A., Tanaka, Y., Hengel, M., and Shibamoto, T. (2003). Gas chromatographic investigation of acrylamide formation in browning model systems. J. Agric. Food Chem., 51:3999-4003.

Yaylayan, V. A., Wnorowski, A. and Perez, C. (2003). Why asparagine needs carbohydrates to generate acrylamide. J. Agric. Food Chem., 51:1753-1757.

Yusa, V., Quintas, G., Pardo, O., Marti, P. and Pastor, A. (2006). Determination of acrylamide in foods by pressurized fluid extraction and liquid chromatography tandem mass spectrometry used for a survey of Spanish cereal-based foods. Food Additives and Contaminants. 23, 237-244.

Zyzak, D. V., Sanders, R. A., Stojanovic, M., Tallmadge, D. H., Eberhart, B. L., Ewald, D. K., Gruber, D. C., Morsch, T. R., Strothers, M. A., Rizzi, G. P. and Villagran, M. D. (2003). Acrylamide formation mechanism in heated foods. J. Agric. Food Chem. 51:4782-4787.

دراسات على تكوين الاكريلاميد في بعض الأغذية المقلية الشائعة في مصر

محمد فوزي عثمان ، محمد عوض عبد الجليل و أمين كمال عمار
قسم تكنولوجيا الأغذية – كلية الزراعة – جامعة كفر الشيخ – كفر الشيخ – مصر.

أجريت هذه الدراسة بهدف دراسة تأثير ظروف القلي على معدل تكوين الاكريلاميد في بعض الأغذية الشعبية المقلية الشائعة في مصر. تم الحصول على رقائق البطاطس المقلية وكذلك الطعمية من ٣ مطاعم في مدينة كفرالشيخ. وكذلك تم الحصول على عجينة الطعمية الخام من هذه المطاعم أما درنات البطاطس تم شراؤها من السوق المحلي وتم تجهيزها قليها تحت ظروف المعمل باستخدام زيت النخيل المستخدم عادة في القلي أو التحمير في المطاعم، وكذلك في خليط من زيت بذرة القطن وعباد الشمس بنسبة (١:١).

حيث أظهرت النتائج أن:-

- ظروف التحمير وخاصة إعادة استخدام زيت القلي أكثر من مرة أدت إلى خفض جودة الصفات الطبيعية والكيميائية للزيت مما أدى إلى زيادة معدل تكوين الاكريلاميد حيث أن العينات المقلية في المطاعم احتوت على مستويات اكريلاميد أعلى من تلك التي تم قليها في المعمل.
- احتوت شرائح البطاطس على معدلات اكريلاميد أعلى منها في الفلافل سواء المقلية في المطاعم أو في المعمل.
- السكريات المختزلة والاسباراجين في العينات قبل القلي لها دور كبير في كمية الاكريلاميد المتكونة، حيث أظهرت النتائج أن المستويات الأعلى منه وجدت في العينات التي احتوت على مستويات عالية من السكريات المختزلة يليها العينات التي تحتوى على مستويات متوسطة من السكريات المختزلة ومستويات عالية من الاسباراجين. بينما وجد أن المستوى المنخفض من الاكريلاميد كان في العينات التي تحتوى على مستويات متوسطة من السكريات المختزلة ومستويات منخفضة من الاسباراجين.
- كما وجد أن نسبة الاكريلاميد في العينات المقلية في زيت النخيل اقل منها مقارنة بالعينات المقلية في الزيت الخليط من بذرة القطن وعباد الشمس.
- كما وجد أن الخواص العضوية الحسية لا تعتبر مؤشرا لمحتوى الاكريلاميد في العينات حيث وجد أن العينات التي لها خواص حسية متقاربة تحتوى على معدلات مختلفة من الاكريلاميد.

لذلك توصى الدراسة بضرورة استخدام الزيوت الطازجة في القلي على درجات حرارة منخفضة لمدة قليلة كلما أمكن ، كذلك محاوله تقليل كمية السكريات المختزلة والاسباراجين قبل القلي أثناء تجهيز العينات لخفض المعدلات المتكونة من الاكريلاميد أثناء القلي.