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Particulate Emissions from High Temperature Pyrolysis of Cashew Nuts

Joshua Kibet
Egerton University, KENYA
Nicholas Rono
Egerton University, KENYA
Maurice Mutumba
Egerton University, KENYA

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ABSTRACT
High temperature pyrolysis procedures of such foods as meat, cashew nuts, and coco beans are associated with bio-hazardous emissions that may be precursors for respiratory health problems including oxidative stress, cancer and lung damage. In this study, 20 mg of powdered cashew nuts was pyrolyzed in a quartz reactor system of volume ~ 1.6 cm^3 at two different temperatures (500 ˚C and 700 ˚C) under 1 atmosphere pressure at a total pyrolysis time of 5 minutes. Particulate emissions were collected in amber vials and extracted using 2 mL dichloromethane through a porous tube diluter. To explore the surface morphology of particulate emissions, a scanning electron microscope (SEM) was used. Image *J* computer software was used to measure the size of particulate emissions while *Igor* graphical code was used to plot the size distribution curves of particulate emissions. Accordingly, it was found that the size of particulates was 13.41 ± 3.47μm at 500 ˚C and 12.44 ± 4.33μm at 700 ˚C. These particulates were approximately within the PM_{10} (10 microns) category of respirable particulates. The findings generated from this study are critical in understanding the potential health risks resulting from inhaling particulate emissions from high temperature cooking processes.
Keywords: cashew nuts, particulate emissions, pyrolysis, scanning electron microscopy

INTRODUCTION

Food preparation procedures especially frying and grilling in homes may cause serious environmental health problems such as asthma, allergies, nasal congestion and ultimately lung damage. Heat treatment (pyrolysis) of proteinaceous foods such as cashew nuts may also yield mutagenic and carcinogenic emissions that are of significant health concern. According to Kemens *et al* (1991) the average particulate matter in indoor air occasioned by cooking, ranged between $PM_{2.5}$ (≤ 2.5 μm) and PM_{10} (≤ 10 μm) and is one of the most significant event for generating small particles in most households [1]. Generally, cashew nuts have a lower fat content than most other nuts in which approximately 82% of their fat is unsaturated, with 66%

Correspondence: Joshua Kibet, *Egerton University, P.O Box 536 – 20115, Kenya.*
jkibet@egerton.ac.ke

of this unsaturated fatty acid content already established as healthy for the heart; similar to those found in olive oil [2]. Studies on diabetic patients have revealed that mono-unsaturated fat, when added to a low-fat diet, can help to reduce high triglyceride levels. High triglyceride levels are associated with an increased risk for heart disease, so eating cashew nuts supply some mono-unsaturated fats in the diet hence reducing heart problems [3]. Nonetheless, heat treatment of cashew nuts may yield toxic particulates which may outweigh its benefits. For instance, it is well-established in literatures that exposure to particulates of diameter of $PM_{2.5}$ and PM_{10} enhances lung cancer, oxidative stress, and cardiopulmonary death [4]. In this regard, particulate matter may be defined as a complex mixture of compounds with considerable variance in composition by source with the major components being soot and organic toxicants [5].

The aerodynamics of airborne particulate emissions and the deposition characteristics in the human lung has shown that $PM_{2.5}$ airborne particulate emissions is the fraction of the particles with the greated impact on human health [6]. Combustion particulate matter are known to contain free radicals and thus airborne fine particles from combustion especially $PM_{2.5}$ may contain radicals capable of causing severe cellular assault [7, 8]. Ultrafine PM (< 0.1 μm) is an important sub-fraction of fine PM and has potentially exceptional toxicological properties [9]. Particulate matter provides a mechanistic carrier for deposit of intermediate radicals deep in the human respiratory system. These radicals subsequently induce immune system responses that can activate the production of more radicals and reactive oxygen species that can cause damage to DNA and/or initiate damage to the respiratory airway [8]. Nonetheless, the mechanism by which airborne particles cause health effects is still an interesting scientific debate which is yet to be understood [6].

The particulate emissions explored in this investigation from high temperature pyrolysis of cashew nuts were approximately PM_{10} classification. These classes of particulates are well known candidates for various disease burdens in the respiratory landscape because they are heavy and may be deposited as large masses in the respiratory system. Scanning electron microscopy has been used to examine the size of particulates emitted during the pyrolysis of cashew nuts. These particulate emissions may be life threatening when inhaled into the respiratory system over a period of time. Pyrolysis studies of food is therefore critical because of the formation of mutagenic and carcinogenic pyrolysates which may cause severe health concerns in the field of food processing. Nonetheless, the toxic action of particulates in the biological system has not been clearly understood but it is believed that the organic intermediate radicals and volatiles embedded in the particulates are partly responsible for cell injury, tumor growth, and chronic coughs.

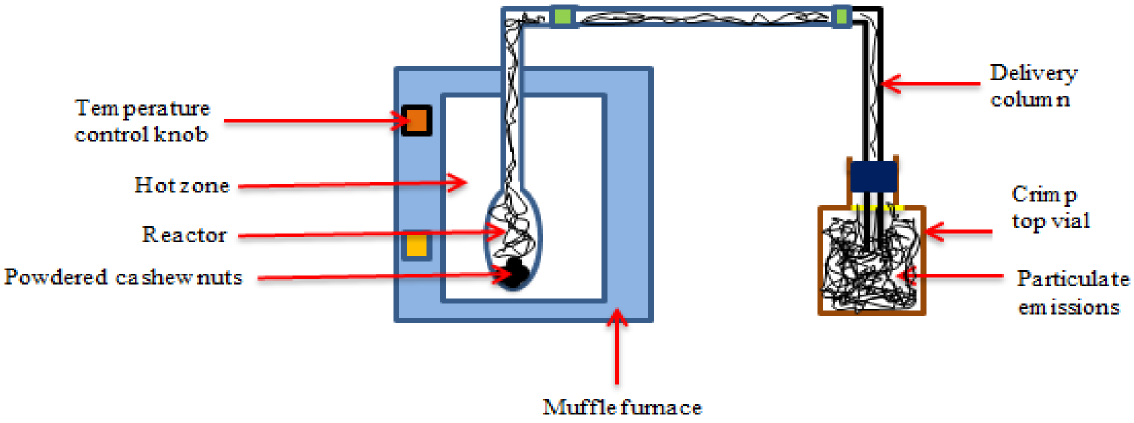

Figure 1. The reactor assembly and the gas-phase trapping apparatus for particulate emissions

MATERIALS AND METHODS

The reactor system

The cashew nuts investigated in this work were directly obtained from the cashew nut plant, dried to remove moisture content, and ground using pestle and mortar. The ground cashew nuts were sieved using a 50 micron sieve. The reactor system used was a muffle furnace (Thermo-Scientific, USA) whose internal heating compartment has dimensions of 5 cm x 6 cm x 8 cm. The heater is fitted with a temperature regulating knob and has a maximum heating temperature of 1000 ˚C. At the top of the heating compartment is a hole which allows the gas-phase trapping tube to pass through. 20 mg sample of powdered cashew nuts was packed into a quartz reactor of dimensions: i.d. 1 cm x 2 cm (volume ≈ 1.6 cm^3) fitted with gas-phase trapping quartz tube. The reactor system used in this study is presented in **Figure 1**.

SEM characterization of cashew nut particulate emissions

Particulate emission of cashew nuts at 500 ˚C and 700 ˚C conducted at 5 minutes contact time was trapped in dichloromethane through a porous tube diluter and then transferred into amber vials. About 5 mg of sample was added to 1 mL methanol and gold grids were dipped into the prepared sample. Twisters were used to pick the gold grids from the sample. A gold coating of 9 nm (prepared using 6 nm by 1.5 nm layers) was applied to the stub to reduce charging of the non-electrically conductive particles [10]. The grids were allowed to dry in the open before putting them into the analysis chamber of the SEM (JEOL JMS 7100F) [11], **Figure 2**. For improved image clarity, a second sample of soot was coated with a 3 nm Au layer to allow higher resolution images to be obtained. All images were taken at an angle of 45˚ to improve the definition of the surface morphology [12].

The sample was analyzed under high vacuum to ensure no interference of air molecules during analysis. The SEM machine was then switched on and imaging of the sample

Figure 2. A photograph of a scanning electron microscope (Courtesy of the Department of Mechanical Engineering, University of Surrey, UK.)

conducted at 5.0 kV using a light emitting diode (LED). The lens was varied at various resolutions until a clear focus of the sample was observed. A detailed procedure for SEM analysis is reported elsewhere [10, 12]. Imaging of the samples was conducted using a scanning electron microscope (cf. **Figure 2**). *Image J* computer platform was used to determine the size of the soot particulates and a distribution curve of soot size was then determined using *Igor* graphical software. The mean sizes of the soot particles at 500 and 700 ˚C were reported and presented as Gaussian curves where the peak of the curve gave the mean of the particulate size. The results reported in this study were conducted in duplicate for statistical analysis of particulate sizes.

RESULTS AND DISCUSSION

At a magnification of x 400, the size of particulate matter from pyrolyzed cashew nuts at temperatures of 500 ˚C and 700 ˚C were significantly different. At 500 ˚C, the particle sizes of emissions were larger ~13.41±3.47 µm (**Figure 3**) as compared to the particles at 700 ˚C ~12.44± 4.33 µm (**Figure 4**). This slight difference in size may be attributed to the fact that at higher temperatures, the particulate matter is largely carbonaceous [13] while at lower temperatures, the particulate size may be composed of organic volatiles which are adsorbed on the particulate surface and hence the apparent increase in the size of the particulates at 500 ˚C.

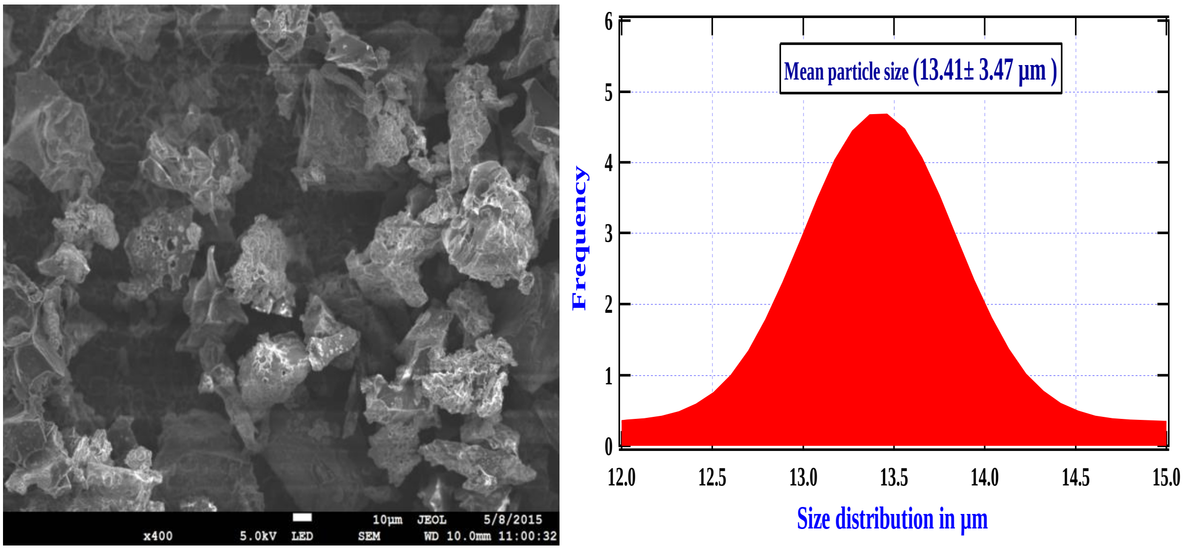

Figure 3. SEM image and particle size distribution (Gaussian red) of particulate emissions of cashew nuts at 500 ˚C

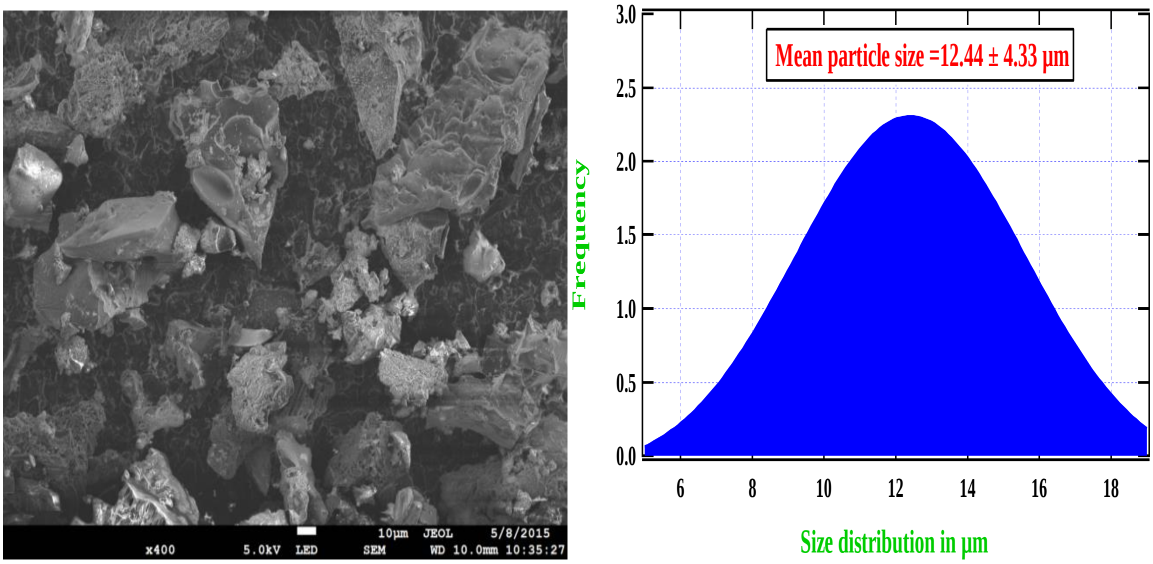

Figure 4. SEM image and particle size distribution (Gaussian blue) of particulate emissions of cashew nuts at 700 ˚C

This suggests that higher cooking temperatures may result in the formation of smaller particulate emissions. The particulate size from high temperature pyrolysis of cashew nuts falls on average under PM10 classification of particulate matter. Accordingly, these results corroborate studies reported elsewhere in literature regarding particulate emissions from pyrolysis of biomass materials from household cooking [1]. According to Kemens et al (1991), most particulates from household cooking ranged from PM2.5 to PM10. Particulates of PM10 category are well-known precursors for respiratory ailments including lung cancer and bronchitis. They may carry with them organic toxins such as phenols, long chain hydrocarbons, and PAHs [14]. In various countries around the world, it has been noted that more than 80% of people spend most of their time indoors thus exposing themselves to harmful emissions as a consequence of high temperature cooking of food stuffs and toxic emissions from indoor fires [15, 16]. Accordingly, epidemiology studies have demonstrated that PM-induced toxic effects are often dependent upon PM size and composition [9]. If the origin of particulate emissions is of organic nature as presented in this study, then the emissions may cause numerous symptoms, including central nervous system breakdown, lung inflammation, and mucous membrane irritation in addition to other illnesses [17].

CONCLUSIONS

The particulate sizes from the pyrolysis of cashew nuts at 500 ˚C and 700 ˚C were slightly greater than PM_{10} classification. Nonetheless, the particulate emissions at 700 ˚C were insignificantly smaller than those produced at 500 ˚C possibly because at high temperatures, the emissions are largely carbonaceous. Based on these results and literature surveys, high temperature cooking may therefore be a source where harmful particulate matter, molecular toxins, intermediates, and free radicals are formed, and which may be precursors for ill health. Consequently, it is important to understand how high temperature pyrolysis of proteinaceous foods results in particulate emissions considered detrimental to the respiratory system and the human metabolic system as a whole. Moreover, it is well-documented in literature that these harmful by-products of combustion are well known precursors for mutagens and carcinogens implicated in numerous disease problems including gouts, aging, cancer, and asthma.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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