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# EFFECT OF DIFFERENT PRE-FRYING PROCESS ON NUTRITIVE VALUE AND ACRYLAMIDE FORMATION IN POTATO CHIPS

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## ABSTRACT

The aim of this study was to investigate the effect of different pre-frying process on nutritive value and acryl amide formation in potato chips, chemical composition, in vitro protein digestibility, protein fractionation and acrylamide formation as affected by different pre frying. Potatoes were peeled and cut into slices and divided into five groups: raw, control, blanched, soaked (in citric acid) and dried sample. Results of chemical composition showed significant differences ($p \leq 0.05$) between all treatments in all parameter (moisture, oil protein, ash and carbohydrates) except fiber which showed no significant differences ($p \leq 0.05$) between samples. The protein fractionation based on solubility showed that albumin is dominant fraction with a 55.88%, 54.63%, 54.50% and 57.08% in control, blanched, soaked and dried samples respectively, while globulin and prolamin fractions showed no significant differences ($p \leq 0.05$) between samples. Increment in glutelin fraction (5.73%) in soaked sample was observed compared with 4.81%, 4.79% and 4.85% in control, blanched and dried sample respectively, while insoluble fraction in soaked sample was decrease significantly 3.24% compared with control, blanched and dried samples (4.38%, 4.38% and 4.81%) respectively. Results of *in vitro* Protein digestibility showed that blanching treatment has a higher digestibility 14.89% compared to other treatment 6.25%, 13.44% and 9.21% for control, soaked and dried sample respectively. Result of acrylamide levels were 4.009, 0.000, 1.27 and 4.994 PPM for control, blanched, soaked and dried samples respectively. Generally, pre-frying processes had an effect on nutritive value and acryl amide content of potato chips. Blanching and soaking treatments resulted in (100%, 68.35%) reduction in acrylamide level respectively. while it was increased by 24.96% in dried sample compared with control. When comparing the obtained results for acrylamide content with the maximum permissible level of WHO (2005), it showed that all pre-frying treatment results were within the permissible level.

**Keywords**: Pre-frying Process, Nutritive Value, Acryl amide, Potato Chips.



## 1. INTRODUCTION

Acrylamide is one of the Maillard reaction products, a potential toxic or carcinogenic compound which is only formed at temperatures above 180°C, especially in baked or fried products (French fries). Acrylamide a chemical suspected of causing cancer forms in some foods when they're fried, baked, or roasted at high temperatures. Acrylamide forms from sugars and an amino acid naturally found in plant-based foods when exposed to high heat. Although high levels of acrylamide cause cancer in laboratory animals, there is insufficient evidence about the risks to human health, if any, according to the U.S. Food and Drug Administration [1]. In general it can be stated that Maillard products have been present in our foods for many thousands of years, and are consumed daily by nearly all people in the world.

Maillard reactions cannot, or hardly, be prevented when heating foods. Only by removing the sugars or the amino acids, or making the product very acid or alkaline, the reactions can be prevented [2]. There are cooking processes to lower acrylamide content in food to be decreasing cooking time, blanching potatoes before frying and have been shown to decrease the acrylamide content of some foods (Kita *et al*. 2004). WHO [3] reported the healthy safe limitations and the daily intake of acrylamide in potato chips based on consumption of 100 gm from potato chips Acrylamide content (μg/100 gm) the permissible level (21-140μg/kg/day for the general population, body weight 70kg).

Potato tubers contain several protease inhibitors that inhibit the activity of trypsin, chymotrypsin and other proteases, thus decreasing the digestibility and the biological value of the ingested protein, Protease inhibitors in potatoes are largely inactivated by boiling and other thermal processes [4], and also foods treated with acids deactivate anti-nutritional factors [5]. Therefore the objectives of this study are aiming to determine the chemical composition, protein fractionation, protein digestibility and acrylamide levels of fried potatoes as affected by different pre-frying processes (blanching, soaking and drying).

## 2. MATERIALS AND METHODS

### 2.1. MATERIALS

Potato samples (*Solanum tuberosum.*) obtained from local market (Khartoum-North). Samples were prepared by washing in tap water and peeling before cutting. The Peeled potato tubers were cut using a stainless steel knife into slices (51 mm x 39.5 mm) of 2.5 mm thickness. Then they were divided into five groups. Sample kept as raw, un-treated, blanched, soaked and dried.

### 2.1. Samples preparation:

Frying process: samples was fried in oil at 180°C for 10 min in an electric fryer and drained on white paper for 5 min. Blanching process: sample was blanched at 80°C for 15 min and then was fried. Soaking process: sample was soaked in citric acid (30g/L) for 30 min (pH 2.05), and then was fried. Drying process: Sample was dried by using cabinet dryer at 70°C for 30 min until moisture decrease to 68.5%, and then was fried. All samples were drained and dehydrated at 60°C in a cabinet air-flow dehydrator, the slices were placed in a single layer, it takes about 2-3 hrs. to reduce the moisture of the slices to below 10%, then samples were ground according to [6].

### 2.2. Chemical Composition:

Approximate analysis was determined According to A.O.A.C. [7] for moisture, ash, protein, fat, fiber and carbohydrates. Protein fractionations were done according to [8]. *In vitro* protein digestibility was determined by the method described by [9] and modified by [10].

### 2.3. Determination of Acrylamide Content:

Acrylamide content was determined by using high-performance liquid chromatography (HPLC) instrument used was Phenomenex-5u (Luna) C18 column, 4.6×250 mm with mobile phase ACN: $H_2O$ (70:30). The flow rate was fixed to 0.5 ml/min and the detection wave length was set as 202 nm. Mode of the HPLC, instrument was isocratic and injection volume was 20 μl.

#### 2.3.1. Preparation of Standard Solution:

0.1, 0.4, 1, 1.6 and 4mg from standard acrylamide dissolved in 100 ml distilled water used to prepare concentration 1, 4, 10, 16 and 40 ppm respectively.

#### 2.3.2. Sample Preparation:

Samples were prepared according to [11]. Each sample (25 g) was soaked in water (75 ml). Samples were homogenated in a beaker glass covered with aluminum foil then incubated for 30 min at 70°C. The beaker glass was covered by aluminum foil to prevent evaporation. 10 g of the homogenate was weighed into a 100 ml centrifuge tubes with a screw cap and thoroughly mixed in blender with 40 ml of 1-propanol. 10 ml (8.4 g) of the supernatant was transferred to measure cylinder, 200 mg of a vegetable oil were added and the water/propanol removed in a rotary evaporator at 50 rpm and 60-70°C. Evaporation was stopped as soon as no liquid was left. The residue from the evaporation was extracted with acetonitrile and defatted with hexane. 3 ml acetonitrile and 20 ml hexane were added and mixed with the sample using ultrasonic bath. The acetonitrile phase was transferred into a 10 ml reagent glass with screw cap using Pasteur pipette. The acetonitrile phase was extracted by another 5 ml hexane; 1.5 ml of the acetonitrile phase was then transferred into a 1.5 ml auto-sampler.

### 2.4. Statistical Analysis:

The analysis of variance was performed to examine the significant effect in all measured parameters. Means were tested by analysis of variance (ANOVA) [12]. Ducan Multiple Range (DMR) test was used to separate the means [13].

## 3. RESULTS AND DISCUSSION

### 3.1. Approximate Analysis of Potatoes as Affected by Different Pre-frying Treatments:

Results of proximate analyses of potato as affected by different pre-frying treatments are shown in Table 1. The moisture content in raw sample of potato was 81.5% while [14-16] reported the moisture content to be 75.17 %, 81.9% and 79.8 respectively. The moisture content of fried samples after blanched showed significant decrease this agree with the results obtained by [15] who reported that moisture content significantly decreased in boiled sample, while significantly increased in soaked sample and significant decrease in dried sample compared with control.

The Fat content of raw samples was 1.23% while [14] reported 1.60% fats in raw potato. [17] reported the fat content in potatoes to range from 0.98-3.12g/100g. On the consistent [15] reported the fat content was 0.11g/100g. Fat content of fried samples after (blanched, soaked) showed significant increase compared with control this agree with [18] who reported that blanched potato slices when fried absorbed considerably amount of oil than control chips. Dried sample showed significant decrease in oil content compared with control sample due to air dehydration which reduces the oil absorption [19].

The protein content in raw sample was 1.07 % while [14] reported that the amount of Protein in raw potatoes sample as 1.6%, [17] reported that protein amount in some potato cultivars was in the range of 7.82-9.45g/100g, which was highly significantly difference compared to Sudanese potato cultivars. In contrast [20] reported that Potato tubers had 1.67% protein in 100 g dry matter. The protein content in fried samples after blanching, soaking and dried treatments showed significant decrease compared with control sample, generally reduction was found in crude protein content for blanched and soaked samples This could be attributed to leaching losses, this agree with [15] who reported significant decrease in fried and boiled potatoes.

Fiber content in raw sample was 3.73% while [14] reported that fiber content in raw potatoes sample was



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0.43%, [16] who reported dietary fiber in the range of 0.4-0.6g/100g, while [15] reported fiber content of raw potato in the range of 2.5-2.6g/100g. Fiber content in all samples result in insignificant differences with a reduce in soaked sample this agree with [21] who found that fiber content decrease in pH 2.with control sample due to hemicelluloses and cellulose are not affected during normal cooking, but upon prolonged heating these polysaccharides undergo some breakdown which may weal the cell wall structure [22].

Ash content in raw sample was 4.45% and control sample was 3.51 while [14] reported that ash content in raw sample and fried samples was 0.83%, 1.25% respectively. [17] reported ash content in the range of 3.95-4.71 g/100g while [15] reported ash content was in raw, boiled and fried samples 4.4, 8.0 and 9.5g/100g respectively, these losses in control sample were due to effectiveness of mineral content during frying method according to [14] who reported that frying decreased significantly four elements (Na, K, P and Mg) and increased the other two (Ca and Fe). Ash content in fried samples after blanched, soaked showed significant decrease compared with control sample while dried sample showed insignificant difference.

Carbohydrate content CHO content significantly decrease by blanching, soaking and drying treatments and this agree with [23] in the case of boiled and fried samples.

**3.2. Protein Fractionation and Digestibility According to Solubility:**

Table 3 shows the results of protein fractionation, albumin fraction in dried sample showed significant increase. While blanched and soaked showed significant decrease compared with control sample. No significant differences between samples in globulin fraction and prolamin fraction while soaked sample showed significant increase with other samples which showed no significant differences between it in glutelin fraction. Soaked sample showed significant decrease in insoluble fraction. These result agree with [20] who reported the albumin fraction to be greater than the globulin fraction, ranging from 49-75% and 23-36%, respectively, also agree with [24] reported several researchers have fractionated potato protein by various techniques the albumin constituted from 30%-60% of total protein and globulin from 10%-40% tuber protein generally contains from 1%-5% prolamin and 5%-10% glutelin, while [25] reported protein fractions in potato tuber 49% albumin, 26% globulin, >4% prolamin and 9% glutelin.

**Table 1: Chemical Composition (%) of Potatoes as Affected by Different Pre-frying Processes**

| Sample | Moisture,% | Fat, % | Protein, % | Fiber,% | Ash, % |
|---|---|---|---|---|---|
| **Raw** | 7.35$^a$±0.15 | 1.30$^e$±0.25 | 1.07$^b$±0.18 | 3.73$^a$±0.63 | 4.45$^a$ ±0.05 |
| **Control** | 2.94$^c$±0.25 | 15.27$^c$ ±0.40 | 1.45$^a$±0.05 | 3.70 $^a$±0.25 | 3.51$^b$±0.50 |
| **Blanched** | 2.3$^d$ ±0.3 | 16.43$^b$ ±0.43 | 0.65$^c$ ±0.5 | 3.84$^a$±0.31 | 1.13$^e$ ±0.19 |
| **Soaked** | 4.85$^b$±0.25 | 20.56 $^a$±0.5 | 0.89$^c$±0.12 | 3.61 $^a$±0.32 | 2.9$^c$ ±0.05 |
| **Dried** | 2.85$^c$ ±0.03 | 14.30$^d$ ±0.32 | 1.17 $^b$±0.15 | 3.75$^a$±0.25 | 3.89$^a$±0.2 |

± Standard deviation; Chemical Composition was determined on dry basis; Values with same letter in the same column are not significantly different at level (p = 0.05).

**3.3. Protein digestibility value:**

Result of protein digestibility is shown in Table 3. Protein digestibility of control potato sample was 6.25% due to Millard reaction caused by racemization of optically active amino acids, and formation of cross links in the protein. All of these tend to make the amino acids less available and, in general, the protein less digestible [26], while [22] reported protein digestibility of fried potato was 5.3%. Protein digestibility of treated samples was increase significantly by pre-treatment when compared with control sample. This increase in soaked sample may be due to the treatment with acid which caused deactivation of anti-nutritonal factors [27].

In the drying treatment, protein digestibility was 9.21 % because dry heating techniques also effective in the reduction of various antinutrient [28], also thermal unfolding of the protease inhibitors between 60°C and 70°C resulted in a decrease in inhibitor activities [29], while [22] reported protein digestibility in dehydrated potato to be 6.0%. Statistical analysis showed significant differences in samples. Deactivated anti-nutritional factors by citric acid solution, boiling of potatoes and dry heating techniques increased the protein digestibility of potato.



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**Table 2: Protein Fractions and Protein Digestibility (%) of Potato as Affected by Different Pre-frying Processes**

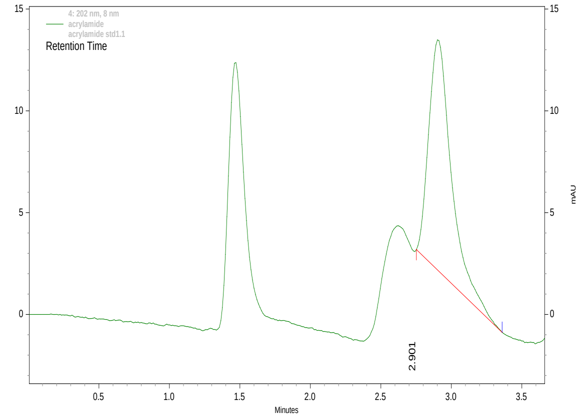
| | | | Protein Fraction | | | |
|---|---|---|---|---|---|---|
| **Sample** | **Albumin** | **Globulin** | **Prolamin** | **Glutelin** | **In soluble** | **Protein dig. %** |
| **control** | 55.88$^{b}$± 0.1 | 32.05$^{a}$± 0.25 | 2.89$^{a}$± o.1 | 4.81$^{b}$± 0.13 | 4.38$^{a}$±0.05 | 6.25$^{d}$± 0.12 |
| **Blanched** | 54.63$^{c}$± 0.05 | 32.0 $^{a}$± 0.1 | 2.98$^{a}$± 0.01 | 4.79$^{b}$± 0.05 | 4.38$^{a}$± 0.05 | 14.89$^{a}$±0.48 |
| **Soaked** | 54.50$^{c}$± 0.03 | 32.0$^{a}$± 0.14 | 2.94$^{a}$± 0.31 | 5.73$^{a}$± 0.11 | 3.24$^{b}$± 0.15 | 13.44$^{b}$±0.26 |
| **Dried** | 57.08$^{a}$± 0.15 | 32.03$^{a}$± 0.1 | 2.88$^{a}$± 0.23 | 4.85$^{b}$ ± 0.01 | 4.81$^{a}$± 0.20 | 9.21$^{c}$±0.16 |

Protein dig. : Protein Digestibility; ± Standard deviation; Protein digestibility determined on dry basis; Values with same letter in the same column are not significantly different at level (p= 0.05).

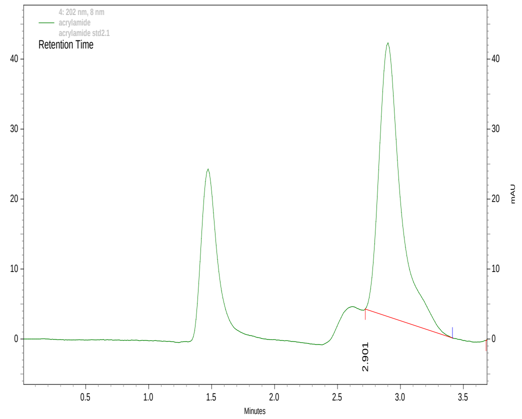
### 3.4. Acrylamide content:

#### 3.4.1. Standard Solution of Acrylamide:

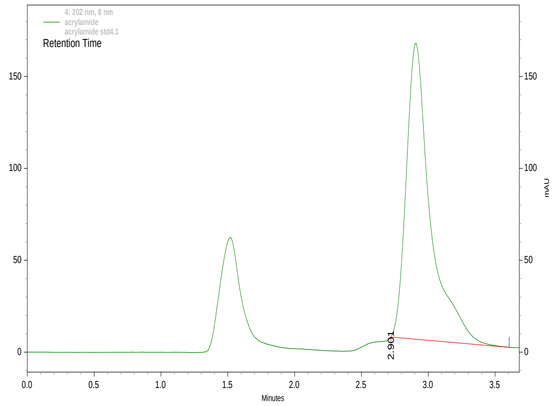
Standard solutions of different concentrations of acrylamide were analyzed with 2 characteristic peaks observed at 2.901 as shown in Fig. 1 (A, B, C) and 2.912 Fig.1 (D and E).



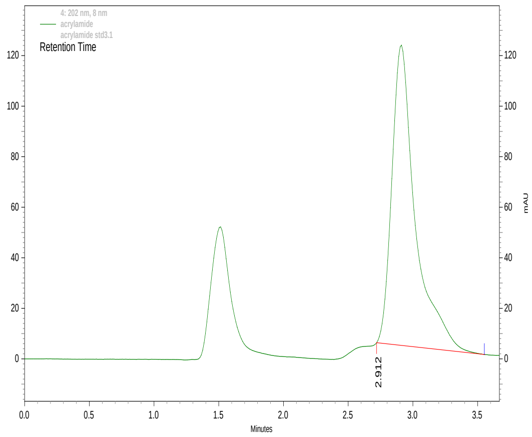

A. Standard 1(1 ppm acrylamide, retention time 2.901)



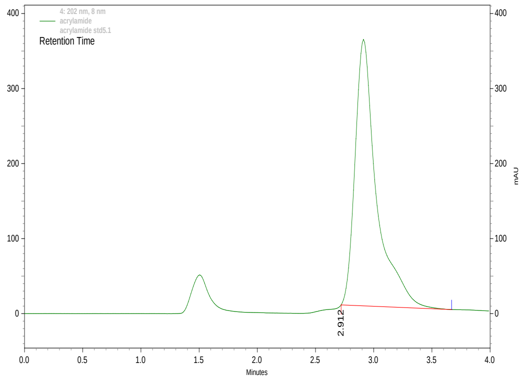

B. Standard 2(4 ppm acrylamide, retention time 2.901)




C. Standard 3(10 ppm acrylamide, retention time 2.901)




D. Standard 4(16 ppm acrylamide, retention time 2.912)




E. Standard 5(40 ppm acrylamide retention time 2.912)

**Fig. 1: Retention time of standard solutions of different concentration of acrylamide**



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**3.4.2. Acrylamide formation in control sample:**

Acrylamide content in control sample was 4.009 ppm (4.00 9 µg/g) showed in Fig. 2A. This agree with [30], who reported that acrylamide contents in control sample was 4000µg/kg (4.000µg/g) when fried at 190°C while [31] reported that acrylamide content in control sample was 2211µg/kg (2.211µg/g) when fried at 180°C.

**3.4.3. Acrylamide Formation in Pre-Frying Treatment:**

**3.4.3.1. Effect of Blanching Process on Acrylamide Formation:**

Acrylamide content in blanched sample was not detected (0.000 ppm or 0.000 µg/g) in Fig. 2B. This is consistent with [31] who reported that acrylamide content in potato chips which is blanched in hot distilled water at 90°C For 10 min before frying at 180°C was 457µg/kg (0.457 µg/g). Blanching in hot water may have caused some loss in reducing sugars and asparagine amino acid contents in potato strips leading to a reduction of acrylamide formation in fried potato strips while [30] reported that acrylamide contents was 3562 µg/kg (3.562 µg/g) when blanching at 70°C for 8 min and frying at 190°C. Result showed that Blanching potatoes (for 80°C for 15 min) prior frying was the effective method to remove acrylamide which resulted in 100% reduction .While [31]) reported that, the reduction of acrylamide was 79.33% when potato were blanched at 90°C for 10 min before frying at 180°C, a 37.51% reduction was reported by [30] when blanching for 8 min contents at 70°C and frying at 190°C.

**3.4.3.2. Effect of Soaking Process on Acrylamide Formation:**

Acrylamide content in soaked sample was 1.269 ppm (1.269µg/g) showed in Fig. 2C. [31] reported that acrylamide content in potato strips when soaked in 1% citric acid for 30 min was 687µg/kg (0.687 µg/g) while [30] reported that acrylamide content was 4200 µg/kg (4.200 µg/g) when soaked in 20 g/l citric acid for 30 min, and acrylamide content was l900 µg / kg (1.900 µg/g) when soaked in citric acid 10 g/l for 30 min when fried at 170°C. Soaking treatment in 30 g/l citric acid for 30 min before frying process at 180°C for 10 min lead to reduction of acrylamide formation in potato chips this may be due to lowering pH of sample, the reduction was 68.35%. [32] proposed a theory of acrylamide reduction by lowering the pH in the raw product before cooking, while [30] reported (70%) reduction, on the other hand, [32] found that dipping potato strips in 10 and 20 g/l citric acid solutions induced 73.1% and 79.7% respectively reduction of acrylamide formation in the resultant French fries when frying at 190°C.

**3.4.3.3. Effect of Drying Process on Acrylamide Formation:**

Acrylamide content in dried potato was 4.994 ppm (4.994 µg/g) showed in Fig. 2D and this result due to drying process, that may be due to the increment of the ratios of sugar and amino acids after drying. [33] reported that acrylamide can be formed at temperatures below 100°C; particularly in drying processes at 65–130°C also [34] found that the dried pears, along with dried prunes, contain surprising amounts of acrylamide. "They are dried at 70°C over a long period of time, which means that acrylamide is formed under mild conditions, This is may lead to a major re-assessment of some natural foods which have always been considered as healthy and natural alternatives to fast food. The drying process at 70°C for 30 min as previous step to frying process could increase acrylamide content to 24.56% when compared with control sample.

The Healthy Safe Limitations and the Daily Intake of Acrylamide in Potato Chips as affected by different pre-frying based on consumption of acrylamide content per 100 gm fried potato chips (µg/100 gm.) compared with maximum permissible level WHO [3]. From the current study it could be noticed that, control sample contained a higher concentration of acrylamide than the permissible level (21-140µg/kg/day for the general population, body weight 70kg) as reported by WHO [3]. From the former data, it could be also noticed in the pre-treatment including drying treatment, anther treatments was within the permissible level.

Table 3 showed control sample contained a higher concentration of acrylamide than the permissible level (21-140µg/kg/day for the general population, body weight 70kg) as reported by WHO (2005). From the former data, it could be also noticed in the pre-treatment including drying treatment, anther treatments was within the permissible level.



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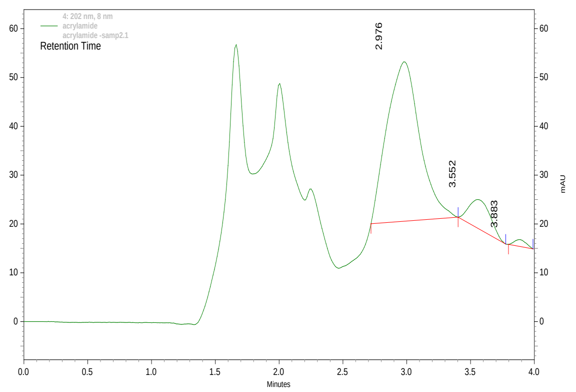
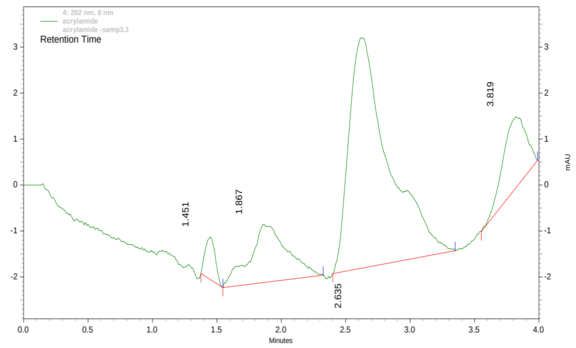
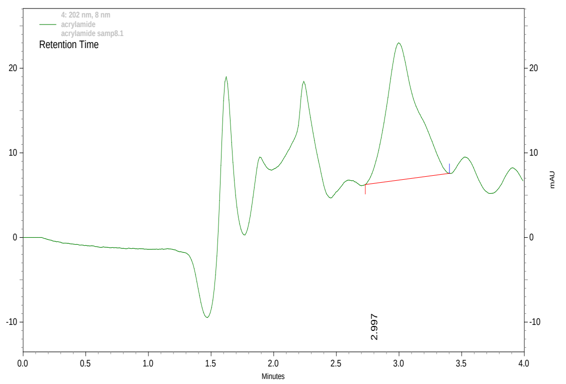


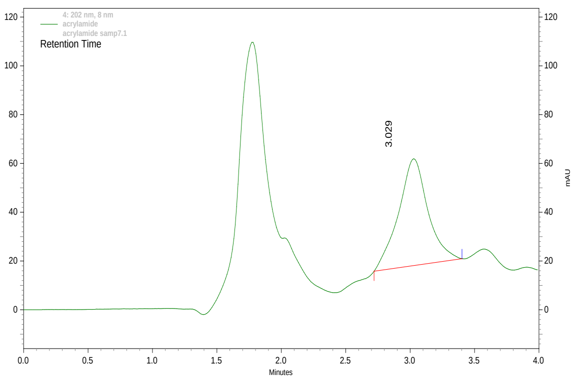

A. Acrylamide formation in control sample




B. Acrylamide Formation affected by Blanching Process




C. Acrylamide Formation affected by Soaking Process




D. Acrylamide Formation affected by Drying Process

**Fig. 2: Acrylamide Formation in control and Pre-Frying Treatment**

**Table 3: Acrylamide content of potato chips as affected by different pre-frying processes compared with maximum permissible level WHO (2005)***

| Sample | Acrylamide µg/100g | Acrylamide content (PPM) | Reduction % | Status |
|---|---|---|---|---|
| **Control** | 400.9 | 4.009 | - | + |
| **Blanched** | 0.0 | 0.000 | 100 | - |
| **Soaked** | 126.9 | 1.269 | 68.35 | - |
| **Dried** | 499.4 | 4.994 | - | + |

(+)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. (-) Daily intake (µg) based on consumption of 100 gm of fried potato strips per day was lower than maximum permissible level of WHO limit. * Maximum permissible level WHO (2005) at range of 21-140 µg/kg/day for the general population (body weight 70kg).

## 4. CONCLUSIONS

It could be concluded that, the approximate analysis of blanching and soaking treatments resulted significant decrease in protein, ash, carbohydrate and albumin fraction, while resulted significant increase in oil content and resulted in significant difference in fiber content. Drying treatment resulted significant decrease in oil, protein and carbohydrate while resulted insignificant in ash and fiber. No significant differences between treatment in globulin fraction and prolamin fraction, while soaking treatment resulted significant increment in glutelin fraction and significant decrease in insoluble fraction. Protein digestion was better improved in blanched potato than the soaked ones. Control and dried sample contained a higher concentration of acrylamide than the permissible level while in the pre-treatment including blanching and soaking treatment was within the permissible level of The Healthy Safe Limitations of WHO 2005. Thus blanching and soaking treatments are recommended before frying potato chips.

**Author Contributions:**

Mashair A. Suliman conceived and designed the experiments; Wala E. A. Hassan performed the experiments; Elhadi A. I. Elkhalil wrote the first draft and all authors. All authors have read and agreed to the published version of the manuscript.



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**Conflicts of Interest:** The authors declare no conflict of interest.

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