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Reduction of Acrylamide Formation In Potato Chips By Gamma Irradiation and Some Pretreatments Processing

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Abstract

This work aims to investigate the effect of gamma irradiation doses (0, 3, 5 and 7 kGy), soaking in citric acid (0.5 and 1%) and calcium chloride ($CaCl_2$) (1 and 2 %) at 30 and 60 min on the formation of acrylamide in potato chips. The treated potato slices were fried at 185 ± 5ºC for 6 -7 min in an electric fryer with palm oil. The untreated potato chips had higher acrylamide content than the treated potato chips. The highest level of acrylamide was found in the samples containing the highest reducing sugars; followed by those contained the moderate level of reducing sugars and the highest level of asparagine. The chemical composition of the chips was determined at zero time and after cold storage at 4 ±1ºC for 30 and 60 days of potato tuber. Furthermore, changes were noted in the percentage of reducing sugars, asparagine content and acrylamide concentration after the cold storage periods. The results showed that the formation of acrylamide depend on the frying condition and chemical composition of the samples in particular on the sugar and asparagine content. Moreover, these results indicated that use of soaking in 2% calcium chloride and 1% citric acid for 60 min may reduce the formation of acrylamide. Meanwhile, irradiation dose at 5 kGy was the best dose for reducing acrylamide formation.

Keywords: Acrylamide. Gamma Irradiation. Asparagine. Reducing sugars. Potato chips.

Introduction

The formation of acrylamide during the frying of potatoes is today one of the main concerns of the agricultural potato processing industry. Fried and baked potato-based foods such as potato chips, French fries, among others are very common all over the world. It was found that when starchy foods like potatoes are fried at high temperatures, certain toxic substances form in these foods. Acrylamide, a known toxic carcinogen, has been detected. **Tareke *et al.*, (2002).** On the other hand, **Mottram, *et al.*, (2002)** presented the formation of acrylamide in starchy foods due to the Millard reaction. They reported that asparagine was the main cause of acrylamide formation in potatoes and cereals. The European Food Safety Authority (EFSA) concluded that the levels of dietary exposure to acrylamide in all age groups indicate a concern due to its carcinogenic effects **(EFSA, 2015).** The European Commission has established mitigation measures in 2017 for the reduction of acrylamide in food and has identified new reference levels for various food categories **(European Commission, 2017).** Regulation 2158/2017 requires food processors and food business operators in Europe to reduce the presence of acrylamide in their products according to the ALARA principle, establishing measures proportionate to the size and nature of the establishments. Potato-based products are one of the main factors contributing to acrylamide exposure **(EFSA, 2015),** and a reference level of 500 µg/kg has been established for ready-to-eat chips **(European Commission, 2017).** Recently, homemade cooking practices for preparing of potato chips from fresh potatoes in Spanish families have reported acrylamide levels twice as high the average estimate of the EFSA report in this food category **(Mesias, *et al.*, 2018).** EFSA experts' opinion stated that the incidence of acrylamide in a domestic environment could increase up to 80% **(EFSA, 2015).** Therefore, the frying practices of families and public food establishments have not been adequately considered in estimating the risk of exposure to acrylamide.

Acrylamide has been shown to be present in a wide range, from low levels in meat and bread products, to much higher levels in potato chips. This preliminary study also showed that temperature and moisture content were key factors in the levels of acrylamide formation **(Burch, 2007).**

Acrylamide has been found mainly in carbohydrate-rich foods. Commercially available foods surveys have shown that levels can vary greatly from one producer to another, and in general, the highest levels were found in potato chips and French fries **(Becalski *et al.*, 2003 and Yusa *et al.*, 2006).**

Acrylamide and its analogues have been widely used since the last century for various chemical and environmental applications and can be formed by heating biological material derived from plant tissues. This compound has previously been identified as a potential industrial hazard, **(Vattem and Shetfy, 2003).** Acrylamide has been shown to be toxic and carcinogenic in animal and has been classified by the International Agency for Research on Cancer (IARC) among others, as probable carcinogenic to humans (**Konings *et al*., 2003).** Considering that acrylamide is classified as a carcinogenic group 2A is detected in common foods prepared or cooked at a temperature above 120°C **(Granda *et al*, 2004).**

Therefore, the aim of present study is to investigate the effect of different pretreatments of calcium chloride $CaCl_2$ and Citric acid at 30 and 60 min on the level of acrylamide in the produced potato chips and the effect of gamma irradiation doses (0, 3, 5 and 7 kGy) as a test to reduce acrylamide levels in fried potato.

Materials and Methods

Potatoes (*Solanum tubersum*), Hermes variety was obtained through 2015 from Agricultural Research Center, Egypt.

Palm oil was obtained from Arma Oil Company [10] th of Ramadan City, Egypt.

Chemicals:

All reagents used for analysis of acrylamide had high purity grade. Acrylamide (99.9%), in addition of syringe filter (0.45 µm. Roth Rotilabo Nylon were purchased from sigma chemical company (USA). HPLC chemicals were obtained from Merck, Alsfelder Str. 19.D. 64289 Darmstadt, Germany. Chloroform, $CaCl_2$, citric acid, acetone, hydrochloric acid and other chemicals were obtained from El Nasr Pharmaceutical Chemicals and El Gamhorya Pharmaceutical Chemicals, Egypt.

Preparation of potato chips:

Eighteen kg's of potatoes samples under investigation were prepared in food irradiation laboratory as follows: whole potato washed in tap water. The potatoes samples were divided into three groups and kept in refrigerator at (4 ± 1°C) after that the potato was peeled with sharp knife, trimmed of undesirable parts and immediately immersed in tap water (25°C). The peeled potatoes were cut into slices (0.2 mm thick) using machine Sue V Pallceders 35010 Masango (PD) made in Italy.

Residual starches on the surface of sliced potatoes were removed with washing water, and excess surface water was removed before weighing **(Kim *et al.,* 2005).** The potato slices portions each 250g, were divided for distribution as one of the treatments and were quickly soaked for 30 and 60 min in one of the following solutions:

1- Calcium chloride (1 and 2%)
2- Citric acid (0.5 and 1%).

The potato tubers were dried for 5 min under forced air flow at room temperature and fried in palm oil in an electric frying pan at 185 ± 5°C for 6 min.

Irradiation process:

Fried potato chips were gamma irradiated at 0; 3; 5 and 7 kGy doses for 38 min by the dose rate 1 kGy per hour using a Russian Gamma Chamber 4000 Cobalt-60 irradiator source.

Methods of Analysis:-

Chemical analysis: Moisture, crude protein, ether extract, ash and fiber of fresh and fried potato chips were determined according to the methods described in **AOAC (2012).** Total carbohydrates were calculated by difference according to the method by **Sharoba and Hassanien (2014).**

The pH of deep-fried potato aqueous extracts was measured according to the method by **Low, *et al.* (2006).**

Total and reducing sugars were determined by Shaffer and Hartman method as described in the **AOAC (2012).**

Asparagine was determined by a High-Performance Liquid Chromatography analysis (Shimadzu HPLC) according to the method described by **Tareke *et al.* (2002).**

Determination of Acrylamide: Preparation of samples and extraction of acrylamide were performed in laboratory and determination was done using HPLC which described by **Vattem and Shetty (2003).**

Sensory evaluation:

Organoleptic evaluation of fried samples was performed by a semi-trained panel of judges using ten-point hedonic-scale ratings for product texture and taste were evaluated under light in a special room with individual booths. Snap was defined as the textural perception at the first bite, while crispness was perceived upon subsequent chewing. Concerning the taste, the product sourness, saltiness and bitterness was evaluated, besides popcorn-like flavour and taste of fried potato. Each of these descriptors was evaluated using a continuous line scale with five anchor points, being 0 (absent), 2.5 (slightly present), 5 (moderately present), 7.5 (strongly present) and 10 (very strongly present). The distance between the origin and the point, indicated by the panelist was measured and standardized to scores between 0 and 10. The product acceptability was also evaluated under light, based on the taste only (‘‘taste appraisal”) and based on both product texture and taste (‘‘overall appraisal”). For this hedonic evaluation, a similar five anchor line scale was used, ranging from zero (dislike very much), over 5 (neither like nor dislike) to 10 (like very much). Consequently, a product with a score above 5 could be considered as acceptable. Water was provided to cleanse the palate in between two tests **Mestdagh *et al.* (2008b).**

Statistical analysis: The obtained data were statistically analyzed by Statistical Package for the Social Sciences (**SPSS, 2011).**

Results and Discussions

Chemical composition of fresh potato:

Chemical composition of fresh potato plays an important role in the formation of the quality of potato tuber, that the characterize product. The results in Table (1) show the chemical composition of hermes potato tubers were moisture 76.86, total solid 23.14, protein 10.34, fat 1.29, ash 3.33 and fiber 7.03 %. These results are agreement with those obtained by **Gumul *et al.*, (2011) and Abboudi *et al.*, (2016).**

Table 1. Chemical composition of fresh potato on dry weight basis (g/100g)

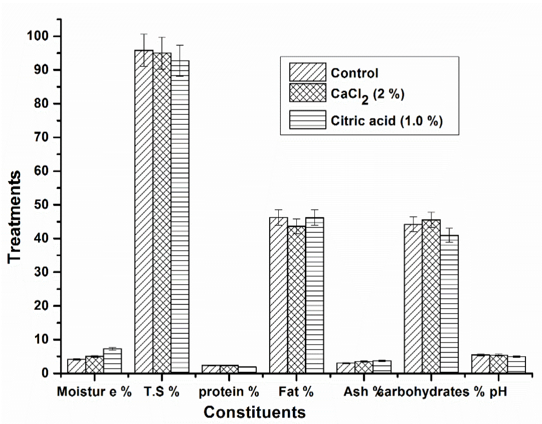
Components	**Values * %**
Moisture	**76.86 ± 0.205**
Total solids	**23. 14**
Protein	**3.31 ± 0.321**
Fat	**1.29 ± 0.292**
Ash	**2.33 ± 0.215**
Fiber	**7.03 ± 0.605**
Total Carbohydrates	**86.04**

*Values are means of evaluations. Means of evaluations having the same letter (s) within a column are not significantly different (P > 0.05).

Impact of soaking in solutions on the chemical composition of fried potato chips after cold storage at 4 ± 1ºC for 30 and 60 days of potato tubers:

During deep fat frying process, product is exposed to high temperature, which affect on the chemical composition and pH value. Therefore, it is important to evaluate the changes in chemical composition and quality characteristic of the chips. During storage periods, notice from the results in Fig (1-2). It could be concluded that cold storage was increased the moisture content while; the protein content was slightly decreased as the storage period increased with all samples. This result indicates that there is detectable effect of cold storage of potato on fat and pH content of potato chips there was a slight increase of fat content on potato chips might due to degradation of tissue of potato tubers. This data agreed with **Mestdagh *et al.* (2008a)** who reported that organic acids, such as citric acid reduced the final acrylamide content, but merely due to a reduced pH. The control sample had significantly differed with the highest fat content. While, the potato chips which soaking in $CaCl_2$ has the lowest fat content. The differences between the chips samples in fat content may be due to the soaking in $CaCl_2$ that decrease oil uptake during frying.

This result are agreement with **Mestdagh *et al.* (2008b)** who found that soaking in $CaCl_2$ reduction acrylamide formation, although decreased oil uptake.



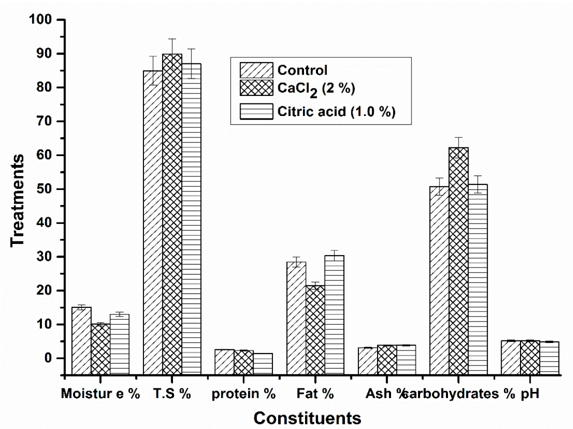


Fig. (1-2): Chemical characteristics of fried potato chips after cold storage of potato tubers at 4 ± 1ºC for 30 and 60 days (% on dry weight basis).

Impact of soaking in solutions on reducing sugars, asparagine and acrylamide levels in potato chips at zero time and after cold storage at 4 ± 1ºC for 30 and 60 days of potato tubers.

Fig. (3 ,4 and 5) showed the effect of soaking solutions and influence of time of potato after frying on the level of reducing sugars, asparagine (mg/g) and formation of acrylamide (µg/kg) in potato chips during deep- fat frying. The data in zero time are a significant differences in reducing sugars, asparagine (mg/g) and formation of acrylamide (µg/kg) of soacked samples in $CaCl_2$ 2 % were lower than socked samples in citric acid 1 % for 60 min, while the control sample had the highest amount of reducing sugars, asparagine (mg/g) and formation of acrylamide (µg/kg) respectively, this may be due reduction of acrylamide by soaking in $CaCl_2$ and citric acid. Our results are in agreement with **Acar *et al.* (2012)** who found that used of $CaCl_2$ can reduce acrylamide formation up to 7.0%. Moreover, **Biedermann *et al.* (2002)** and **Gökmen *et al.* (2007)** found that reducing sugar concentration has a strong correlation with the amount of acrylamide formation upon frying potatoes. The same Fig. (3, 4 and 5) show that the best concentration and time of soaking for reducing of acrylamide with $CaCl_2$ 2 % and citric acid 1 % for 60 min.

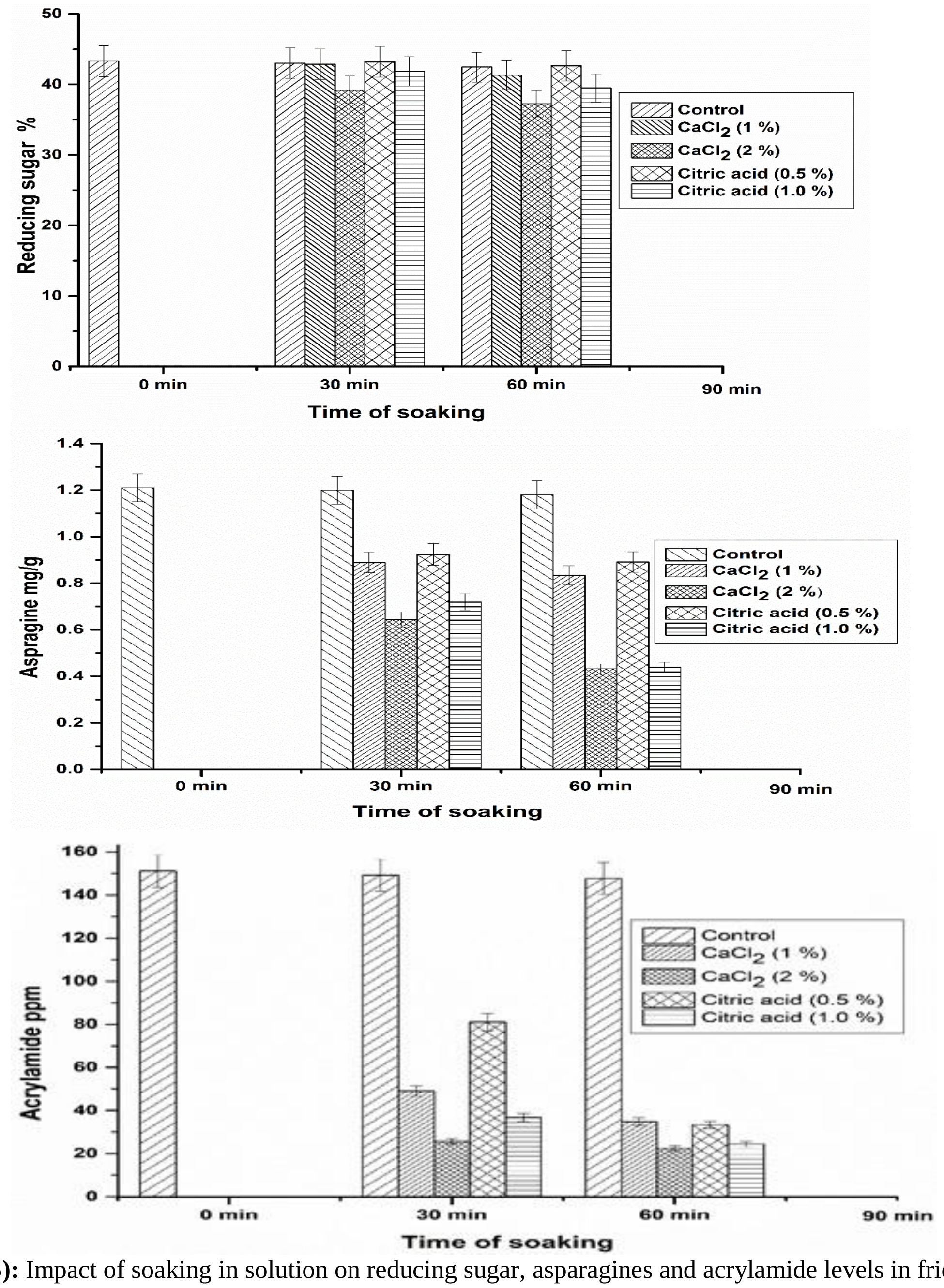


Fig. (3-5): Impact of soaking in solution on reducing sugar, asparagines and acrylamide levels in fried potato chips at zero time.

From data in Fig (6,7). It could be seen that, the levels of reducing sugar in fried potato chips were (37.68, 36.87 and 37.26.) and (39.91, 34.81 and 37.21) While, the levels of asparagine were (0.941, 0.128 and 0.132.) and (0.089, 0.069 and 0.080). Also, the acrylamide levels were (69.04, 12.16 and 25.89) and (27.91, 25.77 and 26.45) for control sample, $CaCl_2$ and citric acid, respectively during cold storage periods for 30 and 60 days. There was presumably from the breakdown of starch and increase of total sugars with increased storage period **(Al-Oaksh, 1985** and **Halford *et al.* 2012)** who reported that there were other interesting differences in the relationship between sucrose and reducing sugars. Differences in activities of invertase, the other sucrose cleavage enzyme, sucrose synthase, and the sucrose synthesis enzymes sucrose phosphate synthase and sucrose phosphate phosphatase are the likely explanation for these differences.

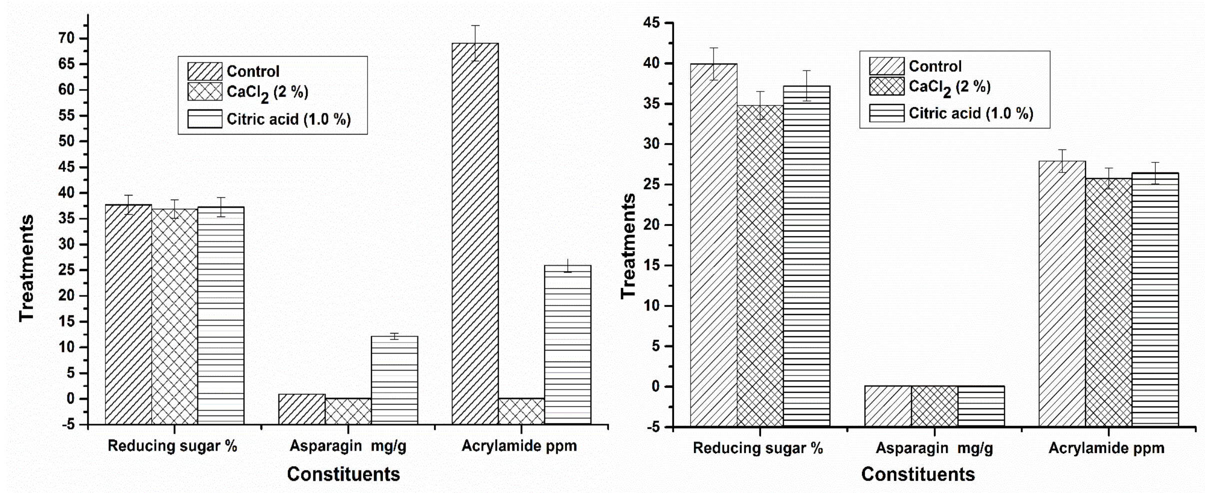


Fig. (6-7): Impact of soaking in solution on reducing sugar, asparagine and acrylamide concentration in fried potato chips after cold storage of potato tubers at 4 ± 1ºC for 30 and 60 days.

Effect of gamma irradiation on the chemical composition of potato chips after cold storage at 4 ± 1ºC for 60 days of potato tubers.

The results in Fig. (8) Evident that was detectable difference in the moisture and fat content of potato chips between un-irradiated and irradiated samples. Moisture, fat and carbohydrate content of irradiated samples were (20.17, 26.32, 67.63), (19.59, 22.25, 71.51**)** and (21.48, 25.74,` 67.35) for doses 3, 5 and 7 kGy, respectively while moisture and fat content in un-irradiated sample was 15.05, 28.44 and 65.81, respectively. **(Beverly, *et al.* 2018).**

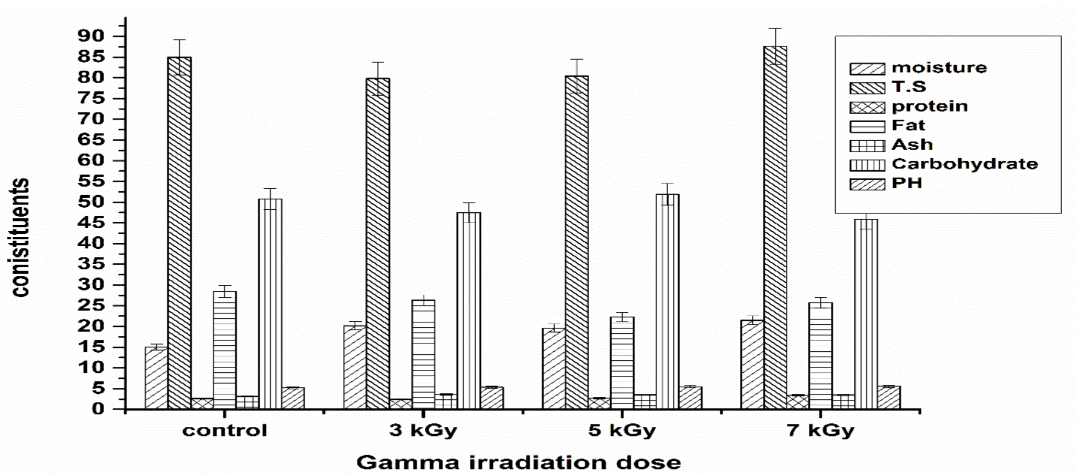


Fig. (8): Chemical composition of fried potato chips after cold storage of potato tubers at 4 ± 1ºC for 60 days.

Gamma irradiation was increased the moisture and fat content of potato chips this might due to the acquisition of moisture during the period of irradiation. A slight difference in T.S % of all potato chips samples after irradiated. While, these data indicate that no difference in protein, ash and pH content in chips between un-irradiated and irradiated samples.

Impact of gamma irradiation on reducing sugars, asparagine and acrylamide concentration in fried potato chips after cold storage at 4 ± 1ºC for 60 days of potato tubers.

The influence of irradiation treatments for produced potato chips on levels of reducing sugars is presented in Fig. (9) It declared that, the levels of reducing sugars in fried potato chips were 39.91, 38.57, 37.44 and 37.21 % while the levels of asparagine were 0.089, 0.040, 0.033 and 0.028 mg/g for samples of control, 3, 5 and 7 kGy, respectively **(Yaliyang, *et al.*, 2016).**

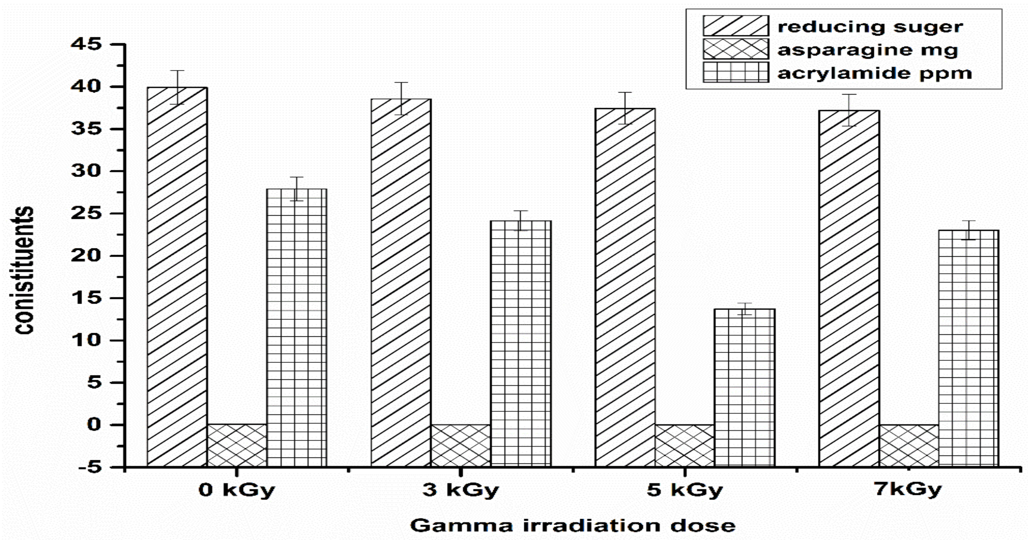


Fig. (9): Effect of gamma irradiation of reducing sugars, asparagines and acrylamide concentration in fried potato chips after cold storage of potato tubers at 4 ± 1°C for 60 days.

A detectable effect of gamma irradiation on reducing acrylamide by different doses while the concentration of acrylamide (27.91) of control sample decreases to (24.16, 13.16 and 23.04 ug/kg) for doses 3,5 and 7 kGy, respectively. The best dose for reducing acrylamide was 5 kGy. These results are in agreement with **Fan and Mastovska (2006)** who found that the increased dose from 0 to 1.5 kGy, decreased acrylamide in water from 1000 ug/mL to approximately 20 ug/mL, as percentage a 98% reduction. On the other hand, in foods with limited water content, irradiation at different doses not cause significant changes in nutrition value and will have little effect on acrylamide levels.

Impact of gamma irradiation on the sensory evaluation of potato chips.

Data in Table (2) show the irradiated chips at dose 5 kGy had high scores for all characteristics compared with irradiated chips at doses 3 and 7 kGy. This may be due to decreasing oil uptake, crispy texture and brighter color of chips treated by 7 kGy. **(Mulla *et al.* (2011).**

Table 2. Impact of gamma irradiation on the sensory evaluation of potato chips.

Property	Texture		Taste					Odor	Surface	Overall
Treatments	Snap	Crispness	Potato	Sour	Salt	Bitter	popcorn	appraisal	color	appraisal
Control	8.10 ^{a} ± 0.25	8.5 ^{a} ± 0.21	9.75 ^{a} ± 0.48	9.89 ^{a} ± 0.41	9.95 ^{a} ± 0.41	9.13 ^{a} ± 0.11	9.79 ^{a} ± 0.20	8.85 ^{a} ± 0.41	8.93 ^{a} ± 0.65	9.25 ^{a} ± 0.68
3 kGy	7.94 ^{a} ± 0.25	7.81 ^{a} ± 0.20	9.57 ^{a} ± 0.30	9.85 ^{a} ± 0.15	9.88 ^{a} ± 0.25	9.10 ^{a} ± 0.15	9.77 ^{a} ± 0.21	8.79 ^{a} ± 0.25	8.65 ^{a} ± 0.58	8.85 ^{a} ± 0.58
5 kGy	7.83 ^{a} ± 0.15	7.54 ^{b} ± 0.15	9.48 ^{a} ± 0.14	9.88 ^{a} ± 0.25	9.87 ^{b} ± 0.15	8.96 ^{a} ± 0.18	7.80 ^{a} ± 0.15	8.75 ^{a} ± 0.18	8.88 ^{a} ± 0.28	8.55 ^{a} ± 0.40
7 kGy	7.41 ^{a} ± 0.20	7.20 ^{b} ± 0.25	9.44 ^{a} ± 0.09	9.87 ^{a} ± 0.17	9.85 ^{a} ± 0.35	8.99 ^{b} ± 0.15	9.98 ^{a} ± 0.21	7.68 ^{a} ± 0.17	7.89 ^{b} ± 0.29	7.68 ^{b} ± 0.51
LSD *	**0.83**	**0.81**	**0.75**	**0.64**	**0.66**	**0.64**	**0.77**	**0.72**	**0.80**	**0.89**

* LSD = least significant difference at 0.05.

Conclusions

It was concluded that the soaked potatoes in 2% $CaCl_2$ or 1% citric acid for 60 minutes showed an important effect in reducing the formation of acrylamide during frying. Additionally, radiation treatment has an effective effect in reducing acrylamide after formation during frying; the irradiation at 5 kGy was the best dose to reduce acrylamide. Furthermore, the irradiated chips at the same dose had high scores for crispy texture and brighter color of compared to control and irradiated chips at 3 and 7 kGy doses.

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خفض تكوين الأكريلاميد في شيبسى البطاطس المصنعة باستخدام أشعة جاما وبعض المعاملات الأولية

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يهـدف هذا البحـــث إلى دراسة تأثير أشعة جاما وبعض المعامــلات الأولية بالنقع قبل القلى لشرائح البطاطس فى محاليل من كلوريد الكالسيوم (1 و 2 %) أو حامض الستريك بتركيزات (0,5 و1%) ومدة نقـع (30 أو60 دقيقه) وكذلك تم دراسه تأثير المعاملات الإشعاعــية بجرعـات (0 ، 3 ،5 ، 7 كيلوجراى) وذلك لخفض محتوى الاكريلاميد فى رقائق البطاطس. تم تجهيز رقائق البطاطس و قليها تحت ظروف المعمل باستخدام زيت النخيل على درجة حرارة 185 ± 5 ° م لمدة 6–7 دقيقة وقد أظهرت النتائج أن المعاملة بالنقع في كلوريد الكالسيوم بتركيز 2% وحامض الستريك بتركيز 1 % لمدة 60 دقيقة أدت إلى خفض كل من السكريات المختزلة والاسبراجين وكانت لها دور كبير في خفض مستويات الاكريلاميد المتكونة. وأظهرت النتائج أيضا أن المستويات الأعلى منه وجدت في العينات المعاملة بحامض الستريك بتركيز 1 % لمدة 60 دقيقة وكانت أقل المستويات في العينات المعاملة بكلوريد الكالسيوم بتركيز 2% لمدة 60 دقيقة. كذلك تم دراسة تأثير أشعه جاما و معاملات النقع المختلفة على الخواص الحسية للبطاطس المقلية وقد أوضحت النتائج أن المعاملة بالنقع فى محلول كلوريد الكالسيوم بتركيز 2 % لمدة 60 دقيقه لها تأثير واضح وجيد فى تحسين الصفات الحسية للبطاطس المقلية مما أدى الى تفوق البطاطس المعاملة بالنقع فى كلوريد الكالسيوم فى الصفات الحسية بالمقارنه بعينات المقارنة أو التى تم معاملتها بالنقع فى حامض الستريك. وكذلك كانت المعاملة بالإشعاع بجرعة 5 كيلوجراى هى الأفضل.