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Research Article
Effect of Deep and Infrared Rays Frying on the Acrylamide Concentration Formation in *Musa paradisiaca*

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Abstract

Background and Objective: Acrylamide is formed in starchy foods as a result of thermal processing methods. Regular frying is a high temperature processing method in which food is submerged in hot oil while infrared (IR) frying works with reduced heating time, reduced quality losses, absence of solute migration in food material and little or no oil providing significant advantages over deep-fat frying. The aim of this study was to compare the effect of deep fat frying and IR frying on the amount of acrylamide formed during frying of plantain. **Materials and Methods:** The samples were subjected to frying with a deep fryer and an infrared fryer. The fried samples were analysed for pH, reducing sugar content, asparagine and acrylamide concentration. Statistical analysis was carried out using Microsoft excel 2010 and results were expressed as standard error of the mean. **Results:** The reducing sugar content in plantain reduced with frying. IR frying resulted in reduced acrylamide contents, with a percentage reduction of the acrylamide content at 74.04% for the ripe samples and 59.9% for the unripe samples when compared to the acrylamide content in the deep fat fried samples. **Conclusion:** During deep fat frying a high amount of acrylamide was formed. In this study, IR frying reduced acrylamide formation significantly while also retaining nutrients, thus providing an alternative to the deleterious deep fat frying method. IR frying of plantain is healthier and should be practiced.

Key words: Acrylamide, infrared cooking, HPLC, deep fat frying, reducing sugar, asparagine

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Acrylamide is a carcinogenic compound which is produced in certain foods due to heating process at high temperature and low humidity conditions[1]. One of the most common food processing methods used for preparing foods worldwide is deep fat frying which occurs at 180°C or above[2]. IR frying is less common than deep fat frying.

The identification of acrylamide in heated food stuffs originated from an animal feeding experiment which was performed to test if acrylamide was formed during heating of foodstuffs. When the animals were fed fried standard feed an abnormal increase in the acrylamide haemoglobin adducts level in blood from rats was observed[3]. When compared with undetectable levels in unheated or boiled foods, low concentration of acrylamide was found in heated proteinous foods (5-50 mg kg^{-1}) and high contents in carbohydrate-rich foods (100-4000 mg kg^{-1}). It has been shown that acrylamide was formed in a temperature-dependent manner in food.

The major route of absorption of acrylamide by the body is food consumption, acrylamide intake varies based on gender, age, physical activity, categories of habitual alcohol consumption etc.

Infrared heating has been applied in drying, baking, roasting, blanching, pasteurization and sterilization of food products. IR cooking is involved in the safe cooking procedure of meatballs from a polycyclic aromatic hydrocarbon (PAH) contamination point of view. This is so because it reduces the amount of PAH formed in meatballs after cooking[4]. In 2015, it was reported that infrared treatment also has effects on enzyme activities such as urease, lipooxygenase in soybean samples[5]. Vacuum frying might offer the opportunity to reduce acrylamide levels in crisps made from potatoes with high reducing sugar content. Par cooking far-infrared heating and dry steam treatments used to make low fat crisps may also reduce acrylamide.

The objective of this study was to compare the effect of deep fat frying and infrared frying on the concentration of acrylamide formed during frying of plantain.

MATERIALS AND METHODS

Plant material: Ten kg of plantain (*Musa paradisiaca*) was purchased from Covenant University farm.

Preparation of sample: The fingers were peeled and washed in distilled water. After which they were cut into thin circular slices.

Vegetable oil was used in the frying of the plantain. A deep fryer was used for frying of the control samples, the plantain was fried at a temperature of 190°C for 5 min. The test samples were fried in an infrared-powered electronic deep fryer with a capacity of 2.0 L at 190°C for a time of 26 min (unripe sample) and 20 min (ripe sample). After cooling, the samples were grinded into powder form using mortar and pestle. The plantain powder samples were kept in ziploc bags and labelled accordingly.

Reducing sugar analysis: Reducing sugar content was determined using 3, 5-Dinitrosalicylic acid method[6].

Analysis of asparagine and acrylamide content: This was done using the HPLC method. The mobile phase was used for the analysis that contained methanol and water mixed in the ratio (90:10). The acrylamide and asparagine standards of HPLC grade were weighed and dissolved in methanol to obtain a concentration of 1000 μg mL^{-1}.

Ten mililiter of HPLC grade methanol was added to the samples and allowed to stand for a week at room temperature. 1.5 mL each of the resulting solution was measured out using a syringe and filtered into appropriately labelled Teflon vials using 0.45 μm syringe filters. The HPLC analysis was performed on a column compartment 1290 and a ZORBAX RRHD Eclipse plus C18 (1.8 μm, 2.1×50 mm), with a linear gradient methanol and water mixed in the ratio (90:10) at a pressure pump limit of 1200 bar and a constant flow rate of 0.150 mL min^{-1}, at 22°C for 25 min with a wavelength of 280 nm.

Determination of pH values: The pH values of all the samples were determined using a calibrated pH meter.

Statistical analysis: Statistical analysis of results was performed using Microsoft Excel 2010 and the significant difference was measured at ($p>0.05$). Results were expressed as standard error of the mean.

RESULTS

During this study, reducing sugar, pH, asparagine and acrylamide tests were conducted.

The reducing sugar analysis conducted in this research showed that regular deep fat frying reduced the reducing sugar content of the plantain by 69.6% as seen in Fig. 1.

IR fried samples which served as the test sample were analysed and the reducing sugar content also reduced by 39.2% as shown in Fig. 1.

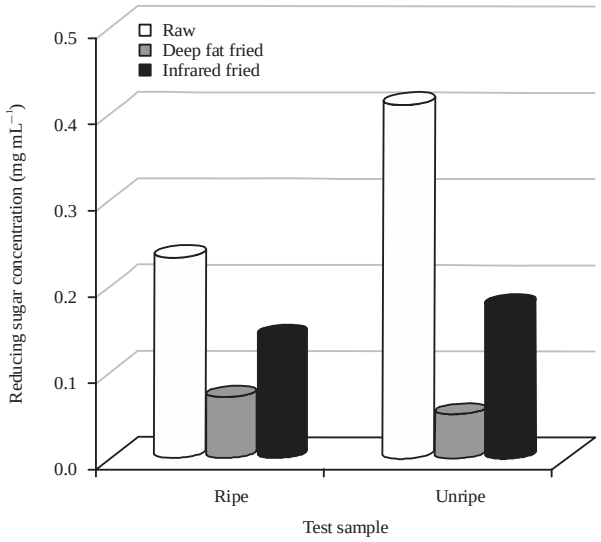

Fig. 1: Graphical representation of reducing sugar content of samples

Reducing sugar content reduced more significantly in the deep fat fried samples as compared to the infrared fried sample

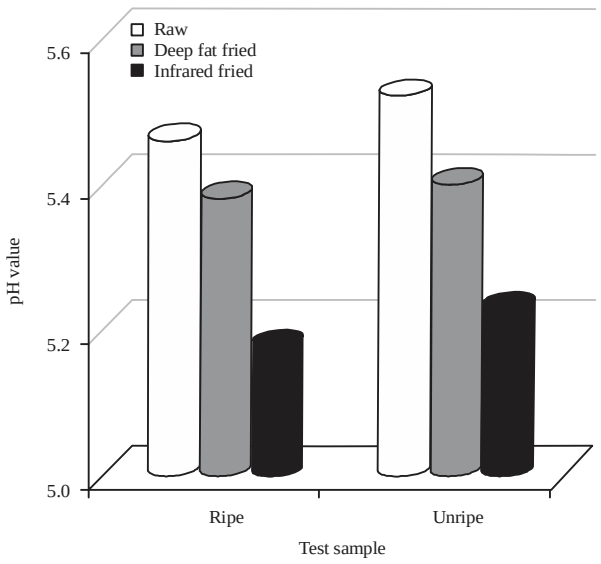

Fig. 2: Graphical representation of the pH value of samples

Infrared fried samples were found to be more acidic than the deep fat fried samples and raw samples

Table 1: Result of acrylamide analysis

	Acrylamide (μg kg^{-1}) (X±S.D)	
Samples	Ripe	Unripe
Raw	11.916±0.1	0.0011±0.21
Deep fat fried	100.02±4.67	18.28±3.29
Infrared fried	25.95±3.54	7.32±5.41

When compared to the raw sample there was a significant increase in the acrylamide content of the deep fried samples while there was no significant difference in the acrylamide content of the infrared fried sample

The pH estimations of the raw and fried samples were measured utilizing a pH meter, the outcomes are indicated in Fig. 2. The pH values were seen to be lower in IR fried samples than deep fried samples.

The acrylamide content was measured using HPLC. During deep fat frying, a significantly high amount of acrylamide was formed in the ripe plantain when compared to that formed in the unripe plantain whereas, during IR frying a minimal amount of acrylamide was formed. The concentration in parts per million is presented in Table 1.

Asparagine content of plantain was also analysed using HPLC, it was present in the raw samples at a relatively low concentration. The raw ripe samples possessed an even lower concentration of asparagine while asparagine was not detected in the fried samples.

DISCUSSION

Acrylamide was observed to be formed in high concentrations in the deep fried samples but the IR fried samples possessed a lower amount of acrylamide as seen in Table 1 which may be due to the lower temperature applied in infrared frying. This result correlates with that of a study conducted to determine the influence of frying process on acrylamide concentration. It was observed that acrylamide formation increased with frying temperature[6]. This result contradicts that reported on soyabean in which during infrared heating, acrylamide formation greatly increased with decreasing moisture content, this was attributed to soybean proteins being highly sensible to Maillard reaction[7].

It was seen that more acrylamide was formed in the ripe plantain than the unripe. This could be due to the fact that the ripe plantain has more moisture which can be replaced by oil during frying[8]. The oil supplies acrolein from which acrylamide may be formed.

At high frying temperatures such as the temperature the deep fryer applies, acrylamide levels increase rapidly at the end of the frying run[9]. IR fryer employs low temperature which could be responsible for the lower acrylamide concentration.

Also the low acrylamide content of the IR fried samples may be due to little fat used in frying. It was noted in a study that infrared pre-frying uses low fat content but is still able to create products with characteristics similar to deep fried products[10].

The low acrylamide content may also be attributed to the low pH observed in infrared fried samples. Acrylamide is readily formed at marginally acidic pH yet IR frying brings about the pH tending more towards acidity subsequently hindering acrylamide formation. These outcomes are

Table 2: Asparagine content of plantain

	Asparagine (ppm)	
Samples	Ripe	Unripe (X±S.D)
RAW	3009±4.3	11648±2.7
Deep fat fried	Not detected	Not detected
Infrared fried	Not detected	Not detected

In the raw unripe sample, asparagine was present in a significantly high concentration but was not detected in any of the fried samples

consistent with that of who found that plunging potato strips in 10 and 20 g L^{-1} citrus acid solution to reduce the pH incited around 70% lessening of acrylamide development in the resultant French fries when frying at 190°C.

The results obtained showed further reduction in the reducing sugar content of the deep fat fried samples when it was compared with that of the IR fried samples. This may due to the fact that the infrared fryer uses low frying temperature[11] this temperature inhibits the breakdown of reducing sugar compounds present in the plantain.

Raw unripe plantain possessed a higher asparagine concentration compared to the raw ripe as shown in Table 2. It was shown that in plantain asparagine content decreased with fruit ripening as observed with the raw and unripe plantain samples[12,13]. In the infrared fried and deep fried samples, asparagine was not detected. This shows that the processing temperature may have caused thermal degradation by bond breakage and new compounds have been formed from asparagine[9,10]. Also in a research on acrylamide formation in sweet bread, L-asparaginase was used in the dough as a treatment. It was observed that there was 73-93% reduction in acrylamide concentration. In another study conducted in 2016, multiple potato varieties were transformed with potato genomic DNA that results in down-regulation of the expression of the asparagine synthetase-1 gene (Asn1), significantly reducing synthesis of free asparagine[14]. The result of this study showed a significant difference between the transformed potatoes and the conventional potatoes. This further proves that asparagine plays a key role in acrylamide formation[10,15].

CONCLUSION

During frying of plantain, acrylamide which is a cancer causing agent is formed. In this study, less acrylamide was formed in fried unripe plantain compared to fried ripe plantain, giving reason why fried unripe plantain is healthier than fried ripe. Likewise, more acrylamide is formed in deep fat fried products than infrared fried products, therefore, if plantain must be fried it should be done with the infrared fryer as it retains nutrients and reduces formation of acrylamide.

SIGNIFICANCE STATEMENTS

This study discovers the possible method of reducing acrylamide formation in food that can be beneficial when processing food by frying. This study will help the researcher to uncover other critical areas of acrylamide formation mechanism that many researchers have not been able to explore. Consequently, a new theory on the reduction of acrylamide formation will be discovered.

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