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Reduction of Acrylamide Formation in Fried Potato Strips by Different Pre-frying Treatments

[1]M.H. EL-Saied, [2]A.M. Sharaf, [2]M.M. Abul-Fadl and [2]N. EL-Badry

[1]Environmental Toxicology Laboratory,
College of Food and Agricultural Sciences, King Saud University, Saudi Arabia
[2]Department of Food Science and Technology, Faculty of Agriculture,
AL-Azhar University, Cairo, Egypt

Abstract: The main purpose of this investigation was to study the effect of different pre-frying treatments on the reduction of acrylamide (AA) formation in potato strips when fried at 150 and 180°C. Potato strips were treated in one of the following ways prior to frying at different times: soaking in distilled water and different solutions (NaCl, $CaCl_2$ and citric acid); blanching in hot distilled water at different times and temperatures; blanching in hot distilled water, followed by soaking in different solutions (NaCl, $CaCl_2$ and citric acid) and exposure to microwaves. Results indicated that soaking potato strips in distilled water reduced AA formation at ratio of 16.37-48.94%. Meanwhile, soaking treatment in $CaCl_2$ solution caused a highly considerable reduction of AA formation at ratio from 86.34-92.1%, followed by treatment with citric acid solution (68.92-74.0%), NaCl solution (59.46-71.23%). In addition, when the soaking time increased the AA formation was clearly decreased in fried potato strips. Blanching in hot distilled water has led to a reduction of AA formation rate ranging between 76.80-82.23%. Moreover, when the blanching temperature increased and the blanching time shortened, the same results of the reduction rate in AA formation were obtained and were ranged from 77.61-81.14%. Soaking in NaCl, $CaCl_2$ and citric acid solutions after blanching treatment caused an obvious decrease of AA formation more than those obtained after blanching treatment alone prior to frying of potato strips. Pre-frying exposure to microwave resulted in a marked reduction in the formation of AA at ratios of 53.77-71.88%, the AA content of fried potato strips decreased with increasing of microwave exposure time from 20 to 60 second. The formation of AA increased dramatically in potato strips for all pre-treatments studied as the frying temperature increased from 150 to 180°C. It could be concluded that the acrylamide content in fried potato strips increased significantly as frying temperature and duration increase. The tested pre frying treatments had a significant inhibitory effect on AA formation in fried potato strips

Key words: Potato strips % Acrylamide % Soaking % Blanching % Microwave

INTRODUCTION

Potato (*Solanum tuberosum*) is one of the world's major agricultural crops and it is consumed daily by millions of people from diverse cultural backgrounds. Potatoes are always cooked before consumption, traditionally by frying and other cooking methods [1, 2]. Deep fat frying is extensively used in food processing both industrially and at home and fried potato products are one of its largest applications [3]. AA is a chemical compound that is formed from food components during heat treatment (frying, baking, roasting and extrusion) as a result of the Maillard reaction between amino acids such as asparagine and reducing sugars [4, 5]. AA aroused worldwide concern after 2002 when it was found that it could be formed in foods during cooking. Although there is no regulation to limit acrylamide level in heat-processing foods and the association between dietary AA and risk of cancer is disputed [6]. In the past several years, AA is known for its potential health hazards. Furthermore the concentration of AA within carbohydrate-rich fried potato has become of great interest due to AA's classification as a cancer suspect agent. Recent assessments by the Joint FAO/WHO Expert

Corresponding Author: M.M. Abul-Fadl, Department of Food Science and Technology, Faculty of Agriculture, AL-Azhar University. Cairo, Egypt

Committee on Food Additives (JECFA) confirmed that a risk cannot be excluded for dietary intake of AA because it is classified as a probable human carcinogen by the International Agency for Research on Cancer [7]. Exposure to AA causes damage to the nervous system in humans and animals and AA is also considered a reproductive toxin, with mutagenic and carcinogenic properties in experimental mammalian in vitro and in vivo systems [8]. Numerous studies have been conducted to explore the possibilities of reducing AA levels in French fries. Considering the high level of acrylamide precursors naturally found in potatoes, reducing strategies that involve pretreatment and/or modification of the frying conditions appear to be a logical approach to control AA levels in the final product. While pretreatment steps such as enzyme treatment, soaking in water and blanching reduce the amount of AA precursors, some other pretreatment steps (e.g., reduction of pH and microwave pre-cooking) were intended to make the conditions less favorable for acrylamide formation [9].

The main target of this investigation was to study the effect of different pre-frying treatments on reduction of acrylamide formation of fried potato strips by deep fat frying method including soaking in distilled water and different solutions (NaCl, $CaCl_2$ and citric acid); blanching in hot distilled water with different times and temperatures; blanching in hot distilled water and soaking in NaCl, $CaCl_2$ and citric acid solutions as well as pre-cooking exposure to microwaves.

MATERIALS AND METHODS

Potato tubers (*Sollamun tuberosum*) variety "daraga" and sunflower seed oil were obtained from the local Egyptian market.

Chemicals: including NaCl, $CaCl_2$ and citric acid were obtained from Algamhoria Co., Cairo, Egypt. Acrylamibe standard (99.8%) was exported from Sigma-Aldrich, USA.

Preparation of Potato Strips and Pre-treatments: Potato tubers were prepared in Food Science and Technology Department Laboratory, Faculty of Agriculture, AL-Azhar University. They prepared by washing in tap water and peeled before cutting. Peeled potato tubers were cut into strips (8mm x 8mm) by using fry cutter machine. These strips were divided into five batches. The first batch was kept as control without any pre-treatments; the strips of the other four batches were treated prior to frying as follows:

First batch was soaked in distilled water and soaked in NaCl, $CaCl_2$ and citric acid 1% solutions for 30 and 60 min.

Second batch was blanched in hot distilled water at 70°C for 10 and 20 min. and at 90°C for 5 and 10 min.

Third batch was blanched in hot distilled water at 70°C for 10 min and soaked in NaCl, $CaCl_2$ and citric acid 0.5% solutions for 30 min.

Fourth batch was pre-cooked by microwave oven (UPO, Samsung, Model No. A2213-A1A, Republic of Korea) for three different time periods (20, 40 and 60 second).

Frying Conditions: All investigated samples of each pre-treatment (100g) were fried in aluminum deep fryer (20cm deep, 20cm diameter) containing 500 ml of hot frying oil (heated on a stove top to the temperature used) at the following temperature-time conditions: 150°C for 8 min and 180°C for 4 min of control and all soaked pre-treatment samples; and 150°C for 6 min and 180°C for 3 min of blanched pre-treatment in hot distilled water, blanched and soaked at different solutions pre-treatment and microwave pre-cooked samples. Frying process was carried out in Food Science and Technology Department Laboratory, Faculty of Agriculture, AL-Azhar University.

All tested samples were fried at different time intervals until reach final moisture approximately 2% on wet basis (stewing point). After frying, the oil was drained from the fryers and was washed between each two batches. Fresh oil was used for each time. After each frying process the samples were drained over a wire screen for 5min and cooled at room temperature and then kept under freezing temperature at-18°C±2 for further analyzed [10-13].

Determination of Acrylamide in Potato Samples: Extraction and analysis for acrylamide in tested fried potato samples were carried out in Environmental Toxicology Laboratory, College of Food and Agricultural Sciences, King Saud University.

Standard Solution: AA was prepared according to the method described by [14].

Extraction by Solid Phase Extraction (SPE)

Sample Preparation: The tested samples were extraction by Solid Phase Extraction (SPE) under the following conditions.

SPE: Discovery MCAX 300mg 3ml tube Discovery C18, 1.0g 6ml tube.

Conditioning: Stack Discovery MCAX SPE on top of Discovery C18 SPE using tube adapter. Condition stacked SPE with 1.0 ml of methanol followed by 1.0 ml water. Pull dry with vacuum. Load 1.0 ml of aqueous extract onto conditioned SPE, pull through with vacuum. Wash stocked SPE with 1.0 ml of water. *Sample Elute:* Remove MCAX SPE and dispose of filtrate. Elute acrylamide from C18 SPE with 2.0 ml methanol. Concentrate samples using a nitrogen manifold at 30°C, reconstitute to 0.50mL with water to be ready for LC/MS analysis [14, 15].

Analysis by LC/MS: Extracted potato strips samples were analyzed with a Waters 2690 LC (Milford, MA) interfaced to a Micro mass Platform LCZ mass spectrometer (Milford, MA) operated in positive electro spray ionization mode. Mobile phase: 100% H_2O, 10 mm ammonium acetate, adjusted to pH 4.6 w/formic acid. Column: 2.0 mm, 150 mm, YMC C18 AQ, 5 µm (Waters; Milford, MA). Flow rate: 0.2 ml/min. LC/MS interface: Direct (no split). Injection volume: 10 µL. Mode: selected ion monitoring (*m/z* 72, 73). Dwell time: 0.5 s. Parts per billion of acrylamide should be calculated using the relationship that the ratio of the amount of internal standard to its response is equivalent to the ratio of the amount of acrylamide to the acrylamide response. This result is then divided by the weight of the test portion and the response ratio [16, 17]. Three replicates was analyzed for all tested samples.

Statistical Analysis: Data were subjected to the statistical analysis according to Analysis of Variance (ANOVA) of Completely Randomized Design as described by [18]. Treatment means were compared using the Least Significant Differences (LSD) at 0.05 level of probability and Standard Error. Computations and statistical analysis of data were done using facilities of computer and statistical analysis system package [19].

RESULTS

The Effect of Pre Frying Soaking on Acrylamide Formation in Potato Strips

Soaking in Distilled Water: Data presented in Table 1 show the influence of soaking in distilled water at different conditions periods on the formation of AA in potato strips during deep-fat-frying process at two different temperatures. It could be observed that the AA content (µg/kg) was reduced after soaking potato strip samples for 30 min before frying.

The reduction of frying temperature from 180 to 150°C, (Table 1). In the same time, it could be seen that the amount of AA was drastically reduced in fried potato strip samples treated with soaking in sodium chloride and calcium chloride solutions before frying, when compared to the control sample (without any pre-treatment). Soaking in $CaCl_2$ solution is more efficient than NaCl solution. Furthermore, the amount of AA formed in fried potato strips decreased as the pre-soaking time increase from 30 to 60 min.

Concerning the effect of soaking in citric acid solution prior to frying process on the AA formation, it could be noticed that potato strips immersion in citric acid solution for 30 min showed considerably reduced AA formation and the reduction become more obvious as the time of soaking increased to 60 min.

Table 1: Effect of pre frying soaking on acrylamide formation (µg/kg) in potato strips (Mean±SE)

	Acrylamide content (µg/kg) in fried potato strips			
Soaking treatments	Frying at 150°C	Reduction of acrylamide (%)	Frying at 180°C	Reduction of acrylamide (%)
Control (without soaking)	1835±3.23^{b}	-	2211±3.40^{a}	-
Soaking in distilled Water				
for 30 min	1352±2.77^{d}	26.32	1849±4.44^{b}	16.37
for 60 min	937±3.11^{e}	48.94	1612±4.84^{c}	27.09
Soaking in solution of NaCl 1%				
for 30 min	744±4.96^{f}	59.46	896±1.50^{e}	59.48
for 60 min	528±2.82^{h}	71.23	688±2.07^{fg}	68.88
Soaking in solution of $CaCl_2$ 1%				
for 30 min	205±3.00^{j}	88.83	302±2.07^{i}	86.34
for 60 min	145±1.96^{k}	92.10	187±2.07^{jk}	91.54
Soaking in solution of citric acid 1%				
for 30 min	521±6.58^{h}	71.60	687±4.90^{fg}	68.92
for 60 min	477±3.81^{h}	74.00	642±7.79^{g}	70.96

L.S.D: Least Significant Difference at probability 0.05 (59.38), Mean±SE: Mean of triplicates samples result±Standard Error; AA Mean having different superscripts is varied significantly

The Effect of Pre Frying Blanching on Acrylamide Formation in Potato Strips: The effect of pre-frying blanching on the formation of AA in potato strips is shown in Table 2, it could be observed that blanching prior to frying of potato strips led to a considerable reduction of AA formation which ranged from 76.80-82.23% as compared to the control sample (unblanched fried potato strips).

On the other hand, the increment effect of blanching period from 10 to 20 min at 70°C resulted in lowing level of AA formation in fried potato strips. When the blanching temperature increased from 70 to 90°C with decreasing the blanching time to the half (from 10, 20 min to 5, 10 min), the same results of the reduction rates in the AA formation was obtained for fried samples at 150°C.

The obtained data (Table 2) also showed that the amount of AA formation increased in blanched fried potato strips when the frying temperature was increased.

The Effect of Pre Frying Blanching Followed by Soaking on Acrylamide Formation in Potato Strips: The effect of blanching followed by soaking in different solutions (NaCl, $CaCl_2$ and citric acid solutions) before frying on the AA formation in fried potato strips, as shown in Table 3. Blanching at 70°C for 10 min alone can reduce of AA formation by 77%. Meanwhile, blanching followed by soaking treatments can reduce up to 88% of the AA content in fried samples. The Blanched Potato Strips Pre-treated with Soaking in $CaCl_2$ Solution Had the Highest Reduction of AA Formation

Effect of Pre Frying Exposure to Microwaves on Acrylamide Formation in Potato Strips: Pre-frying exposure to microwaves at different periods (20, 40 and 60 seconds) caused, in general, a highly inhibition of the AA forming in fried potato strips samples at a variable rates depending upon microwaving period. Whereas, these treatments caused a highly considerable reduction in the acrylamide formation at ratios of 53.77%-71.88% (Table 4).

The effect of temperature appeared to be exponential on the AA formation in fried potato strips, whereas the AA formation decreased dramatically in fried potato strips as the frying temperature decreased.

Table 2: Effect of pre frying blanching on acrylamide formation (µg/kg) in potato strips (Mean±SE)

	Acrylamide content (µg/kg) in fried potato strips			
Blanching treatments	Frying at 150°C	Reduction of acrylamide (%)	Frying at 180°C	Reduction of acrylamide (%)
Control (without blanching)	1835±3.23^{b}	-	2211±3.40^{a}	-
Blanching in hot distilled water at 70°C				
For 10 min	405±1.50^{g}	77.93	513±1.84^{c}	76.80
For 20 min	326±2.07^{j}	82.23	434±1.73^{f}	80.37
Blanching in hot distilled water at 90°C				
For 5 min	392±5.13^{h}	78.64	495±4.33^{d}	77.61
For 10 min	346±1.50^{i}	81.14	457±2.02^{e}	79.33

L.S.D: Least Significant Difference at probability 0.05 (7.72), Mean±SE: Mean of triplicates samples result±Standard Error; AA Mean having different superscripts is varied significantly

Table 3: Effect of pre frying blanching followed by soaking on acrylamide formation (µg/kg) in potato strips (Mean±SE)

	Acrylamide content (µg/kg) in fried potato strips			
Soaking treatments	Frying at 150°C	Reduction of acrylamide (%)	Frying at 180°C	Reduction of acrylamide (%)
Control (without any treatment)	1835±3.23^{b}	-	2211±3.40^{a}	-
Blanching in hot distilled water at 70°C				
for 10 min	405±1.50^{d}	77.93	513±1.84^{c}	76.80
Blanching in hot distilled water at 70°C for 10 min and soaking in				
NaCl 0.5% for 10 min	227±2.88^{i}	87.63	299±1.67^{f}	86.47
$CaCl_2$ 0.5% for 10 min	205±3.81^{j}	88.83	263±4.33^{h}	88.10
Citric acid 0.5% for 10 min	275±2.65^{g}	85.01	371±0.80^{e}	83.22

L.S.D: Least Significant Difference at probability 0.05 (7.50), Mean±SE: Mean of triplicates samples result±Standard Error; AA Mean having different superscripts is varied significantly

Table 4: Effect of pre frying exposure to microwaves on acrylamide formation (µg/kg) in potato strips (Mean±SE)

	Acrylamide content (µg/kg) in fried potato strips			
Treatments	Frying at 150°C	Reduction of acrylamide (%)	Frying at 180°C	Reduction of acrylamide (%)
Control (without any pre-treatment)	1835±3.23^{b}	_	2211±3.40^{a}	_
Pre-cooking by microwave oven for:				
20 second	849±5.13^{d}	55.36	1022±5.54^{c}	53.77
40 second	612±5.19^{g}	66.64	784±4.38^{e}	64.54
60 second	516±4.33^{h}	71.88	664±0.92^{f}	69.96

L.S.D: Least Significant Difference at probability 0.05 (12.09), Mean±SE: Mean of triplicates samples result±Standard Error; AA Mean having different superscripts is varied significantly

Table 5: The healthy safe limitations and the daily intake of acrylamide in potato strips based on consumption of 100 gm from the tested potato strips

	Acrylamide content (µg/100 gm) in fried potato strips compared with maximum permissible level WHO (2005)*			
Pretreatments	Frying at 150°C	Status	Frying at 180°C	Status
Control (without soaking)	183.5	+	221.1	+
Soaking in distilled water				
for 30 min	135.2	-	184.9	+
for 60 min	93.7	-	161.2	+
Soaking in solution of NaCl 1%				
for 30 min	74.4	-	89.6	-
for 60 min	52.8	-	68.8	-
Soaking in solution of $CaCl_2$ 1%				
for 30 min	20.5	-	30.2	-
for 60 min	14.5	-	18.7	-
Soaking in solution of citric acid 1%				
for 30 min	52.1	-	68.7	-
for 60 min	47.7	-	64.2	-
Blanching in hot distilled water at 70°C				
For 10 min	40.5	-	51.3	-
For 20 min	32.6	-	43.4	-
Blanching in hot distilled water at 90°C				
For 5 min	39.2	-	49.5	-
For 10 min	34.6	-	45.7	-
Blanching in hot distilled water at 70°C for 10 min and soaking in				
NaCl 0.5% for 10 min	22.7	-	29.9	
$CaCl_2$ 0.5% for 10 min	20.5	-	26.3	-
Citric acid 0.5% for 10 min	27.5	-	37.1	-
Pre-cooking by microwave oven for:				
20 second	84.9	-	102.2	-
40 second	61.2	-	78.4	-
60 second	51.6	-	66.4	-

(+) Daily intake (µg) based on consumption of 100 gm of fried potato strips per day was a higher than maximum permissible level of WHO limit (0.3-2 µg/kg/day for the general population , body weight 70kg).

(-) Daily intake (µg) based on consumption of 100 gm of fried potato strips per day was lower than maximum permissible level of WHO limit (0.3-2 µg/kg/day for the general population, body weight 70kg).

* Maximum permissible level WHO (2005) at range of 21-140 µg/kg/day for the general population (body weight 70kg)

The Healthy Safe Limitations and the Daily Intake of Acrylamide in Fried Potato Strips: As shown in Table 5, the control fried potato strips contained a higher concentration of AA than the permissible level (21-140 µg/kg/day for the general population, body weight 70kg) as reported by WHO (2005). From the former data, it could be also noticed the pre-treatments including soaking in NaCl and $CaCl_2$ and citric acid; especially with dipping in $CaCl_2$, followed by blanching in the hot distilled water (at 70°C for 20 min) and microwave pre-cooking prior to frying process had the highest inhibitory effect on the AA formation in fried strips, Whereas, the AA content in the tested fried samples treated with the former pre-treatments was within the permissible level.

DISCUSSION

In the present experiment, pre-frying soaking in distilled water at ambient temperature caused a marked reduction in AA formation in potato strips throughout frying process. On the other hand, the AA content formed in the tested fried samples decreased significantly with

prolonging the soaking period. The reduction effect of soaking process in distilled water on the AA formation in fried potato strips may be due to the leaching out of important AA precursors, such as reducing sugars and asparagine, into the soaking medium [2]. These results are coincident with those reported by [2, 5, 20, 21].

The current results revealed that pre-frying soaking in NaCl and $CaCl_2$ solutions individually at ambient temperature were more effective in an inhibiting the AA formation in fried potato strips; especially with the second treatment, at different rates depending upon the valance of the cation occurred in soaking medium, the period of soaking treatments and frying process conditions. These results coincide with those found by [6, 22] who reported that the divalent cation, Ca^{2+} was more effective than the monovalent cation Na^{+} as regards to the amount of AA formed in fried potato strips without pre-treatment, the inhibition percentage of AA formation increased in fried samples treated by dipping in calcium chloride solution for 60 min at ambient temperature (95%). The AA inhibiting mechanism by sodium chloride and calcium chloride may be due to its complexation with amines and some intermediates of the Maillard reaction products, especially acrylic acid, a prevalently recognized precursor for forming AA [23, 24]. The inhibition of AA formation during frying was mainly attributed to the presence of mono or divalent cations in the potato strips after the soaking treatment, rather than the reduction of AA precursors by soaking [25, 26].

With regards to the influence of soaking in citric acid solution at ambient temperature, this treatment caused a considerable reduction in AA content formed throughout frying process in soaked potato strips. The decrement effect of soaking in citric acid on AA formation was increased in fried potato strips with increasing the soaking period. Therefore, soaking in citric acid solution was one of the most efficient ways to diminish AA formation considerably during frying process [20]. The effect of citric acid may be related to the lowering of the surface pH value thereby causing asparagine (which has a relatively low pKa compared to other amino acids) to be protonated therefore diminishing its preferential reaction with the carbonyl moiety at the start of the reaction [27].

Concerning the effect of blanching treatment prior to frying process in hot distilled water at 70°C for either 10 and 20 min on AA formation in fried potato strips as evident in obtained data, it could be concluded that the AA content in fried potato strips pre-treated with blanching was much lower than of unblanched fried samples. This effect may be due to that blanching in hot distilled water may cause some loss in reducing sugars and asparagine contents in potato strips leading to a reduction of AA formation in fried potato strips [28]. In addition that the inhibitory effect of blanching treatment on AA formation in fried potato strips was increased significantly with the extending blanching period from 10 to 20 min. Also, when increasing the blanching temperature from 70 to 90°C with decreasing the blanching time to the half resulted in, somewhat, the same results of the reduction rates in the AA formation. The present results are in agreement with those found by [2, 29, 30].

The present study showed that the multi-treatments of blanching in hot distilled water at 70°C for 10 min followed by soaking in the solution of either NaCl and $CaCl_2$ or citric acid for 10 min caused a high exceptional inhibition on AA formation in potato strips samples throughout their frying process, when compared the control fried sample. The highest reduction in AA formation was exhibited for fried potato strips pre-treated with blanching followed by soaking in $CaCl_2$ solution, while the lowest reduction of AA formation was found in that pre-treated with blanching followed by soaking in citric acid solution after frying process. This inhibitory effect related to the reasons previously mentioned for each single treatment. The current results are in accordance with those obtained by [31].

Regarding pre-frying exposure to microwaves, a highly exceptional reduction in the AA formation was recorded in potato strip samples throughout their frying process at a variable rates affecting by the period of microwave exposure and frying process conditions. Where, the AA level in fried samples was decreased significantly with increasing the microwave exposure period and with lowering the applied frying temperature. These results are in accordance with those obtained by [32] who reported that the most straightforward way of reducing AA level was to reduce the time and temperature of frying without compromising the product quality. Similar results were observed in the study of [9] who reported that microwave application prior to frying resulted in a marked reduction of AA level. In this concern, pre frying exposure to microwaves was effective in reducing AA levels in the surface region of French fries, where most of the AA formation takes place. The reduction was a consequence of the combined effect of reduced frying time and surface temperature. Water transport rate from the interior during frying was shown to play an important role in limiting AA formation in the surface region. Microwave pre-cooking requires little time and since the reducing sugars and asparagine are retained

within the strip, surface characteristics of the final product are not adversely affected [9].

From the healthy point of view the maximum permissible level and the healthy hazards due to dietary intake of AA in processed foods (i.e. fried potato products) are accurately indefinite and varied from country to another. In this concern, the average dietary intake of AA is estimated to be up to 35 µg/day, corresponding to 0.5 µg/kg body weight/day assuming a body weight of 70 kg in Sweden [33]; 0.48 µg/kg body weight/day in Germany [34]; 0.36 µg/kg body weight/day in Norwegian [35]. Also, the world Health Organization [36] estimates a daily intake of dietary AA in the range of 0.3- 2.0 µg/kg body weight/day for the general population. The healthy safe quality of the tested fried potato strips was evaluated in relation to the most considerable limitation of AA and possible daily intake of these component with consumption of 100 gm of the tested potato strips. When the maximum permissible level and the dietary intake of acrylamide based on consumption of 100 gm of fried potato strips per day were taken in our consideration, the fried potato strips samples should be treated before frying process with soaking in distilled water and the tested variable soaking media; especially in $CaCl_2$ solution, followed by blanching in hot distilled water and microwaving pre-cooking prior to pan-fat frying process, as their the inhibitory effect on the AA formation in the tested foodstuff, to ovoid the formation of AA in fried potato products at carcinogenic level or at the healthy hazard level. Also, it should be avoided the frying potato strips without pre treatments as it encourages the formation of AA at a higher levels than the maximum permissible level (21-140 µg/kg/day for the general population, body weight 70kg) [36] and which possible causing health hazard and cancer diseases.

In conclusion, the acrylamide content in fried potato strips increased significantly as frying temperature and duration increase. The tested pre frying treatments (soaking, blanching and microwave pre-cooking) had a significant inhibitory effect on AA formation in fried potato strips. These results could be applied to reducing AA levels in fried potato products.

REFERENCES

1. Kim, C.T., E-S. Hawang and H.J. Lee, 2005. Reducing acrylamide in fried snack products by adding amino acids. J. Food Sci., 70: c354-c358.
2. Pedreschi, F., K. Kaack and K. Granby, 2006. Acrylamide content and color development in fried potato strips. Food Research Int., 39: 40-46.
3. Pedreschi, F., K. Kaack, K. Granby and E. Troncoso, 2007a. Acrylamide reduction under different pre-treatments in French fries. J. Food Eng., 79: 1287-1294.
4. Martin, F.L. and J.M. Ames, 2001. Formation of Strecker aldehydes and pyrazines in a fried potato model system. J. Agril. Food Chem., 49: 3885-3892.
5. Pedreschi, F., K. Kaack and K. Granby, 2004. Reduction of acrylamide formation in potato slices during frying. Lebensm.-Wiss. u.-Technol., 37: 679-685.
6. Ou, S., Q. Lin, Y. Zhang, C. Huang, X. Sun and L. Fu, 2008. Reduction of acrylamide formation by selected agents in fried potato crisps on industrial scale. Innovative Food Sci. Emerging Technologies, 9: 116-121.
7. IARC., 1994. International Agency for Research on Cancer (IARC) monographs on the evaluation of carcinogenic risks to humans, 60: 389-433.
8. Gökmen, V. and T.K. Palazo™lu, 2008. Acrylamide Formation in Foods during Thermal Processing with a Focus on Frying. Food Bioprocess Technology, 1: 35-42.
9. Erdo™du, S.B., T.K. Palazo™lu, V. Gökmen, H.Z. Ôenyuva and H.I. Ekiz, 2007. Reduction of acrylamide formation in French fries by microwave pre-cooking of potato strips. J. Sci. Food Agric., 87: 133-137.
10. Ahn, J.S., L. Castle, D.B. Clarke, A.S. Lboyd, M.R. Philo and D.R. Speck, 2002. Verification of the findings of acrylamide in heated foods. Food Additives Contaminants, 19: 1116-1124.
11. Becalski, A., B.P.Y. Lau, D. Lewis and S.W. Seaman, 2003. Acrylamide in foods :Occurrence, Sources and modeling. J. Agril. Food Chemi., 51: 802-808.
12. Vattem, D.A. and K. Shetty, 2003. Acrylamide in food a model for mechanism of formation and its reduction. Innovative Food Sci. Emerging Technologies, 4: 331-338.
13. Wickund, T., H. Østlie, O. Lothe, S.H. Knutsen, E. Bråthen and A. Kita, 2006. Acrylamide in potato crisp-the effect of raw material and processing. LWT-Food Sci. Technol., 39: 571-575.
14. Gökmen, V. and H.Z. Senyuva, 2006. A generic method for the determination of acrylamide in thermally processed foods. J. Chromatograph., 1120: 194-198.
15. Henares, R.J.A., D.C. Andrade and F.J. Morales, 2006. Relationship between acrylamide and thermal-processing indexes in commercial breakfast cereals: A survey of Spanish breakfast cereals. Molecular Nutrition Food Res., 50: 756-762.

16. Henares, R.J.A. and F.J. Morales, 2006. Determination of acrylamide in potato chips by a reversed-phase LC-MS method on a stable isotope dilution assay. Food Chem., 97: 555-562.
17. Senyuva, H.Z. and V. Gökmen, 2006. Interference free determination of acrylamide in potato and cereal-based-foods by laboratory validated liquid chromatography-mass spectrometry methods. Food Chem., 97: 539-545.
18. Gomez, K.A. and A.A. Gomez, 1984. Statistical procedures for agricultural research 2nd Edn. John Wiley, New York, USA.
19. SAS, 1985. Statistical Analysis System (SAS) user's guide: Statistics, 5th Edn. Cary, N.C.: SAS Institute, Inc.
20. Jung, M.Y., D.S. Choi and J.W. Ju, 2003. A novel technique for limitation of acrylamide formation in fried and baked corn chips and in French fries. J. Food Sci., 68: 1287-1290.
21. Pedreschi, F., O. Bustos, D. Mery, P. Moyano, K. Kaack and K. Granby, 2007b. Color kinetics and acrylamide formation in NaCl soaked potato chips. J. Food Eng., 79: 989-997.
22. Gökmen, V. and H.Z. Senyuva, 2007. Acrylamide formation is prevented by divalent cations during the Maillard reaction. Food Chem., 103: 196-203.
23. Stadler, R.H., F. Robert, P. Riediker, N. Varga, T. Davidek and S.P. Devaud, 2004. In-depth mechanistic study on the formation of acrylamide and other vinylogous compounds by the Maillard reaction. J. Agril. Food Chem., 52: 5550-5558.
24. Yaylayan, V.A., C.P. Locas, A.O. Wnorowski and J. Brien, 2004. The role of creatine in the generation of n-methylacrylamide: A new toxicant in cooked meat. J. Agril. Food Chem., 52: 5559-5565.
25. Grob, K., M., S. Biedermann, A. Biedermann-Brem, A. Noti, D. Imhof and T. Amrein, 2003. French fries with less than 100 lg/kg acrylamide. Collaboration between cooks and analyst. European Food Res. Technol., 271: 185-194.
26. Kita, A., E. Bråthen, S.H. Knutsen and T. Wicklund, 2005. Effective ways of decreasing acrylamide content in potato crisps during processing. J. Agril. Food Chem., 10:1021.
27. Hanley, A.B., C. Offen, M. Clarke, B. Ing, M. Roberts and R. Burch, 2005. Acrylamide reduction in processed foods. Chemistry and Safety of Acrylamide in Food, Friedman and Mottram (Eds.), Springer Science and Business Media, Inc., 561: 387-392.
28. Califano, A.N. and A. Calvelo, 1987. Adjustment of surface concentration of reducing sugars before frying of potato strips. J. Food Process. Preservation, 12: 1-9.
29. Mestdagh, F., J. Maertens, T. Cucu, K. Delporte, C. Van Peteghem and B. De Meulenaer, 2008. Impact of additives to lower the formation of acrylamide in a potato model system through pH reduction and other mechanisms. Food Chem., 107: 26-31.
30. Cumminsa, E., F. Butlera, R. Gormleyb and N. Bruntonb, 2008. A methodology for evaluating the formation and human exposure to acrylamide through fried potato crisps. LWT-Food Sci. Technol., 41: 854-867.
31. Park, Y., H. Yang, J.M. Storkson, K.J. Albright, W. Liu, R.C. Lindsay and M.W. Pariza, 2005. Controlling acrylamide in french fry and potato chip models and a mathematical model of acrylamide formation. Chemistry and Safety of Acrylamid in Food, Friedman and Mottram (Eds.), Springer Science and Business Media, Inc., 561: 343-356.
32. Claeys, W.L., K. De Vleeschouwer and M.E. Henrickx, 2005. Quantifying the formation of carcinogens during food processing: acrylamide. Trends Food Sci. Technol., 16:181-193.
33. Svensson, K., L. Abramsson, W. Becker, A. Glynn, K.E. Hellenäs, Y. Lind and J. Rosén, 2003. Dietary intake of acrylamide in Sweden. Food Chem. Toxicol., 41: 1581-1586.
34. Konings, A.J., A.J. Baars, J.D. van Klaveren, M.C. Spanjer, P.M. Rensen, M. Hiemstra, J.A. van Kooij and P.W. Peters, 2003. Acrylamide exposure from foods of the Dutch population and an assessment of consequent risk. Food Chemical. Toxicology, 41: 1569-1579.
35. Norwegian Food Agency, 2002. June 2002. Available: http://www.snt.no/nytt/ tema/Akrylamid/ analyseresultater.htm
36. World Health Organization, 2005. Summary Report of the Sixty-Fourth Meeting of the Joint FAO/WHO Expert Committee on Food Additive (JECFA). Rome, Italy. The ILSI Press International Life Sciences Institute, Washington DC., pp: 1-47.