SODIUM CHLORIDE INHIBITS ACRYLAMIDE FORMATION DURING DEEP FAT FRYING OF PLANTAIN

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Abstract-
Processing is often essential in order for food to become comestible and delectable e.g. addition of salt to food during frying to improve its taste. Acrylamide is formed during processes which occur at high temperature. This study ascertains that sodium chloride (NaCl) prevents the formation of acrylamide. It also compares the effects of different concentrations of table salt on formation of acrylamide during deep frying process of plantain. Test samples were treated by immersion in 1%, 5% and 10% sodium chloride for 60 minutes at room temperature before frying. Fried and raw plantain samples were evaluated for their asparagine and acrylamide content. The results showed frying causes acrylamide synthesis in plantain. The acrylamide concentration decreased with reducing pH values and increasing sodium chloride concentration. At 5% and 1% concentration of NaCl, there was no significant difference in the amount of acrylamide formed. The result of this study also revealed that the concentration of acrylamide in plantain significantly decreased (p<0.05) by 98.9% in ripe plantain and 35.4 % in unripe with the addition of 10% sodium chloride. Hence, sodium chloride at a high concentration reduces the formation of acrylamide.

Key words: acrylamide, plantain, salt, food, maillard reaction

1. Introduction
Sodium chloride is an additive usually used to improve the taste of plantain during frying. Frying occurs at a high temperature; this high temperature often leads to the synthesis of harmful compounds e.g. acrylamide thereby causing nutritional value of food to decline. Acrylamide is formed during thermal processing of carbohydrate-rich food. However, the main precursors required for the maillard reaction to occur in foods of plant sources are reducing sugars and asparagine, this was confirmed by another reporter who stated that synthesis of acrylamide during deep frying of plantain was influenced by asparagine concentration but not by other amino acids present[1]. In April 2002, Swedish scientists first discovered acrylamide in starchy foods since then many studies have been done about its mechanisms of formation in these food systems [2]. Also a study conducted on market samples of plantain chips (ripe and unripe) showed significantly high levels of acrylamide in ripe plantain chips [1]. Therefore there is the need to study new means of reducing acrylamide concentration in food products.

The major mechanism of acrylamide formation is associated with the Maillard non enzymatic browning reaction that occurs at high temperatures and is required for palatable flavour, colour and aroma production. A reaction occurs between acrolein which is the product of fatty acid (oil) oxidation and ammonia to form CH2=CH-CHOH (NH2), or with asparagine to form an N-glycoside which could transform into acrylamide by oxidation [3]. Sodium chloride acts through different mechanisms to reduce acrylamide formation. It may form complexes with amines and some intermediates of the Maillard reaction products. Recently, evidence has shown that positive ions change the direction of the Maillard pathway favoring removal of water from glucose [4]. Also Na+ has been observed to interact with asparagine to prevent acrylamide
synthesis [5]. Sodium chloride addition may also decrease water activity resulting in reduced oil uptake hence favoring acrolein formation [6]. The aim of this study was to evaluate the inhibitory properties of NaCl on acrylamide formation in plantain during frying.

2. Methodology
2.1 Plant material
10 kg of plantain (Musa paradisiaca) was purchased from Covenant University farm.

2.2 Sample preparation
The fingers were washed and peeled in distilled water, then cut into thin circular slices. The test samples were soaked 1%, 5% and 10% concentration of NaCl solution at room temperature for 60 minutes. The control sample did not undergo the soaking treatment. Vegetable oil was used to fry using a deep fryer. The plantain was fried at 190°C for 5 minutes. The samples were air-dried and ground into powder using mortar and pestle. The samples were stored in Ziploc bags and labelled accordingly.

2.3 Analysis of asparagine and acrylamide content
This was done using a HPLC method as described previously with minor modifications [7]. The asparagine and acrylamide content of the sample was measured using high performance liquid chromatography. Similar methods were used for the chromatographic separation of acrylamide and asparagine using Agilent 1290 Infinity LC system. After the soaking period, 1.5 ml each of the samples was measured out using a syringe and filtered into appropriately labeled Teflon vials using 0.45μm syringe filters. The liquid chromatography was performed using Agilent 1290 infinity LC system, equipped with a column compartment 1290 and a ZORBAX RRHD Eclipse plus C18 1.8μm, 2.1 mm x 50 mm, auto sampler 1290, auto sampler thermostat, Binary pump and diode array detector or dual wavelength UV detector. 10μl was injected on the column. A pressure pump limit of 1200 bar and flow rate of 0.150 ml/min was used at 220°C. The sample was allowed a running time of 25 minutes with an isocratic solution during which the components separated.

2.4 Determination of pH Values
The pH value of the samples was determined using a calibrated pH meter.

3. Result and discussions
For sodium chloride to inhibit acrylamide formation, it has to alter the reaction conditions or reactants. Asparagine was present in the raw samples at a relatively low concentration; it was observed that raw ripe plantain possessed an even lower asparagine concentration compared to the raw unripe as shown in table 1. Asparagine concentration has been reported between 1.80 and 2.89 mg/g for the different stages of plantain ripening analyzed [1]. However, the change in asparagine content during ripening did not follow a pattern.

This result agrees with that of [7]. It was revealed that asparagine concentration in plantain reduces with increased fruit ripening as observed with the raw and unripe plantain samples [8]. In the fried samples, asparagine was not detected which indicates that the high temperature
caused thermal degradation by bond breakage and new compounds have been formed from asparagine.

Table 1: Effect of NaCl on asparagine content of plantain

|                | ASPARAGINE (ppm) |
|----------------|------------------|
|                | RIPE             | UNRIPE           |
| RAW (control)  | 3009 ± 4.3       | 11648 ± 2.7      |
| 0% NaCl        | ND               | ND               |
| 1% NaCl        | ND               | ND               |
| 5% NaCl        | ND               | ND               |
| 10% NaCl       | ND               | ND               |

ND: Not detected

As observed in the table above, asparagine was detected in the raw samples but not detected in any of the fried samples.

In other studies, asparagine, total amino acids and sugar levels varied from 1.5 to 11.4, from 11 to 31.5 and from 0.86 to 23, respectively in raw potato tubers [9].

The pH values of the raw and fried samples were measured using a pH meter; the results are shown in figure 2. The pH values were observed to reduce with increasing NaCl concentration and decreasing acrylamide. This may be due to the fact that acrylamide is readily formed at slightly acidic pH but NaCl results in the pH tending more towards acidity hence inhibiting acrylamide formation.

![Figure 1: Graphical representation of the pH value of samples](image)

According to the table above, there was a consistent decrease in pH across the fried samples. The increase in concentration of NaCl caused a further reduction in the pH of the samples.

These results are consistent with that of Pedereschi et al. [10] who found that dipping potato strips in 10 and 20g/l citric acid solutions induced about 70% reduction of acrylamide formation in the resultant French fries when frying at 190°C due to lowered pH.

The acrylamide content was measured using HPLC; the results are represented in table 2. Contrary to what was expected, the fried ripe plantain which had lower asparagine content had higher acrylamide concentration than fried unripe plantain which had a higher amount of free asparagine to be used in the formation of acrylamide. These results are consistent with Omotosho et al. and Quayson and Ayernor [7], [11] who showed that the acrylamide content was lower in unripe plantain than in ripe ones. This inverse relationship shows that acrylamide
formation is independent of asparagine in plantain unlike in potatoes, where the high acrylamide content is thought to be dependent on and as a result of the high asparagine concentration of the raw samples. Also it was proven in 2011 that 50% asparagine extraction by pretreatment did not result in acrylamide reduction in fried plantain [8]. From these results the most probable mechanism of acrylamide formation in plantain seems to be that involving acrolein gotten from transformation of lipids (oil). Water replacement mechanism clarifies the reason for ripe plantain absorbing more oil than unripe and hence possessing more acrylamide [12].

Shamla and Nisha reported levels of acrylamide in raw and fried ripe plantain chips ranging from 15-1700 μg/kg and 25-1960 μg/kg respectively [1]. Other scientists also revealed that acrylamide concentration ranges from 270 to 3600 μg/kg in banana fritters which is produced from overripe banana [13]. Acrylamide levels of 900 μg/kg have been reported in plantain products [8], thus reemphasizing the fact that acrylamide formation levels increases with ripening as also seen in the contrasting levels of acrylamide measured in ripe and unripe plantain in this study.

Table 2: Effect of NaCl on acrylamide formation

|                  | Mean AA (μg/kg) | UNRIPE  |
|------------------|----------------|---------|
|                  | RIPE           |         |
| Raw              | 11.916 ± 0.1a  | 0.0011 ± 0.21a |
| 0% NaCl          | 100.02 ± 4.67b | 18.28 ± 3.29b |
| 1% NaCl          | 90.46 ± 3.64c  | 13.344 ± 5.61c |
| 5% NaCl          | 90.12 ± 6.79d  | 12.846 ± 4.54d |
| 10% NaCl         | 1.018 ± 4.56e  | 11.804 ± 2.26e |

*Mean ± SEM (n = 3)

*Values are significantly different from each other at P ≤ 0.05. According to the table above, there was an exponential increase in the acrylamide content of the fried samples. High concentration of NaCl reduced the acrylamide concentration.

Table 2 shows the effect of NaCl treatment on acrylamide formation in plantain. According to Franco Pedreschi [14], surface water activity of a slice of potato affects the acrylamide formation during frying. A potential way to reduce water activity is to increase the local salt concentration. Soaking of plantain in NaCl solution for 60 minutes each reduced the acrylamide concentration either by decreasing water activity or by reducing oil uptake. Reducing oil uptake seems to be a more plausible means of action of NaCl in plantain as the mechanism of formation of acrylamide might be dependent on acrolein which results from lipid (oil) transformation. No significant difference was observed when acrylamide formed after soaking in 1% and 5% NaCl solutions was compared to that formed in the control. However, it was recorded that soaking of blanched potato slices in 3% NaCl solution reduced potato chip acrylamide formation by 36% after frying at 190°C [15]. 10% NaCl concentration and 60 minutes soaking time was observed to reduce the amount of acrylamide formed by 35.43% in unripe plantain.
and 98.98% in ripe plantain. From these results it could be proposed that 10% NaCl significantly reduced oil uptake during frying of plantain. A striking difference was observed in the effect of 10% NaCl on unripe when compared to ripe; this may be due to a factor that limits oil absorption. Also 40% reduction in acrylamide formation when 10% NaCl was added to a heat treated model food matrix containing equal concentrations of glucose and asparagine has also been reported [16].

Researchers who worked on potato chips also thought that NaCl acts by preventing the formation of the strecker intermediate in the maillard reaction hence inhibiting this reaction and allowing accumulation of the reactants; this might not be so for plantain. From the results of this study, the proposed mechanism of action of NaCl is not through the maillard reaction which involves the reducing sugar and asparagine reactants. It inhibits acrylamide formation by reduced oil uptake. This corresponds with the observation of Bunger et al. that NaCl highly reduces oil uptake by food samples [15], [17]. Also the type of oil used could have contributed to the results that were observed[18].

4. Conclusion
During frying of plantain, acrylamide is formed. More acrylamide is formed in ripe than in unripe plantain. High concentration of sodium chloride reduces the amount of acrylamide formed during deep fat frying of plantain.

5. Recommendation
The toxicity of 10% NaCl should be studied to ascertain its deleterious effects on the body. The sensory evaluation of 10% NaCl treated fried plantain should be carried out to determine the acceptability of this food product by the public. More research should be done on other concentrations of NaCl to determine the optimum NaCl concentration which is not toxic to the human body and at which there is a significant decrease in acrylamide concentration. The major mechanism of formation of acrylamide in plantain should be further studied, in order to effectively reduce the acrylamide formed in plantain. As the method of reduction discovered for potatoes and other starchy foods may not be applicable to plantain. The knowledge gained through this study should be applied in real technological procedures of food processing.

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