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EFFECT OF SOME PRETREATMENTS ON REDUCING ACRYLAMIDE CONTENT OF FRIED POTATO CHIPS

Ramadan, Afaf –haniem, M.* and Rania E. El-gammal**

*** Home Economic Dept., Fac. of Specific Education, Mansoura Univ., Egypt**

**** Food Industries Dept ., Fac. Agriculture , Mansoura Univ., Egypt.**

ABSTRACT

Reduction of acrylamide formation in potato chips in the relation of frying temperature and different pretreatments before frying was studied.

Potato chips were fried at 140°C and 160 °C for 7 min. , with different pre treatments prior to frying such as :Blanching at 100°C for 5 min ; immersing in water and different solutions for 10 min : water as control at 25 °C ,warm water at 40°C and hot water 90°C , Electrolytic salt solutions : $Cacl_2$ and $Nacl_2$; organic solutions; citric and acetic acids , the concentration of solutions was 10g/ l at 90 °C . Results of HPLC indicated that potato chips blanched at 100 °C for 5 min. had the lowest acrylamide content 13.2±0.91and 51.5±2.71 µg/ kg when compared with control potato chips and other treatments at 140° and 160 °C . Immersing in organic acids solutions namely citric and acetic acid and electrolytic salt solutions like $Cacl_2(Ca^{2+})$and $Nacl(Na^{1+})$ lowering the acrylamide content in potato chips fried at 140°C and 160 °C in compare with potato chips immersed in, water at 40, 90°C and 25 °C (control). Immersing potato chips in $Cacl_2$ 10g/ l for 10 min. caused a highly considerable reduction in acrylamide (88.96 and 75.28 %) at 140 °C and 160°C respectively. A considerable decrease in reducing sugar % was observed in all fried potato chips at 140 °C for 7 min. in compare with those fried at160 °C .

Pre frying treatments were improved the sensory properties namely colour , taste, odour, crisps and oil uptake for all potato chips fried at 140°C and 160°C except color for potato chips immersed in acetic and citric acid solutions . From , healthy safe quality point of view all tested pretreatment fried potato chips at 140° and 160°C were ranged in the legal permissible level of acrylamide (21-140 µg/ kg / day) of body weight 70 kg according to WHO(2005). So, It could be concluded that pre frying treatments (immersing in different solutions, temperature and pH) had a clear inhibitory effect on the acrylamide content and formation in potato chips during frying at 140°C and 160°C and these results are within the safety legal limit of acrylamide .

keywords: potato chips, reducing sugar , pH, Acrylamide content, Sensory evaluation .

INTRODUCTION

Frying is widely used cooking method that create unique textures and flavours in foods . Potatoes (*Solamun tubersum*) one of the most major crop in the world, is consumed daily by millions of people from diverse cultural .

In April 2002, Swedish researchers shocked the food safety world when they presented primary findings of acrylamide in some fried and baked foods most notably potato chips and french fries at the level of 30-2300µg/kg (Rosen and Hellenäs 2002).

Acrylamide is an industrial chemical material used in the manufacture of poly acrylamides, and has also been detected in a wide range of foodstuffs at relatively high concentrations. It is formed during the frying, roasting or baking of a variety of foods, particularly starchy foods such as potatoes and

cereal products. Food scientists worldwide have been concerned about the presence of acrylamide in food, because of its toxicity. (Hanley *et al* ., 2005).

Possible health effects of acrylamide in food have been its carcinogenicity and genotoxicity (DNA-damaging effects). It causes tumors in laboratory rats, although there is no definitive evidence that exposure to acrylamide in food causes cancer in humans. It has also been shown to be neurotoxin in humans and may affect reproductive processes. A number of national and international agencies have carried out risk assessments on acrylamide in food and have concluded that efforts should be made to reduce levels to as low as possible (Jose *et al* ., 2006). Further more the concentration of acrylamide formation within carbohydrates rich fried potato has become of great interest due to acrylamide classification as a cancer suspect agent (Ou *et al.*, 2008) .

This work is a trial for reducing and lowering acrylamide content and formation in fried potato chips using some pretreatments which can be easily applied on home and industrial scale.

MATERIALS AND METHODS

Materials

Potato tuber (*Solanum tuberosum L.*) variety *Spunta* were obtained from Horticultural Research Center Institute , Agricultural research center, Giza, Egypt Palm oil were purchased from Misr Oil and Soap Company ,El-Mansoura - Egypt

Chemicals: Nacl , $Cacl_2$,Citric acid and Acetic acid were obtained from El-Gomhoria for Chemicals Company, Mansoura, Egypt

Pretreatments:

Potato were washed , peeled in distilled water , then chopped into uniform pieces using domestic knife in order to perform each frying experiment .

Firstly, potato chips were rinsed after chopping for 1 min. in distilled water to eliminate some starch material adhering to the surface prior to frying. Then potato chips were immersed in water and different solutions for 10 min. with the concentration of 10g/l . As followed:

Electrolytic Salt solutions: $Cacl_2$ and Nacl, acidifier solutions citric and acetic acids. Distilled water (25° C) control treatment , warm water at 40 °C and hot water 90° C .

Finally, blanching was accomplished by soaking potato chips at 100 °C for 5 min.. (Pedereschi *et al* ., 2007) .

Frying conditions: All potato samples were fried in domestic fryer model (Arion at 140° C and 160°C for 7 min. , Fried potato were drained after frying over a wire screen for 5 min and to allow to cool .

Methods :

- **pH measurement :** according to A.O.A.C (2000) using pH meter model Jenway 3505 .U.K.
- **Reducing sugar%** : were determined according to (Ranganna1977) at Chemistry Dept., Faculty of Agriculture , Mansoura university, Egypt.

- **Acrylamide Content Extraction and analysis of acrylamide of fried potato:** was carried out in Central Laboratory of Higher Institute for Public Health, Alex University, using Shimadzu HPLC CRA Chromatography PAC, mobile phase 0.1 % acetic acid: methanol 0.5%, wave length: 230nm, Injection volume 30 µl , Colum rate 1ml/ m.
- **Reduction of acrylamide content %** were calculated according to (Allam, 2008) as following equation :

$$\text{Reduction of AA \%} = \frac{AAT - AAC}{AAC} \times 100$$

AAT= Acrylamide content in treatment
AAC= Acrylamide content in control

- **Sensory Evaluation:** Fried potato chips with different pretreatments were served warm and examined for sensory properties and results were expressed as a mean of 10 panel testers (Watts *et al.*, 1989) .

Statistical Analysis:

Values represented are the means and standard error , significance was used at $p.\leq 0.01$and $p\leq 0.05$,(ANOVA) was done using SPSS 17 program for windows.According to SPSS, (2007).

RESULTS AND DISCUSSIONS

Influence of different pretreatments on reducing acrylamide formation in potato chips fried at 140°C and 160°C.

Influence of pH:

Data in Tables 1 , 2. Describing the acrylamide content as a function of pH was used to evaluated the mitigation of acrylamide content due to the addition of different food additives were merely attributed to the pH .

Citric acid was the most acidifier additives, followed by acetic acid these solutions lowering the pH from 7 in control treatment to 3.7 and 4.5 respectively.

Table (1): pH , Acrylamide content µg/kg and Reducing acrylamide % of fried potato chips at 140 °C for 7 Min.

Pretreatments Immersing in solutions :	pH	Acrylamide content (AA) µg/kg	reducing of acrylamide%
1-control(C)	7.0	1922±2.32	----
2-warm water (W.W)	7.0	890*±2.19	53.69
3-hot water (H.W)	7.0	723*± 4.88	62.38
4-$Cacl_2$	4.5	212*± 1.88	88.96
5- Nacl	6.0	515*±4.22	73.20
6- citric acid (C. acid)	3.7	618*± 6.81	67.84
7- Acetic acid (A. acid)	4.5	612*±5.19	68.15
8- Blanching(B)	7.0	13.2 *± 0.91	99.15

***Significant differences at p < 0.05 . Means of triplicates samples results± SE .**

$Cacl_2$ is already used as firming agent in fruit , vegetable processing. Concerning the data of pH in table 1 and 2 , it revealed that $Cacl_2$ significantly lowering the finial acrylamide content , the reduction due to

decrease pH as the result of Ca $^{2+}$ with pectin this lead to mitigation of acrylamide up to 88%. In compared to control fried potato. Cations such as Ca $^{2+}$ would also change the reaction path from the Millar reaction toward dehydration of glucose, at low pH aspargine is more prone to react electrophillis , for instance aldhydes groups in carbohydrates resulting in sciff base formation the intermediate product in Millard reaction (Mesldagh *et al.*, 2008b and Serpen, and GÖkmen 2009)).

Table (2): pH , Acrylamide content µg/kg and Reducing acrylamide% of fried potato chips at 160 ˚C for 7 Min.

Pretreatments Immersing in solutions :	pH	Acrylamide content (AA) µg/kg	reducing of acrylamide%
1-control(C)	7.0	1922 ±2.32	----
2-warm water (W.W)	7.0	990* ±1.96	48.49
3-hot water (H.W)	7.0	748 *±3.17	61.08
4-$Cacl_2$	4.5	475*±2.50	75.28
5- Nacl	6.0	530*±6.61	72.42
6- citric acid (C. acid)	3.7	677*±3.18	64.77
7- Acetic acid (A. acid)	4.5	650*±2.19	66.18
8-Blanching (B)	7.0	51.5*±2.71	97.32

***Significant differences at p < 0.05 . Means of triplicates samples results± SE**

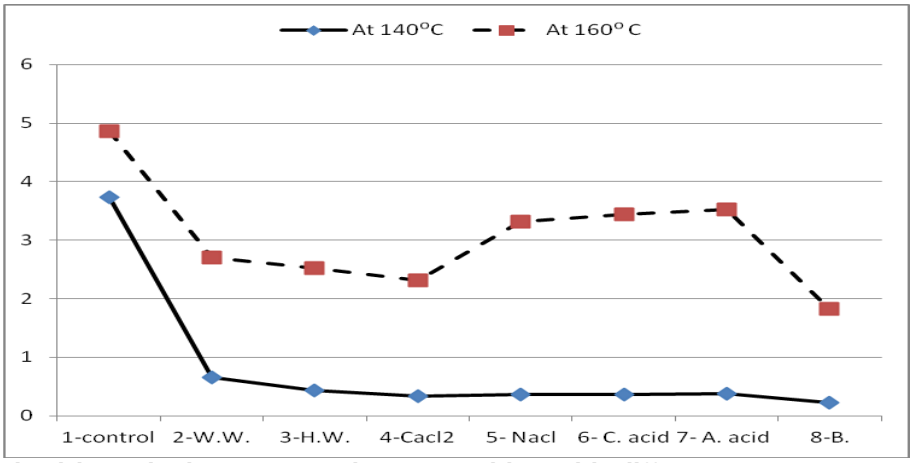

Fig. (1): Reducing Sugar % in potato chips with different pretreatments after 140˚C and 160 ˚C for 7 Min.

Immersing in water (warm and hot)

Data in Tables 1 and 2 indicated that immersing in distilled water at 25˚C (control treatment) for 10min prior to frying caused some loss in potato chips, while immersing in hot water at 90˚C showed an observed reduction in acrylamide to 723±4.88,and 748±3.17 µg/kg t 140˚C and 160˚C respectively in fried potato chips in compare with control from 1922±2.32 µg/kg .

Concerning the results in the same table it was observed that, low frying temperature at 140˚C decreased the content of acrylamide, also, immersing potato chips in hot water at 90˚ C could reduced acrylamide

content % to 62.38 and 61.08% in fried potato at 140°C and 160° C respectively.This may be due to hot water removes some soluble starch particles from the upper layer which being a precursor for Millard reaction (pedreschi *et al.*, 2004)

These results are nearly in accordance with (Jung *et al.*, 2003) who reported that dipping in hot water for 20 min. induced most of 25 % reduction of acrylamide formation .

Immersion in $Cacl_2$ and Nacl :

The current results in Table 1 and 2 revealed that the pretreatment prior to frying in $Cacl_2$ and Nacl solutions individually at 90^0C for 10 min. were more effective in inhibiting acrylamide formation , especially immersing in $Cacl_2$ at 10 g /l . The same trend of acrylamide reduction % were also observed in potato chips immersing in $Cacl_2$ and Nacl which were 88.96 , 73.20 and75.28, 72.42 % in fried potato chips at 140°C and 160 °C respectively.

The acrylamide inhibiting mechanism for calcium may be due to its complexation with amines and some intermediates or the Millard reaction products especially acrylic acid ,a prevalently recognized precursor for forming acrylamide (Delgado *et al* ., 2004 , Allam *et al* ., 2008 and Ou *et al.*, 2008)

Also, divalent Cations Ca^{2+} was more effective than the monovalent Cations Na^{1+} as regard to the amount of the acrylamide formation in fried potato chips (pedreschi *et al.*,2010)

Also, immersing potato chips in 10g／l Nacl solution for 10 min. was effective in reducing acrylamide up to 73.2% , while immersing in hot water reduced up to 62%, So, the difference 11.2% could be attributed to the effect of Nacl . Results suggests that immersing in Nacl could produced some changes in the microstructure of potato tissue that make easier the diffusion of Nacl which produces some kind of inhibition in acrylamide content .(Perdreschi *et al.*, 2010) . Also, Feridman and Levin (2008),stated that the inhibitory effect of salts is relate to the ionic or the electronic associations of the Cations with asparagine suppressing the early stage of Millard reactions and the ionic strength induced by Na+ ions affects the rate of addition reactions of amino groups of amino acids in the double bonds of vinyl compounds like acrylamide .

So, the inhibition of acrylamide formation during frying was mainly attributed to the presence of mono and divalent cations in potato chips after the soaking treatments rather than the reduction of acrylamide content precursor by the soaking only . (GÖkmen and Senyuva2007)

Immersing in acidifier solutions (citric and acetic acids):

The effect of immersing fried potato chips in citric and acetic acids (10g /l for 10 min.) on acrylamide formation was studied.

Results in Tables 1 and 2 Showed that acrylamide content in potato chips immersed in citric acid solution and fried at 140°C was 618±6.18 µg/kg and 677±3.18 µg/kg in potato chips fried at 160° C for 7 min. Also, addition of these acids decreased the pH of solution from 7 in control solution to 3.7

and 4.5 after being in citric and acetic acid solutions which have a direct effect on reducing acrylamide content .

Concerning the data in Table 1and 2 of immersing potato chips in citric acid solution . This treatment caused a considerable reduction in acrylamide formation . The decrement effect of immersing in citric acid may be related to the lowering of the surface pH value there by causing aspargine (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 reaction (Mestdagh *et al* ., 2008 a and Hanley *et al.*,2005)

Blanching

Results in Tables 1 and 2 showed the effect of blanching potato chips at 100° C For 5 min. on acrylamide content .

Blanching process prior to frying was an effective pretreatment, in reducing both of acrylamide content and reducing sugar % . (Fig .1)

Blanching process reduced acrylamide content with 13.2 and 51.5 µg/kg respectively in potato chips fried at 140 and160°C for 7 min.

Blanching of potato chips fried at140°C resulted in the lowest level of reducing sugar % which was 0.2 % in compare with control sample 3.7 % and other pretreatments . (Fig .1)

In general blanching removes much more glucose and aspargine from the potato chips than, the water soaking treatment consequently leading to lower acrylamide formation in fried potatoes (Pedreschi *et al* ., 2007).

Our results are in accordance with Mäthaus *et al* ., 2004 who reported that a reduction of the reducing sugar by blanching could reducing the acrylamide concentration of about 60% according to the raw material (potato and field site) and the production process variable namely, blanching conditions and frying temperature .

Healthy safe limit and the daily intake from acrylamide in potato chips on consumption of 100 gm from the potato chips.

Healthy safety quality of fried potato chips was evaluated for acrylamide formation and the possible daily intake of these compounds were estimated Table 3. From obtained results in table 3 ,When the maximum level of acrylamide base on consumption 100 gm ,the fried potato chips should be treated before frying process with different pretreatment namely blanching , soaking in $Cacl_2$, Nacl ,Acetic acid and Citric acid for reducing the content of acrylamide during frying at high temperature 140°C. and 160°C.

So, These pretreatments could inhibit the acrylamide up to 1.92 µg/100g While the average of dietary intake estimated to be up to 35 µg/kg body weight 70 kg in Sweden , and World Health Organization estimate a daily intake of dietary Acrylamide in the range of (21-140 µg/100 g)for the general population (body weight 70kg . (EL-saied *et al.*, 2008; WHO, 2005 and Sevensson *et al.*, 2003). According to data stated by FDA 2004, daily intake of acrylamide from potato chips or crisps for children of age (2-5 years) was 1.26 µg/kg body weight / day. Table 3 .

These means that estimated acrylamide in samples with different pretreatments are quite safe for children except fried potato chips immersing in warm water.

Table (3): Healthy safe limit and the daily intake from acrylamide of all fried potato chips under investigation.

frying temperature / Pre treatments Immersing in :	Acrylamide content (µg/100 g.) in fried potato chips with maximum permissible level(WHO, 2005).* Acrylamide content (µg /30 g.) in fried potato chips with maximum permissible level (FDA ,2004).**					
	Potato fried at 140° C	Status*	Status**	potato fried at160° C	Status*	Status**
1-control	192.2	+	+	192.2	+	+
2-warm water	89.0	-	+	99.0	-	+
3-Hot water	72.3	-	-	74.8	-	-
4-$Cacl_2$	21.2	-	-	47.5	-	-
5- Nacl	51.5	-	-	53.0	-	-
6- citric acid	61.8	-	-	67.7	-	-
7- Acetic acid	61.2	-	-	65.0	-	-
8-Blanching	1.32	-	-	5.15	-	-

- ***maximum permissible level WHO,(2005) at range of (21-140 µg/100 g)for the general population (body weight 70kg).**
- **** permissible level FDA,(2004) 1.26 µg /30 g)for children of age(2 -5) years.**

(+) : more than the permissible limit (-) : less than the permissible level

Sensory evaluation:

Sensory evaluation data are showed in Tables 4 And 5, .The results showed that immersing potato chips in different solutions enriched the fried potato before frying at 140° C and 160°C statically different from the control regarding to tested attributes that included taste, colour , odor, crisps and oil uptake

The obtained results also, in tables 5 and 6. Showed that Blanching could improved colour, taste ,texture and crisps of potato chips and also reduced their oil uptake this may be due to that blanching of potato could leach out and reducing sugar from the tissue before frying process . and low reducing sugar content are required to minimize colour development during frying . (Pedreschi *et al* ., 2005)

Except for the potato samples immersed in acetic acid at the concentration of 10 g/l for 10 min .which had low scores of colour in comparison to the one with the best scores this was in accordance with Stadler 2002 and perdreschi *et al.*, 2004 who reported , that the formation of acrylamide in food that is closely linked to the formation of desirable properties such as colour , because of Millard reaction is favorable by conditions of high temperature and (Pedreschi *et al* ., 2005) stated that immersing potato chips in acidic solution bedside the higher frying temperature 160°C ,get the fried potatoes more dark and accelerate enzymatic browning reactions at highly temperature dependent .

It is important to note that immersing in $Cacl_2$ has a specific effect on taste and crisps often acceptable by panel testers (Mesldagh 2008 a) .

However using blanching process enriched all tested properties of fried potato at 140° C and 160°C for 7 min . So, blanching and immersing potato chips in different solutions in potato chips are very attractive for the food

industry ,which has to cope with increasing consumer demands for variety and healthier food choice.

Table (4): sensory evaluation of fried potato chips at 140°Cfor 7 min .

Characteristics Pretreatments Immersing in solutions :	Taste (10)	Colour (10)	Crisps (10)	Odour (10)	Oil Uptake (10)
1-control	8.51**± 2.28	8.54**±0.16	8.21**±0.12	8.32**±0.13	8,76**±0.14
2-warm water	9.41**± 0.18	9.40**±0.32	9.30**±0.13	9.40**±0.15	9.46±0.24
3-hot water	9.52 **±0.13	9.50**±0.19	9.43**±0.14	9.34**±0.16	9.48**±0.24
4-$Cacl_2$	9. 54**±0.24	9.65**±018	9.45**±0.16	9.44**±0.17	9.43**±0.23
5- Nacl	9.30**±0.12	9.33**±0.13	9.43**±0.14	9.34**±0.17	9.60**±0.51
6- citric acid	9.20**±0.13	9.14**±0.15	9.11**±0.13	9.25**±0.61	9.33**±0.13
7- Acetic acid	9.43**±0.14	9.23**±0.14	9.21**±0.14	9.11**±0.12	9.21**±0.12
8-Blanching	9.80**±0.12	9.54**±0.11	9.85**±0.17	9.57**±0.14	9.61**±0.14

** **Significant differences at p ≤ 0.01.**

Table (5): sensory evaluation of fried potato chips at 160°Cfor 7 min .

Characteristics Pre treatments Immersing in solutions	Taste (10)	Colour (10)	Crisps (10)	Odour (10)	Oil Uptake (10)
1-control	7.51**± 0.19	7.92**±0.33	8.50**±0.43	8.63**±0.45	8.52**±0.14
2-warm water	8.61**± 0.18	8.89**±0.24	8.81**±0.19	8.00**±0.13	8.77**±0.12
3-hot water	8.22** ±0.13	9.07**±0.18	9.56**±0.15	9.33**±0.16	9.01**±0.13
4-$Cacl_2$	9.10**±0.12	9.04**±0.18	9.21**±0.14	9.24**±0.23	8.07**±0.14
5- Nacl	9.10**±0.12	9.01**± 0.12	9.00**±0.12	9.00**±012	9.01**± 0.15
6- citric acid	8.78**±0.13	7.50**±0.14	8.32**±0.19	8.43**±0,12	9.02**±0.32
7- Acetic acid	8.50**±0.12	7.40**±0.24	8.54**±0.18	8.54**±0.21	9.01**±0.14
8-Blanching	9.71**±0.21	9.00**±0.18	9.55**±0.24	9.07**±0.61	9.03**±0.34

** **Significant differences at p ≤0.01**

Conclusion

The pretreatments of potato chips appear to have great potential to reduce acrylamide formation. For all pretreatments, acrylamide formation significantly diminished at p ≤ 0.01 as the frying temperature decreased from140° C and 160 ° C.

Addition of $Cacl_2$ and organic acid gave significant acrylamide reductions due to lowering pH by pinding divalent ions to asparagines in order to prevent sciff base formation which played a basic role in the formation of acrylamide .

Pre treatments such as blanching or soaking reduce the amount of acrylamide precursors or reducing pH . These pretreatments were intended to make the media less favorable for acrylamide formation.

Blanching was an effective pretreatments which lead to a significant p<0.05 reduction of acrylamide formation

Immersion potato chips in hot water decreased the acrylamide formation with non significant reducing sugar .

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تـاثير بعـض المعـاملات الاوليـة علـي تقليـل محتـوي الاكريلاميـد فـي البطـاطس الشيبس المحمرة .

عفاف هانم محمود رمضان* و رانيا ابراهيم الجمال**

*** قسم الاقتصاد المنزلي- كلية التربية النوعية –جامعة المنصورة- مصر.**

**** قسم الصناعات الغذائية – كلية الزراعة- جامعة المنصورة- مصر .**

اجريت هذه الدراسة لتقليل محتوي الاكريلاميد في عينات البطاطس الشيبس المحمرة وعلاقة كلا منها بدرجات حرارة التحمير والمعاملات الاولية المختلفة قبل عملية التحمير .

البطاطس المحمرة علي درجة حرارة ١٤٠ و ١٦٠°م لمدة ٧ دقائق والمعاملة بمعاملات اولية مختلفة قبل عملية القلي كالسلق في الماءالمقطر ١٠٠م / ٥ق والغمر في الماء والمحاليل المختلفة التالية لمدة ١٠ دقائق : ماء مقطر علي درجات حرارة ٢٥° م (كنترول) و ماء دافي٤٠م و

الماء الساخن ٩٠° م و محاليل ملحية الكتروليتية كلوريد الكالسيوم وكلوريد الصوديوم و محاليل عضوية حمض الستريك وحمض الخليك بتركيز ١٠ جم / لتر علي درجة ٩٠ °م .

وكانت اهم النتائج كالتالي :

اظهرت نتائج تحليل جهاز HPLC الكروماتوجرافي عالي الاداء ان اعلي انخفاض لمحتوي الاكريلاميد في عينات بطاطس الشيبس المحمرة علي درجتي ١٤٠° م و١٦٠° م والمعاملة بالسلق /١٠٠°م / ٥ق كان ١٣,٢ و ٥١,٥ ميكروجرام / كجم علي التوالي مقارنة بعينات الكنترول والمعاملات الاخري .

المعاملة بالغمر في المحاليل العضوية كمحلول حامض الستريك والخليك و المحاليل الملحية الالكترولتية مثل كلوريد الكالسيوم (كاتيونات الكالسيوم) وكلوريد الصوديوم (كاتيونات الصوديوم) ادت الي انخفاض محتوي الاكريلاميد في كلا من عينات الشيبس المحمرة علي ١٤٠ و١٦٠°م مقارنة بالمعاملة بالغمر في الماء علي درجتي ٤٠ و٩٠°م وايضا الكنترول . المعاملة بالغمر في محلول كلوريد الكالسيوم ١٠جم /اللتر/ ٩٠° م / ١٠ق سجل اعلي انخفاضا لتقليل نسبة الاكريلاميد وكانت ٨٨,٩٦ % و ٧٥,٢٨%علي التوالي لكلا من عينات الشيبس المحمرة علي درجتي حرارة ١٤٠و ١٦٠ °م لنفس المدة.

سجلت نسبة السكرات المختزلة انخفاضا واضحا في عينات البطاطس المحمرة علي درجة ١٤٠°م لجميع العينات المعاملة مقارنة بمثيلاتها المحمرة علي درجة ١٦٠° م .

اظهرت نتائج التقييم الحسي تحسن في الصفات الحسية (اللون- الطعم – الرائحة – القرمشة – خروج الزيت) لجميع عينات بطاطس الشيبس المعاملة اوليا والمحمرة علي ١٤٠و ١٦٠° م فيما عدا اللون للبطاطس الشيبس المعاملة بمحلول حامض الخليك وحامض الستريك .

اتضح ايضا من خلال الدراسة ان محتوي الاكريلاميد لعينات بطاطس الشيبس لجميع المعاملات الاولية والمقلية علي ١٤٠و١٦٠ °م في الحد الصحي الامن المسموح به (٢١-١٤٠ ميكرو جرام / كجم/ اليوم) للفرد وزن ٧٠ كجم تبعا WHO 2005.

تخلص نتائج البحث ان المعاملات الاولية (محاليل الغمر المختلفة- درجات الحرارة- انخفاض pH) التي اجريت علي عينات البطاطس الشيبس المحمرة علي درجتي ١٤٠و ١٦٠° م قد خفضت تكوين ومحتوي الاكريلاميد في جميع العينات تحت الدراسة وكانت في الحد الامن المسموح به .

قام بتحكيم البحث

أ.د / عبد الحميد ابراهيم عبد الجواد — كلية الزراعة – جامعة المنصورة

أ.د / عبد الجواد محمد الشواف — معهد الكفايه الانتاجيه – جامعة الزفازيق