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Full Length Research paper

Assessing the level of chemical contaminant migration associated with cooking foods in polyethylene bags: A case study of Ugali

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The level of lead concentration profiles were assessed for maize meal (Posho) commonly known as Ugali cooked in black polyethene bags. The kinetics of degradation of color was employed assuming first-order color degradation to obtain the cook values during thermal treatment of white posho cubes at 25, 70, 80, 90 and 100°C. Posho cubes wrapped in black polyethylene bags were subjected to heat treatments equivalent to the obtained cook values and the samples were analyzed for amount of lead present. Lead ions were found to migrate to posho at all cooking temperatures and the resulting concentrations increased with increase in cooking temperature. Lead ions concentration was extremely low at the control temperature and increased with increase in treatment temperature. The maximum concentration of lead of 0.484 µg/dl was obtained at 80°C. The Lead concentration profiles within the posho cubes were determined by plotting the amount of migrated lead ions at different layers of posho cubes against depth. Lead concentrations were maximum and minimum at the surface and the centroid of the posho cubes respectively. The study revealed that the concentrations of Lead ions that migrated to posho cubes from polyethylene bags were within the stipulated consumer standards since it was just a tenth of the EPA published drinking water standard for lead of 0.05 mg/L (5 µg/dl).

Key words: Polyethylene bags, posho, lead contamination, migration, cook value, temperature, color degradation, reaction kinetics.

INTRODUCTION

Wrapping food in banana leaves for the purposes of keeping it hot/warm has been practiced for centuries across communities in Uganda. However, the use of polyethylene bags as opposed to banana leaves is on the steady increase. Increase in the use of polyethylene bags in this role is due to their high thermo-sealability and barrier properties to water (Kanetkar et al., 2007). Commercial food vendors are sure to serve a hot meal without necessarily spending a lot on energy. However, it is recommended that food materials should not interact with the food components in any way (Hotchkiss and Risch, 1991; Hotchkiss, 1997) to produce undesirable effects, such as food contamination or food safety problems. A number of studies (e.g., Gosselin and Mondy, 1989) have suggested that polythene materials contain a wide range of potential migrants for example residues from polymerization process, degradation compounds and additives; including lead and cadmium. Lead is toxic to human being when exposed to it. Lead is also a cumulative poison which poses a possibility of bioaccumulation in man even when exposed to low concentrations continuously (Agboola et al., 2005).

Color measurement techniques can improve the understanding on processing changes and reaction kinetics in foods (Ahmed et al., 2002). Dependable models that accurately predict the progress of a color degradation taking place in a homogeneous liquid or semi-solid during thermal degradation. A complete color description requires the use of three dimensions, and a control

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automatic system may be based on specifications set to provide an idea of food discoloration during sterilization, thermal treatment, roasting or storage (Barbosa et al., 2006). Foods, along with other materials, have color properties, which depend exclusively on their composition and structure (Giese, 2000). Ahmed et al. (2002) have reported that color degradation kinetics during thermal processing is best studied using tri-stimulus color values.

Pflug (1987), Gosselin and Mondy (1989) and Smout et al. (2003) suggested that knowledge of contaminants associated with polyethylene bags is prime for food safety. The state-of-the-art literature indicates that identifying hazards and risks associated with wrapping and packaging local food stuffs in colored low density polyethylene bags during and/or after cooking is *'a* little-studied topic' in Uganda whereas experiences from elsewhere (e.g., Heck et al., 1994) point to the fact that such a practice is potentially devastating. In this study, a commonly consumed maize meal (posho) also known as Ugali is prepared and cooked in polyethylene bags. The resulting lead migration profiles and color changes are documented and analyzed for any risks. Therefore, the global objective of this study was to quantify the amount of lead contamination during thermal treatment of Posho wrapped in polyethylene bags. To achieve this goal, the color degradation of Posho was studied basing on first order color degradation kinetics and the resulting values were used to estimate the temperature and cook value at which lead contamination would be at maximum.

MATERIALS AND METHODS

Determination of heating times (t)

A solution of 0.1 M of the Sodium hydroxide was prepared by dissolving sodium hydroxide pellets in water. This was used together with 95% ethanol liquid to neutralize all the equipment and apparatus used in this study. De-mineralized water used to prepare all solutions. Packaged maize flour was brought from the market and was used to prepare Posho. A stainless steel pan was used to prepare posho with a wooden mingling stick. An Aluminium molding box with inside dimensions of 5 cm was used to cut posho into 5 cm cubes. The experiment was carried out in 108 black polyethylene bags (Plasto-Foam brand, medium size 15" gauge) of 30 µm thickness. The cubes were heated in a well-stirred thermo-stated water bath (Grant instruments, Cambridge England) for pre-set times of 0, 10, 15, 20 and 25 min. The heating time was measured from the time the specimen's temperature reached the required processing temperature. In this study, five (5) holding temperatures were used, that is, 25, 70, 80, 90 and 100°C; each replicated three (3) times.

Color measurements

The most often used color measurement techniques in the food-processing studies are the Hunter color L, a, b system and CIE LAB color scales (Giese, 2000). Objective color measurements were made with a Color quest 45/0 spectrophotometer (Hunterlab, Reston, VA). The apparatus (45°/0° geometry, illuminant D65, 10° observer) was calibrated with a standard white tile (L = 90.55, a = -0.71, b = 0.39). Approximately 1 ± 0.5 g of the thermal treated Posho was comminuted in a laboratory size grinder fitted with a 14 mesh (1.19 mm) screen to obtain a meshed posho of uniform size. The meshed posho was dissolved in de-mineralized water to make 5 ml of a Posho puree. The puree was placed in a cylindrical glass cell (also known as a cuvette) and covered with a white plate to avoid inclusion of air bubbles before placed in the spectro-photometer. A glass cell containing the thermally-treated posho puree was placed above the light source and post-processing L, a, b values were recorded. Color measurements were taken in duplicate and average values were taken for calculation.

Determination of degradation rate constant (*k*)

The degradation rate constant was obtained using the equation for first order degradation kinetics (Equation 1)

$$\left(C/C_0 \right) = \exp\left(-kt\right) \qquad (1)$$

With C_0 symbolizing the measured Hunter a-value for color at zero time; C the measured a-value for color at any time t; k the degradation rate constant during heating; and t the heating time.

Determination of D and Z values

The k-values obtained from Equation (1) were converted into decimal reduction times (D-values) using the thermal death time (TDT) model using equation (2).

$$D = \frac{2.303}{k} \qquad (2)$$

Using thermal death time (TDT) model, the temperature dependence of the decimal reduction time was expressed by the z-value using Equation (3)

$$Z = \frac{(100-T)\ln 10}{\ln\left(\frac{D_T}{2.387}\right)} \qquad (3)$$

Determination of cook values

The z-values obtained in Equation (3) were used to estimate the corresponding cook values using the equation below

$$C = \int 10^{\frac{T-T_{ref}}{Z}} dt \qquad (4)$$

With C symbolizing the cook value in minutes and taking T_{ref} = 100°C and z as a kinetic degradation parameter of degradation of posho.

Determination of lead concentration

The Maize flour was mingled into Posho in a stainless steel saucepan using de-mineralized water. The resulting Posho was cut into 5 cm cubes using the aluminum mould and each cube was wrapped in a black polyethylene bag and placed in an aluminum sauce pan with a top cover. The cubes were heated in a well-stirred thermo-stated water bath (Grant instruments, Cambridge England) for pre-set times equivalent to the cook value at the given temperature. Five (5) holding temperatures were used, that is, 25°, 70, 80, 90, and 100°C. Three (3) replications were used for each

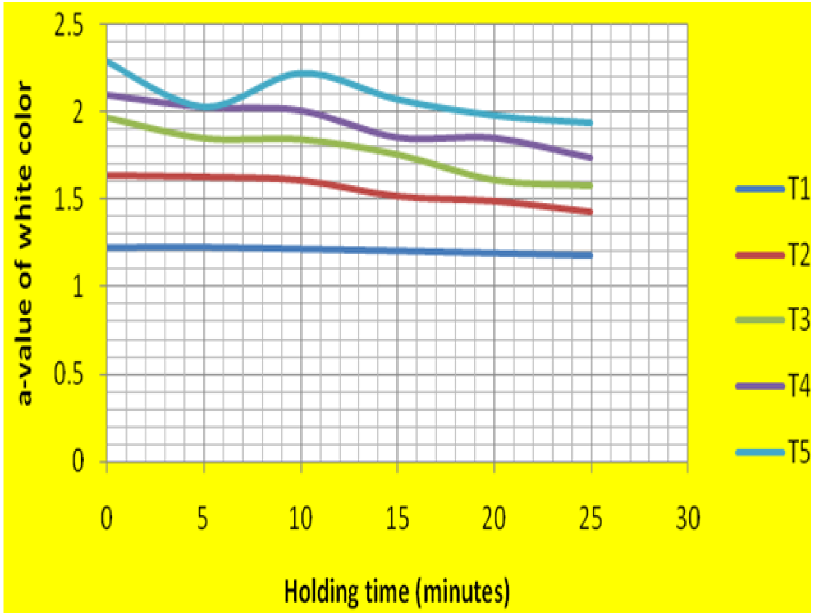

Figure 1. Average color values in white phoso ($T_1 < T_2 < T_3 < T_4 < T_5$).

Table 1. Average a-color values of the thermally treated posho cubes at different holding times (min) and treatment temperatures (℃).

Heating Time (Min)	a-value of T_1 (10^{-12}m)	a-value of T_2 (10^{-12}m)	a-value of T_3 (10^{-12}m)	a-value of T_4 (10^{-12} m)	a-value ofT_5 (10^{-12} m)
0	1.224	1.634	1.971	2.101	2.290
5	1.226	1.625	1.853	2.030	2.030
10	1.216	1.605	1.846	2.010	2.225
15	1.206	1.514	1.760	1.853	2.073
20	1.194	1.487	1.614	1.85	1.980
25	1.182	1.425	1.581	1.734	1.937

holding temperature. The thermally treated posho samples were transferred to ice water to avoid cooling lags which due to natural cooling and taken to the analytical laboratories for lead analysis using a UV- visible spectrophotometer.

Determination of migration profile

The thermal treatment that resulted in the most significant lead contamination was duplicated and the resulting posho cubes was mapped to produce a Lead concentration profile, samples were taken from cube surface up to the centroid of the cube. A graph of the migration profile with the centroid of the cube as the origin was plotted.

RESULTS AND DISCUSSIONS

Color measurements

The residual *a*–colour values were determined on the basis of isothermal heating experiments for temperatures ranging from 25 to 100℃ (With T_1 = 25℃, T_2 = 70℃, T_3 = 80℃, T_4 = 90℃, T_5 = 100℃) as summarized in Table 1. Figure 1 shows that the a-Color values increased with increase in the treatment temperatures, where as the a-value of posho decreased with increase in holding time for each respective treatment temperature and this concurs with the findings of Steet and Tong (1996) and Ahmed and Debnath (2002) that color values decreases during heating. Results summarized in Table 1 and depicted in Figure 1 show that the a-color value decreased with increase in holding time but increased with increase in treatment temperature.

Results depicted in Figure 1 indicate that the a-color value decreased with increase in holding time but increased with increase in treatment temperature. For lower temperature such as T_1 and T_2, the rate of decrease of the color values was smoother whereas for higher temperature T_3, T_4 and T_5 the rate of decrease

Table 2. Ratios of a-color values used to develop and compute degradation rate constants of first-order reaction kinetics.

Temp	Time (min)				
	5	10	15	20	25
T_1	0.00163	0.0066	0.0148	0.0248	0.0349
T_2	0.00552	0.0179	0.0763	0.0943	0.1369
T_3	0.06174	0.0655	0.1132	0.1998	0.2204
T_4	0.03438	0.04428	0.12561	0.12723	0.19198
T_5	0.01629	0.02879	0.09955	0.14545	0.16741

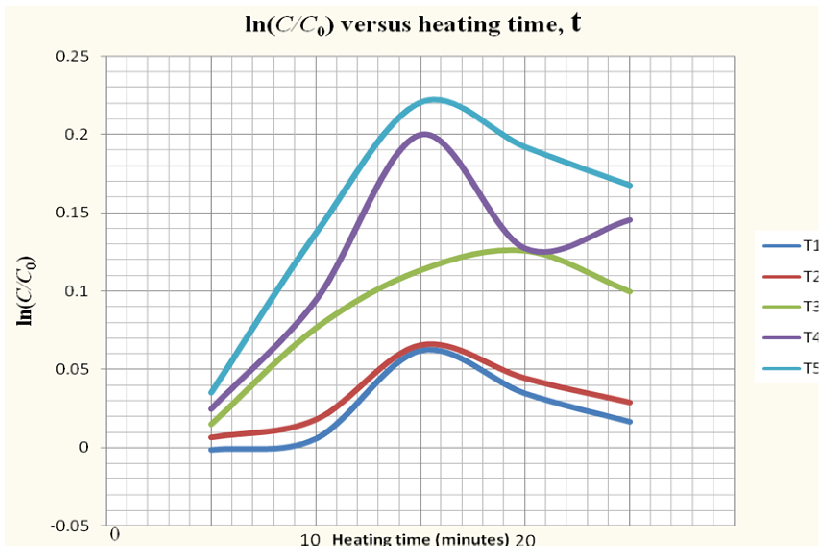

Figure 2. Color degradation of posho cubes at selected temperatures based on first-order reaction kinetics technique.

Table 3. Kinetic parameters for color change (Computed decimal values and cook values) for white posho for the selected treatment temperatures with T5 taken as the reference temperature.

Treatment	K (min^{-1})	D (min)	C (min)
T1	0.999	2.305	77.8
T2	0.950	2.424	67.6
T3	0.960	2.399	19.2
T4	0.953	2.417	11.9
T5	0.965	2.387	0

was steeper.

Determination of degradation rate constant

Using a-color values at 0 min as the initial color observation at each temperature, values were developed for the remaining holding times to satisfy Equation 1 as shown in Table 2.

In Figure 2, the first-order reaction kinetics curves show generally color degradation increases, reaches a maximum and then start to decline. Treatments at T_4 and T_5 take a short time to reach the maximum color degradation values where treatments at the lower treatment temperatures take a slightly longer time interval.

The kinetics parameters showed in Table 3 indicate that the degradation rate constants for the posho obtained from the first order kinetics linear regression analysis.

Results summarized in Table 3 and Figure 3 indicate the color changes under study obeyed first order degradation kinetics. At higher treatment temperatures, the shorter cook value times were obtained. This concurs with conventional knowledge that more time is required to cook at a lower temperature. Therefore the optimum contaminant migration from polyethylene to Posho was obtained after 77.8 min at room temperature (25°C), 67.6 min at 70°C, 19.2 at 80°C and 11.9 min at 90°C.

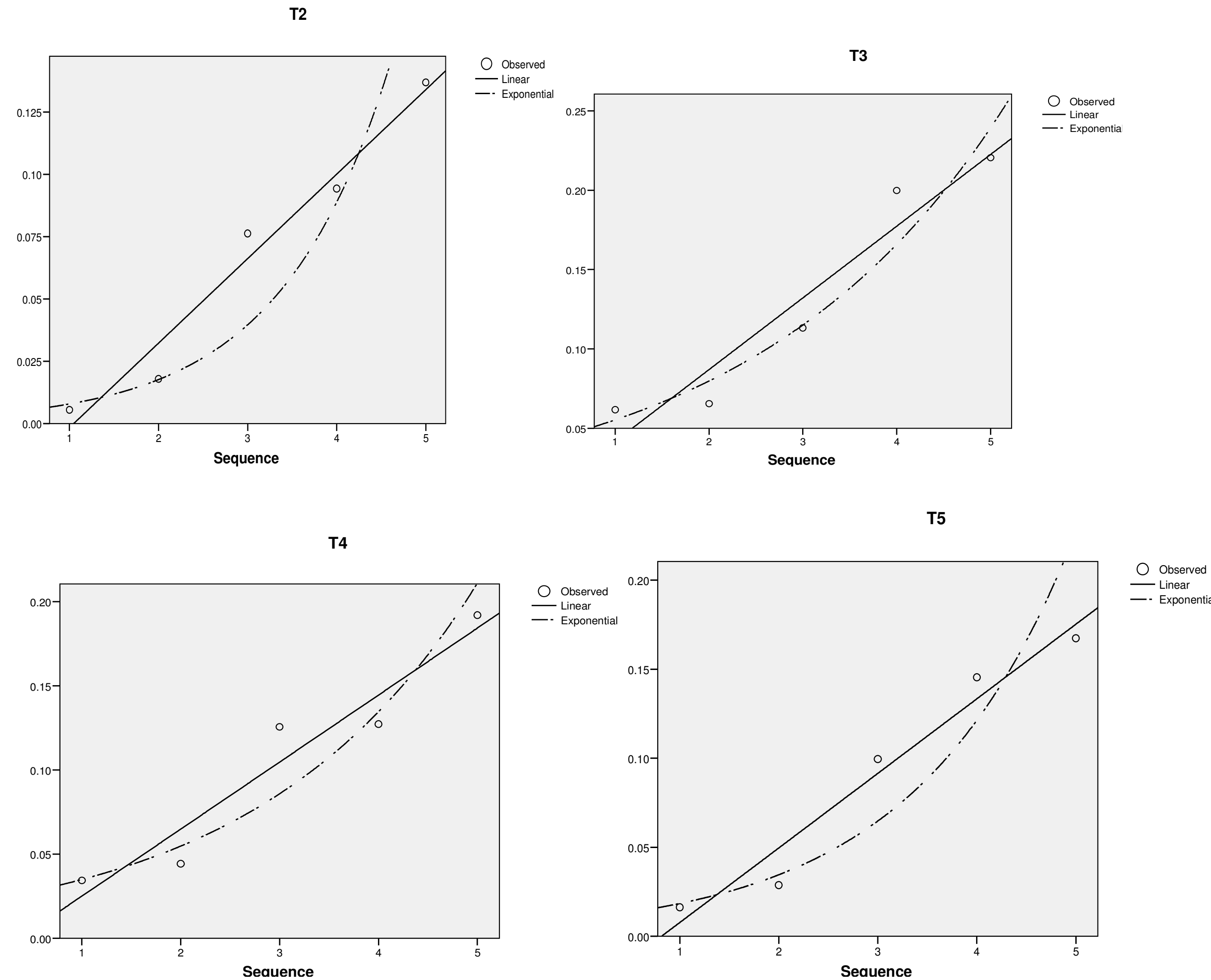

Figure 3. Color degradation kinetics of white *Posho* puree at selected temperatures of (a) *T*1 (b) *T*2 (c) *T*3 (d) *T*4 and (e) *T*5.

Table 4. Results of determination of lead concentrations (µg per deciliter) of the *posho* purees treated at different holding temperatures and corresponding holding times.

Treatment	Lead concentration (µg per deciliter) Replications			Total	Mean
	I	II	III		
T1(77.8)	0.052	0.033	0.098	0.183	0.061
T2(67.6)	0.257	0.216	0.286	0.759	0.253
T3(19.2)	0.498	0.472	0.483	1.453	0.484
T4(11.9)	0.371	0.396	0.344	1.111	0.370

Table 5. Profiling lead (µg per deciliter) migration.

Position	Lead concentration (µg per deciliter) Replications			Total	Treatment Mean
	I	II	III		
1 (Surface)	0.465	0.391	0.478	1.334	0.445
2 (0.5)	0.107	0.198	0.077	0.382	0.127
3 (1.0)	0.012	0.007	0.002	0.021	0.007
4 (1.5)	0.001	0.000	0.004	0.005	0.002
5 (2.0)	0.000	0.001	0.000	0.001	0.000
6(2.5)	0.002	0.000	0.000	0.002	0.001

Determination of Lead concentration

In a further step, the migration of lead and its associated accumulation (concentration) in the posho cubes upon heating was studied in depth for temperatures ranging from 25 to 90°C. The obtained results are summarized in Table 4.

Lead concentration was extremely low at the control temperature and increased as with increase in treatment temperatures. T_3 produced the maximum concentration of lead of 0.484 µg per deciliter as indicated in Table 4. This was in agreement with study of Hotchkiss (1997) that also observed that migration (diffusion) increased with increase in temperature.

The amount of lead concentration decreased as the centroid was approached and it was very minimal. The surface of the posho cube contained the highest lead concentration and gradually decreased along a gradient as represented in Table 5. This concurred with Fick's first law of diffusion since a concentration gradient exist between the polyethylene bag and the posho, diffusion takes place and creates another concentration gradient within the cube leading to a diffusive flux.

CONCLUSIONS AND PERSPECTIVES

Results in this study indicated that cooking posho at temperature of 80°C for 19.2 min produced the highest contamination of Lead 0.484 µg/dl of posho. Comparing this concentration with the EPA published drinking water standard for lead of 0.05 mg/l (5 µg/dl), the lead concentration in posho at the investigated temperatures is just a tenth of the drinking water standard. This implies that lead concentrations in posho wrapped in polythene bags does not pose an acute danger to human health. However, this study did not investigate the chronic effects or dangers associated with consuming such amounts of lead. Further research could focus on migration of chemical contaminants of different wrapping polyethene bags at higher temperatures and food-contact surface area effects. It may be interesting to investigate the diffusion and dispersion dynamics of such chemicals in food during cooking. Conclusively, the results from this study indicate that (1) lead migrates into foods wrapped in polythene bags that were investigated and that (2) the associated kinetics is first order.

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REFERENCES

Agboola OS, Durosinmi LM, Morakinyo MK, Ogunfowokan AO (2005). Levels of lead and cadmium in some Nigeria confection wrappers. J. Appl. Sci., 5(6): 1032-1035.

Ahmed J, Shivhare US, Debnath S (2002). Color Degradation and Rheology of Green Chilli Puree During thermal processing. Int. J.

Food Sci. Technol., 37: 57–64.
Smout C, Banadda EN, Hendrickx MEG, Van Loey AML, (2003). Nonuniformity in lethality and quality in thermal process optimization: A case study on color degradation of green peas. J. Food Sci,. 68: 545-550.
Barbosa-Cánovas GV, Juliano P, Peleg M (2006). Engineering Properties of Foods, in Food Engineering, [Ed. Gustavo V. Barbosa-Cánovas], in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, EOLSS Publishers, Oxford, UK.
Giese J (2000). Color Measurement in Foods as a Quality Parameter. J. Food Proc. Pres., 24: 253–263.
Gosselin B, Mondy NI (1989). Effect of packaging materials on the chemical composition of potatoes. J. Food Sci., 54(3): 629-631.
Hotchkiss JH (1997). Food-packaging interactions influencing quality and safety. Food Add. Cont., 14: 601–607.
Hotchkiss JH, Risch SJ (1991). In S. J. Risch and J. H. Hotchkiss (Eds.), Food and packaging interactions II. ACS symposium series, American Chemical Society: Washington, DC., 473: 1–10
Kanetkar VR, Sajilata MG, Singhal RS, Savitha K (2007). Scalping of flavors in packaged foods. Comp. Rev. Food Sci. Food Safety. 6: 17–35.
Pflug IJ (1987). Factors Important in Determining the Heat Process Value for Low Acid Canned Foods. J. Food Prot., 50: 528-533.
Steet JA, Tong CH (1996). Degradation Kinetics of Green Colour and Chlorophyll In Peas By Colorimetry and HPLC. J. Food Sci., 61: 924–931.