IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 9, Issue 11 Ver. I (Nov. 2015), PP 46-53
www.iosrjournals.org

The Effect of Using Some Treatments on Reduction of Acrylamide Formation in Processed Potatoes

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Abstract: *Reduction of acrylamide formation in potato chips was investigated in relation to ten pretreatments before frying. Potato slices were fried at 170 C for 5 min. Prior to frying, potato slices were soaked in one of the following solutions for 60min : (1) tap water ; (2-4) NaCl solutions (1%, 2% and 3%); (5-7) citric acid solutions (0.5 %, 1 % and 2%); (8) combined solution (NaCl 3% +0.5% citric acid); (9)tomato juice and (10) combined tomato juice(tomato juice + 1% NaCl + 0.5% citric acid). Reducing sugars and asparagine contents were determined in potato slices before frying, whereas acrylamide content was determined in the resultant fried potato chips. All studied treatments decreased both of reducing sugars and asparagene content (except tap water with asparagene), and consequently acrylamide formation. The highest reduction effects were recorded for combined tomato juice, tomato juice and combined solution of 3% NaCl+ 0.5 % citric acid, respectively. Oil uptake of fried potato only affected by NaCl treatments either separated or combined and tomato juice. In relation to sensory parameters, all studied treatments improved the sensory characteristics, with 2 exceptions: the first is the undesirable effect of citric acid treatments on taste and the second is the undesirable effect of 2% NaCl on crispiness. The highest value of over all acceptability was recorded for combined tomato juice followed by tomato juice.*

Keywords: *Potato slices; Frying; Acrylamide; Reducing sugars; Asparagine ;oil uptake, sensory characteristics*

I. Introduction

Frying is a widely used cooking method that creates unique textures and flavors in foods. Potatoes (Solanum tuberosum), one of the world's major crops, is consumed daily by millions of people (specially children) from diverse cultural backgrounds **(Clark, 2003)**.

In April 2002, Swedish researchers shocked the food safety world when they presented preliminary findings of acrylamide in some fried and baked foods, most notably potato chips and French fries, at levels of 30–2300 mm/kg. As acrylamide has not been detected in unheated or boiled foods, it was considered to be formed during heating at high temperatures. They attributed this fact to the higher temperatures reached in Maillard nonenzymatic browning reactions required for desirable color, flavor and aroma production (**Coughlin, 2003**).

Acrylamide is a known carcinogen substance in experimental animals, it has been classified as probably carcinogenic in humans.

Former studies focused mainly on: (i) accurate analytical methods of acrylamide and its substrates **(Biedermann et al.,2002; Rosén & Hellenäs, 2002; Zhang et al., 2011)**,(ii) formation mechanisms of acrylamide **(Mottram et al., 2002; Stadler et al., 2002, 2004; Zyzak et al., 2003)**, and (iii) the possible mitigation strategies in heat-processed foods. Existing strategies to reduce acrylamide content include three basic aspects: modification of raw materials, optimization of processing conditions and addition of exogenous additives. For raw materials, the key is to control the content of carbonyl source and asparagine. Choosing a relatively higher storage temperature **(Chuda et al., 2003)** can reduce the content of reducing sugars in potatoes, thus reduce the acrylamide level in the final product. For processing conditions, an appropriate heating temperature should be set and long-time processing of the foodstuff should be avoided **(Mottram et al., 2002)**. As for exogenous additives, many substances are reported to be effective for the mitigation of acrylamide, including some organic acids (e.g. citric acid, **Cook & Taylor, 2005)**, some amino acids (e.g. glycine, **Claeys et al., 2005)**, and some mono- and divalent cations (e.g. Na+ or Ca2+, **Gökmen & Senyuva, 2007)**. Moisture contents also a factor to be considered, where low moisture level was reported to favor acrylamide formation. However, it was also observed that lowering water activity at the surface of products for pre frying was an approach to reduce acrylamide formation **(Morales et al.,2008)**.

The objective of this work was to study the effect of different treatments (included tap water, NaCl, citric acid, combined NaCl+ citric acid, tomato juice and combined tomato juice +NaCl + citric acid) on reducing acrylamide formation in fried potato slices and on fried potato quality parameters

II. Materials And Methods

Materials

Potatoes (Sponta variety) and sunflower oil were obtained from the local market in Egypt.
Potatoes were washed and peeled. Slices (diameter: 37 mm, width: 1.5 mm) were prepared by using a mechanical slicer (Italimport SRL, Model 90915, China). .

Pre-treatments

Slices were rinsed immediately after cutting for 1 min in distilled water to eliminate some starch material adhering to the surface prior to frying. Then, 10 batches (400g for each) of potato slices were soaked for 60 min in 1L of the following solutions:

1- tab water
2- 1 % NaCl solution
3- 2% NaCl solution
4- 3% NaCl solution
5- 0.5 % Citric acid solution
6- 1 % Citric acid solution
7- 2 % Citric acid solution
8- 3% NaCl + 0.5 % Citric acid solution
9- Tomato Juice
10- Tomato Juice +1% NaCl + 0.5 Citric acid
- Rinsed slices in water without soaking treatment were considered as the control.

Frying conditions

Thirty slices of each pre-treatment were fried in a laboratorial fryer containing 1.2 L of oil at 170 C for 5 min. These frying conditions allowed the chips to reach final moisture contents of 1.7 g water/100 g (wet basis). Frying temperature was maintained constant since the potato mass to oil mass ratio (g/g) was kept very low (1:11).

Analysis

- pH of the citric acid solutions and potato samples before and after soaking of the slices was measured using a pH meter Metrohm (Model 691,Switzerland).
- Moisture content: were determined according to the **AOAC (1990)** .
- Determination of Total Soluble Solids: A drop of the each soaking solution was spread on the digital refractometer (Models 10430, 0- 30 °Brix, Cambridge Instruments Inc, USA) **(AOAC, 1990)**.
- Total lipids: were determined according to the **AOAC (1990)**
-Reducing Sugars: Reducing sugars were analyzed as described by **Ross (1959)**. Different pretreated potato samples were dried at 60°C. Every sample was grinded with glass powder and suspended in distilled water. After filtration, the samples were suspended in distilled water and filtered through Whatman No1 filter paper. 1ml of the filtrate was added to 3 ml of dinitrophenol solution (0.038 M). The mixtures were incubated at 65–70°C for 6 min. and then cooled under running water. Changes were estimated at 600 nm spectrophotometrically.
- Amino acids: Amino acids were extracted with an acetate buffer at pH 7.0 in water, derivatization of the amino acid hydrolysate with 6-aminoquinoline-hemi-succinylcaramin and quantification using reverse phase HPLC and gradient elution according to **Cohen and Michaud (1993)**.
- Acrylamide analysis: was determined according the method described by **Gokmen and Senyuva, (2006)**.
acrylamide (2-propene amide) [CAS No. 79-06-1] (>99.5%) was obtained from Sigma-Aldrich (St. Louis, MO, US). Labelled d3-acrylamide (>98%) was from Polymer Source Inc. (Dorval, Quebec Canada). The SPE columns were Isolute Multimode 300 mg from International Sorbent Technology (Hengoed, Mid Glamorgan, UK). Mini uniprep Teflon filter vials 500 ml, filter pore size 0.45 mm, Whatman Int. Ltd (Kent, UK). The water used was MilliQ water (Millipore Corp., Bedford, MA, USA).

The acetonitril was ofHP LC grade from Rathburn Chemicals (Walkerburn, Scotland). Formic acid for the eluent (0.1% in water) was from Merck (Darmstadt,Germany). All stock solutions of acrylamide and d3-acrylamide (1000 and 10 mg/ml) as well as calibration standards (2–30 ng/l) were prepared in water and kept at _18_C until use.

4.00 g of homogenized potato were extracted with 40.0 ml MilliQ water by an Ultra-turrax mixer (Janke & Kunkel, Staufen, Germany) (after addition of 200 ml d3-acrylamide 10 mg/ml as internal standard). Each analytical batch included 1–2 spiked samples for recovery measurements. The samples were centrifuged for 10 min. at 3500 rpm (Hereaus Sepatech Megafuge 3.0R (Osterode,Germany)). The clean up was made on 300 mg Isolute Multimode SPE columns (IST), using an ASPEC TM XLi automatic SPE clean up system

(Gilson Inc.,Middleton, WI, US). The SPE columns were conditioned with acetonitrile (1 ml) and water (2_2 ml). The first 500 ml was discharged and the following 400 ml of sample was collected in Mini uniprep Teflon filter HPLC vials. A HP1100 HPLC system (Agilent Technologies, Palo Alto, CA, USA) was used for acrylamide separation ona Hypercarb column, 5 mm, 50mm_2.1mm (Thermo-Hypersil, Cheshire, UK, www.thermohypersil.co.uk) after a guard column (Phenomenex SecurityGuardTM,C18 ODS, 4mm_2.0 mm, Cheshire, UK). 10 ml was injected and eluted with 0.1% formic acid in water at a flow of 250 ml/min. The MS/MS detection was performed on a Quattro Ultima triple quadrupole instrument with masslynx software (Micromass Ltd.,Manchester, UK). The electrospray was operated in the positive ion mode, and the capillary was set to 3.0 kV, the cone voltage was 31 V, and the collision energy 10 eV. The source temperature was set at 120C and the desolvation temperature at 400C. Nitrogen was used as nebulizer gas (flow 500 l/h) and desolvation gas (flow 150 l/h), and argon was used as collision gas at a pressure of 2.3_3 mbar. The multiple reaction monitoring (MRM) mode ofthe degradation patterns m=z 72-55 (acrylamide) and m=z 75-58 (d3-acrylamide) were used for quantification.

- **Sensory evaluation:**

Sensory properties were evaluated as described by **Balatsouras and Doutsias, (1983)**, where the final products from all treatments were presented to 10 untrained member panelists for organoleptic evaluation. The panelists were requested to assess the samples for taste, color, odor, crispiness and over all acceptability by 10 points in scale levels of quality.

-Statistical analysis:

All determinations were carried out in triplicate and data is reported as mean. Significant differences ($p<0.05$) were calculated using Duncan's multiple range test, followed the method reported by **Steel and Torrie, (1980)**.

III. Results And Discussion

1-Soaking solutions pH and TSS before and after treatments:

The pH and TSS profile of each soaking solution was measured before and after soaking treatments (to join the obtained results of the processed potato with certain conditions) and the data are presented in table (1).

From the presented data in table (1), it could be noticed that, the pH values of water and NaCl solutions (1%, 2% and 3%) were decreased from an initial pH values of 7.2 and 7.1 to 6.4 and 6.3, respectively. This may be due to the lower pH of potato slices (approx 6) comparing with pH of mentioned solutions.

On the other hand, the pH values of citric acid solutions (0.5 %, 1% and 2%), NaCl 3% + 0.5% citric, tomato juice and tomato juice + NaCl 1% + 0.5% citric were increased from initial pH values of 2.5, 2.2, 2.0 , 2.4, 4.3 and 3.3 to 3.8, 3.2, 2.9, 3.4, 4.7 and 3.9, respectively. These results are in harmony with **Pedreschi, et al.,(2004)**, who found that pH of the 10 g/l citric acid solution before and after 30 min of potato slices immersion was 2.45 and 2.71, respectively. For the 20 g/l citric acid solution, the corresponding values were 2.25 and 2.50, respectively

Table (1) : The pH and TSS profiles of different soaking solutions before and after soaking process.

	pH		TSS	
	Before soaking	After soaking	Before soaking	After soaking
Water	7.2^{a}	6.4^{a}	0.0^{i}	0.2^{h}
NaCl 1%	7.1^{a}	6.3^{a}	1.0^{g}	1.2^{f}
NaCl 2%	7.1^{a}	6.3^{a}	2.0^{de}	2.2^{de}
NaCl 3%	7.1^{a}	6.3^{a}	3.0^{c}	2.3^{cd}
Citric acid 0.5 %	2.5^{d}	3.8^{c}	0.5^{h}	0.6^{g}
Citric acid 1 %	2.2^{e}	3.2^{e}	1.0^{g}	1.2^{f}
Citric acid 2 %	2.0^{f}	2.9^{f}	1.9^{ef}	2.2^{de}
NaCl 3% + citric 0.5%	2.4^{d}	3.4^{d}	3.5^{a}	3.7^{a}
Tomato juice	4.3^{b}	4.7^{b}	1.8^{f}	2.1^{e}
Tomato juice + NaCl 1% + citric 0.5%	3.3^{c}	3.9^{c}	3.2^{b}	3.5^{b}

Values bearing the same superscript within the same column are not significantly different ($P> 0.05$)

Regarding to TSS contents, it could be observed that, there was a slight increment in the TSS contents of all studied solutions as a result of soaking process, these increments ranged from 0.1 to 0.3 %. This may be as a result of transferring of some components from the potato slices to soaking solutions and from the soaking solutions to the potato slices.

The Effect of pretreatments on reducing sugars content.

The reducing sugars content of potato slices after different soaking treatments in addition to control sample was determined and the obtained results were presented in Fig. (1).

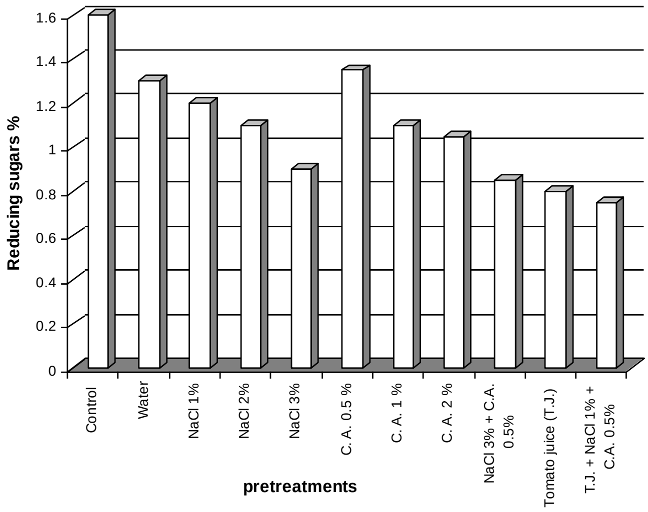

Fig.(1): The effect of pretreatments on reducing sugars content

The presented data indicated obviously that, all studied soaking treatments had a positive effect on decreasing reducing sugars content comparing with the control sample. The reduction percentage was 18.75, 25, 31.25, 43.75, 15.62, 31.25, 34.37, 46.87, 50.0 and 53.12 % for water, NaCl 1%, NaCl 2% NaCl 3%, citric acid (C.A.) 0.5 %, citric acid (C.A.)1%, citric acid (C.A.) 2%, NaCl 3%+ C.A. 0.5%, Tomato juice (T.J.) and T.J. + NaCl 1%+ C.A. 0.5%, respectively. The highest effect was observed to the combined treatment (T.J. + NaCl 1%+ C.A. 0.5%) which led to decrease the reducing sugar content by 53.12 % followed by tomato juice (50.0%) and the combined treatment of NaCl 3% + citric acid 0.5% (46.87%). This may be due to that, soaking potato chips in NaCl solutions lead to a higher leaching of one important acrylamide precursor such as glucose **(Anese et al., 2009)**.

These findings agreed with those of **Amany and Shaker, (2013)**,who found that, soaking of potato slices before frying in distilled water (contains 1% NaCl) and citric acid solution (1%), led to remarkable decrease in glucose contents (30-45%) of potato slices comparing to control sample (unsoaked).

The Effect of pretreatments on asparagene content.

The asparagene content of potato slices after different soaking treatments in addition to control sample was determined and the results were presented in Fig. (2).

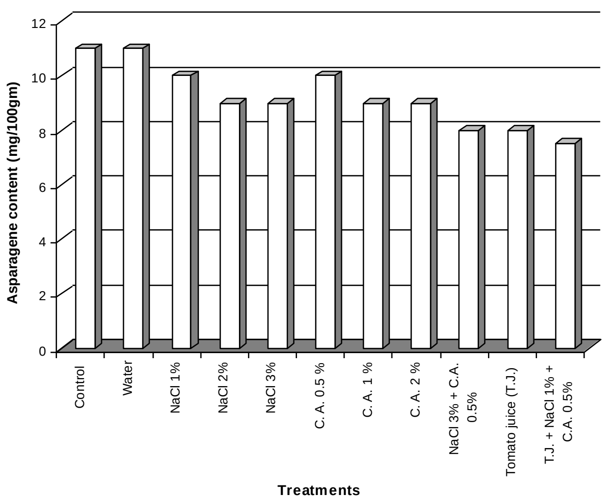

Fig. (2): The effect of pretreatments on asparagene content

From the presented data in Fig.(2), it could be noticed that, soaking potato slices in tab water had no effect on asparagene content, while the lowest effect on decreasing asparagene content was recorded for NaCl 1% and citric acid 0.5% treatments. On the other hand, the highest effect on reduction asparagene content was recorded for the combined treatment of Tomato juice + NaCl 1% + citric acid 0.5% followed by both tomato juice treatment and combined treatment of NaCl 3% + citric acid 0.5%, while the moderate effect was observed for both NaCl 2%, NaCl 3% , citric acid 1% and citric acid 2%. This may be due to the pH lowering and leaching out of free asparagine from the surface layer of potato cuts to the solutions (**Jung et al., 2003)**. These results are in harmony with those reported by **Amany and Shaker, (2013)**,who found that, soaking of potato slices before frying in citric acid solution (1%) led to significant difference in the asparagene content between acid immersed samples and control.

The Effect of pretreatments on acrylamide level.

The acrylamide content of fried potato slices after different soaking treatments in addition to control sample was determined and the results were showed in Fig. (3).

The presented data, showed obviously that, soaking potato slices in tap water for 60 min led to reduce the acrylamide content by 35.55% this is in agreement with that reported by **Pedreschi et al., (2004)**, who found that, soaking potato slices in distilled water for 90 min led to decrease acrylamide content by 38 % after frying at 170C.

Concerning to NaCl soaking treatments (1%, 2% and 3%) of potato slices recorded higher acrylamide reduction percentages 38.88% , 42.22 % and 51.11 %, respectively. These finding are in harmony with those of **Gokmen and Senyuva, (2007),** who found that, longer time dipping of potato in sodium chloride or calcium chloride led to much less amount of acrylamide formed compared with samples dipped in water. They reported also that, at amounts equivalent to those of asparagene and fructose, added divalent cations such as Ca^{2+} were found to prevent acrylamide formation completely, whereas monovalent cations, such as Na^{+}, almost halved the acrylamide formed. This may be due to the role of NaCl in decrease the water activity at the surface of potato slices which influence the mechanism of acrylamide formation (**Pedreschi and Zuniga, 2009).**

Regarding to citric acid soaking treatments (0.5%, 1% and 2%), the presented data showed obviously that, the higher the acid concentration, the higher the acrylamide reduction, where, these treatments led to decrease acrylamide formation by 33.33 % , 36.66 % and 40.00 % , respectively.
These results agreed with those of **Pedreschi et al., (2004)**, who found that, At 150 C, slice immersion in citric acid solutions of10 and 20 g/l reduced significantly acrylamide formation (70%) with respect to the control. Also, this result is coincident with that reported by **Jung et al., (2003)** who found that dipping potato strips in 10 and 20 g/l citric acid solutions induced 73.1% and 79.7% reduction of acrylamide formation in the resultant French fries when frying at 190C. This may be due to lowering the pH with citric acid before frying was an efficient way to considerably diminish acrylamide formation in French fries **Jung et al., (2003**)

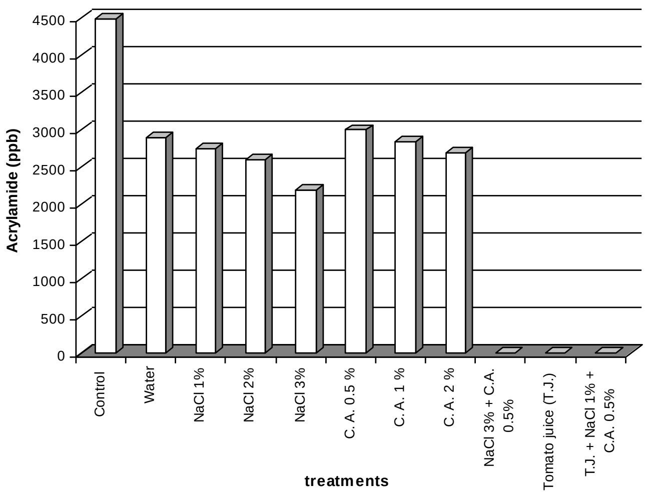

Fig.(3): The effect of pretreatments on acrylamide level

In relation to tomato juice and combined treatments either "NaCl 3% + 0.5 % citric acid" or "tomato juice + NaCl 1% + 0.5% citric acid", the presented results indicated obviously that, these three treatments had the same effect on reduction acrylamide formation completely, where acrylamide not detected in fried potato samples treated with these three treatments. This may be as a result of synergistic effect of low pH and presented cations which achieved all the previous effects on reduction acryalmide formation.

The Effect of pretreatments on oil uptake.

The oil uptake of different pretreated potato samples during frying in sunflower oil at 170C for 5min is shown in Fig. (4).

From the presented data in Fig. (4), it could be observed that, different citric acid pretreatments (0.5%, 1% and 2%) had slight effect on oil uptake of fried potato, while NaCl pretreatments (1%, 2% and 3%) had noticeable effect on reduction the oil uptake of fried potato, where the highest reduction (31.27%) was recorded for 3% NaCl treatment. On the other hand, tomato juice and combined treatments either "NaCl 3%+ 0.5 citric acid" or "tomato juice+ NaCl 1% + 0.5% citric acid" had a lower reduction effect on oil uptake when compared with 3%NaCl, where they recorded 33.79%, 31.49% and 35.11%, respectively.

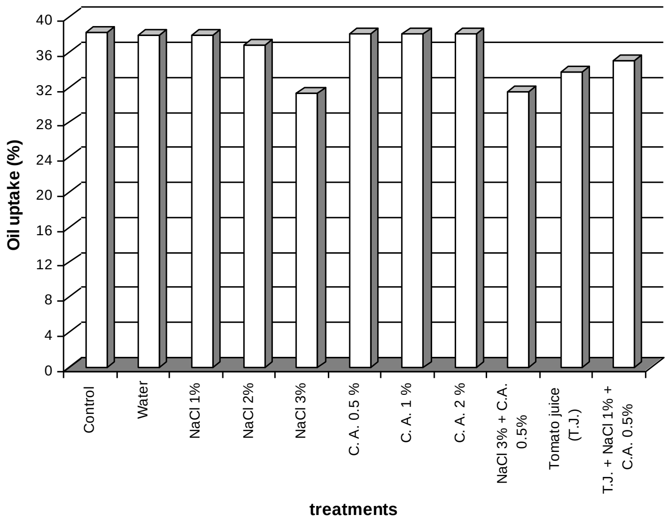

Fig.(4): The effect of pretreatments on oil uptake of fried potato

These findings are in harmony with those reported by **Bunger et al., (2003),** who found that, potato strip impregnation in 3% NaCl solution per 50 min allowed obtaining French fries with lower oil content by 22%. They also, reported that, during frying, solutes are concentrated on the surface, enhancing crust formation.

The Effect of pretreatments on sensory properties of fried potato.

Sensory quality characteristics of fried potato chips after different pretreatments are evaluated for color, taste, odor, crispiness and over all acceptability and the obtained results were tabulated in table (2).

Table (2): The effect of different pretreatments on sensory properties of fried potato.

	Color (10)	Taste (10)	Odor (10)	Crispiness (10)	Over all acceptability (10)
Control	8.50^{de}	7.66^{f}	8.50^{f}	7.50^{df}	8.00^{e}
Water	8.33^{de}	8.00^{e}	8.55^{ef}	7.88^{e}	8.11^{d}
NaCl 1%	8.77^{bc}	8.33^{d}	8.55^{ef}	9.27^{a}	8.66^{b}
NaCl 2%	8.22^{e}	8.44^{cd}	8.66^{de}	6.00^{g}	7.61^{f}
NaCl 3%	8.38^{de}	8.55^{bc}	8.77^{dc}	8.33^{d}	8.66^{b}
Citric acid 0.5 %	9.27^{a}	7.38^{g}	9.11^{a}	9.00^{b}	8.55^{c}
Citric acid 1 %	9.05^{ab}	7.22^{g}	8.88^{bc}	8.66^{c}	8.11^{d}
Citric acid 2 %	8.83^{bc}	7.00^{h}	8.88^{bc}	8.66^{c}	8.16^{d}
NaCl 3% + citric 0.5%	8.61^{cd}	8.44^{cd}	9.00^{ab}	8.72^{c}	8.66^{b}
Tomato juice	8.55^{cd}	8.66^{ab}	8.77^{cd}	9.22^{a}	8.77^{a}
Tomato juice + NaCl 1% + citric 0.5%	8.55^{cd}	8.72^{a}	9.11^{a}	8.94^{b}	8.83^{a}

Values bearing the same superscript within the same column are not significantly different (P> 0.05)

Regarding to color results presented in table (2), it could be noticed that, the highest values of color were recorded for citric acid treatments (0.5 %, 1% and 2%) comparing to control, where their recorded color value were 9.27, 9.05 and 8.83, respectively. These results are in agreement with those reported by **Amany and Shaker, (2013),** who found that, fried potato slices pretreated by immersion in acid solution (citric acid 1%), was characterized by an appropriate golden-yellow color, while other treatment led to produce fried potato with slightly darker color.

Concerning to taste results, the highest taste values were recorded for fried potato chips treated by tomato juice either separated or combined which recorded 8.72 and 8.66, respectively. While the lowest values were recorded for citric acid treatments (0.5%, 1% and 2%) where their taste values were 7.38, 7.22 and 7.00 , respectively. These findings agreed with those of **Jung et al., (2006),** who reported that sensory quality of French fries worsened when the added citric acid reached the level of 2% (w/w).

In relation to odor results presented in table (2), it could be noticed that, all studied treatments had a positive effect on improving the product odor, where, the highest effect was recoded for 0.5 citric acid and combined tomato juice treatments.

Crispiness results presented in table (2), showed obviously that, all studied treatments improved the crispiness state of fried potato chips except NaCl 2% treatment, where the highest improving effect was recorded for NaCl 1% treatment followed by tomato juice treatment.

Regarding to overall acceptability results in table (2), it could be noticed that the highest acceptability sample was combined tomato juice followed by tomato juice then both NaCl 1% and 3% in addition to combined NaCl 3% + citric acid 0.5%.

IV. Conclusion

Tomato juice either separated or combined with 1% NaCl + 0.5% citric acid in addition to combined solution of 3% NaCl+ 0.5 % citric acid had the highest effect on reduction of acrylamide formation in fried potatoes (not detected), also these treatments improved the sensory properties of resultant product in addition to their role in decreasing the oil uptake of the fried potatoes. The other studied treatments, had considerable effect on reduction of acrylamide formation in fried potatoes and on sensory properties improvement (with some exceptions) but their effects were lower than those of the previously, three treatments.

References

[1]. Amany, M. M. Basuny and Skaker, M. Arafat, (2013). Reduction of acrylamide formation, polymer compounds and oil uptake in potato slices during frying. Curr. Res. Microbiol. Biotechnol.,1(3): 111-118.

[2]. Anese M, Bortolomeazzi R, Manzocco L, Manzano M, Giusto C, Nicoli MC (2009). Effect of chemical and biological dipping on acrylamide formation and sensory properties in deep-fried potatoes. Food Research International, 42: 142-147.

[3]. A.O.A.C., (1990). Official Methods of Analysis. 15th ed., Association of Official Analytical Chemists. Washington, DC.

[4]. Balatsouras, G., and G. Doutsias, (1983). Effect of fermentation and control on the sensory properties of Conservolea variety green olives. Environmental Microbiology, 68-74

[5]. Biedermann, M., Biedermann-Brem, S., Noti, A., & Grob, K. (2002). Methods for determining the potential of acrylamide formation and its elimination in raw materials for food preparation, such as potatoes. Mitteilungen aus Lebensmitteluntersuchung und Hygiene,93, 653–667.

[6]. Bunger A, Moyano P, Rioseco V (2003) NaCl soaking treatment for improving the quality of French-fried potatoes. Food Res Int 36:161–166

[7]. Chuda, Y., Ono, H., Yada, H., Ohara-Takada, A., Matsuura-Endo, C., and Mori, M. 2003. Effects of physiological changes in potato tubers (Solanum tuberosum L.) after low temperature storage on the level of acrylamide formed in potato chips. Biosci., Biotechnol., Biochem.67:1188-90.

[8]. Claeys, W.L., de Vleeschouwer, K., and Hendrickx, M.E. 2005. Effect of amino acids on acrylamide formation and elimination kinetics. Biotechnol. Prog. 21:1525-30.

[9]. Clark JP (2003). Happy birthday, potato chips and other smack developments. Food Technology, 57: 89-92.

[10]. Cohen, S. A., & Michaud, D. P. (1993). Synthesis ofa fluorescent derivating reagent, 6-aminoquinolyl-N-hydroxysuccinimidyl carbamate, and its applicсation for the analysis of hydrolysate amino acids via high performance liquid chromatography. Analytical Biochemistry, 211, 279–287.

[11]. Cook D.J., and Taylor, A.J. 2005. On-line MS/MS monitoring of acrylamide generation in potato- and cereal-based systems. J. Agric. Food Chem. 53:8926-33.

[12]. Coughlin, J. R. (2003). Acrylamide: What we have learned so far. Food Technology, 57(2), 100.

[13]. Gökmen, V. and Senyuva, H.Z. 2007. Acrylamide formation is prevented by divalent cations during the Maillard reaction. Food Chem. 103:196-203.

[14]. Jung, M. Y., Choi, D. S., & Ju, J. W. (2003). A novel technique for limitation of acrylamide formation in fried and baked corn chips and in French fries. Journal of Food Science, 68,1287–1290.

[15]. Jung, M.Y., Choi, D.S., Ju, J.W. A novel technique for limitation of acrylamide formation in fried and baked corn chips and in french fries. J. Food Sci., 2006, 68, 1287–1290.

[16]. Morales, F., Capuano, E., Fogliano, V. Mitigation strategies to reduce acrylamide formation in fried potato products. Ann. N.Y. Acad. Sci., 2008, 1126, 89–100.

[17]. Mottram, D. S., & Wedzicha, B. L. (2002). Acrylamide is formed in the Maillard reaction. Nature, 419, 448–449.

[18]. Pedreschi F, Kaack K. and Granby K. (2004). Reduction of acrylamide formation in potato slices during frying. Lebensm Wiss Technol 37(6):679-85.

[19]. Pedreschi F, and R, Zuniga, (2009). Acrylamide and oil reduction in fried potatoes : A Review. Food3 (Special Issue 2), 82-92 ,Global Science Books

[20]. Rosen, J., & Hellen.as, K. E. (2002). Analysis ofacrylamid e in cooked foods by liquid chromatography tandem mass spectrometry.Analyst, 127, 880–882.

[21]. Ross, A. F., 1959. Dinitrophenol method for reducing sugars. The Avi. Publishing Company, First edition, Wesport.

[22]. Stadler, R. H., Blank, I., Varga, N., Robert, F., Hau, J., Guy, A.,Robert, P., & Riediker, M. C. (2002). Acrylamide from Maillard reaction products. Nature, 419, 449–450.

[23]. Stadler, R.H., Robert, F., Riediker, S., Varga, N., Davidek, T., Devaud, S., Goldmann, T., Hau, J., and Blank, I. (2004). In-depth mechanistic study on the formation of acrylamide and other vinylogous compounds by the Maillard reaction. J. Agric. Food Chem. 52:5550-58.

[24]. Steel, R. G. D., and J. H. Torrie, 1980. Principles and procedures of statistics. London: McGraw Hill.

[25]. Zyzak, D., Sanders, R. A., Stojanovic, M., Tallmadge, D. H., Ebehart,L., Ewald, D. K., Gruber, D. C., Morsch, T. R., Strothers, M. A., Rizzi, G. P., & Villagran, M. D. (2003). Acrylamide formation mechanism in heated foods. Journal of Agricultural and Food Chemistry, 51, 4782–4787.

[26]. Zhang, Y., Ren, Y. P., Jiao, J. J., Li, D., & Zhang, Y. (2011). Ultra high-performance liquid chromatographytandem mass spectrometry for the simultaneous analysis of asparagine, sugars, and acrylamide in Maillard reactions. Analytical Chemistry, 83, 3297–3304.