NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 52 Number 1, April 2021 Pg. 201-211
Available online at: http://www.ajol.info/index.php/naj
https://www.naj.asn.org

EFFECTS OF DIFFERENT PACKAGING MATERIALS ON THE CHEMICAL AND SENSORY PROPERTIES OF *MOI-MOI*

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Abstract
The preparation of *moi-moi* usually involves wrapping of cowpea slurry with packaging materials such as broad leaves, aluminium foils, aluminium cans, nylon, plastic plate or stainless steel plate before cooking to form a gel. There are concerns that these packaging materials are pathways for the migration of hazardous substances into the food. The packaging materials and ingredients for *moi-moi* preparation were obtained from Ndoro Oboro periodic market, Ikwuano Local Government Area, Abia State, Nigeria. The *moi-moi* mix was prepared using standard method and wrapped in the packaging materials listed before cooking. The proximate composition, heavy metals and volatile components of *moi-moi* samples were characterized using standard methods. The moisture, crude protein, fat and ash content of the samples were significantly affected by packaging material. The nickel content of the *moi-moi* samples ranged from 0.017 (in *moi-moi* cooked with plastic plate) to 0.335 mg/l (in *moi-moi* cooked with Aluminium foil). The cadmium content ranged from 0.031mg/l (in moi-moi cooked with leaves) to 0.092mg/l (in *moi-moi* cooked in aluminium foil). The aluminium content of the samples packaged in aluminium can and aluminium foil was significantly higher than that of the other samples. The lead content ranged from 0.009mg/l (in *moi-moi* packaged in stainless steel) to 0.036mg/l (in *moi-moi* packaged in plastic plate, aluminium can and nylon). A total of seventy seven (77) volatile compounds were identified in the *moi-moi* samples, some of which were suspected to have migrated from the packaging materials. Among which were Morphinan-4, 5-epoxy-3, 6-di-ol, 6,-[7-nitronenzofuran-4-yl] amino which was identified in *moi-moi* cooked in leaves and is a by-product of polychlorinated dibenzo-furans (PCDFs) used as pesticide. The compound;10-Acetoxy-2-hydroxy-1,2,6a,6b,9,9,12a-heptamethyl-1,3,4,5,6,6a,7,8,8a,9,10,11,12,12a,12b,13,14b octadecahydro present in the *moi-moi* packaged in nylon is likely to be a product of triacetin used for manufacturing food contact plastics. The results from this study indicate that packaging materials have significant effects on the proximate, heavy metals, sensory and volatile compounds composition of *moi-moi* produced from the same bean slurry.

Keywords: Food contact surfaces, *moi-moi*, heavy metals, volatile organic compounds

Introduction

Food contact surfaces are made up of materials which can be transferred from the food contact surface into the food and are consequently taken up by humans. Scientific findings have shown that food contact materials are relevant exposure pathways for hazardous substances. The society is striving for waste reduction with a focus on food packaging. In this regard, suggestions are made for reuse, recycling or alternative (non-plastic) materials, however, chemical safety of these materials are often over looked. *Moi-moi* is a gel produced by heating slurries containing cowpea solids of 15% and above in packaging materials such as broad leaves of plants, aluminium foil, aluminium plates, cellophane etc. (Akusu and Kiin-Kabari, 2012). Natural packaging materials like banana and broad (*Thaumatococcus danielli)* leaves used in packaging *moi-moi* boost the colour, flavour and enhance the nutritional potentials by leaching some biochemical compounds into *moi-moi* during cooking (Ajala, 2011; Onwuka, 2014). However, they are permeable to moisture, oxygen, odour or micro-organisms.

There have been some health concerns regarding residual monomer and components in plastics, including stabilizers, plasticizers, and condensation components such as bisphenol A. Aluminium cans naturally coated with aluminium oxide are the most widely used material for cooking *moi-moi* with higher effective barrier to temperature, moisture, high resistance to most forms of corrosion and chemical attack (Marsh and Bugus, 2007). The use of Aluminium cookware, utensils and wrappings can increase the amount of Aluminium in food; however the magnitude of this increase is not of practical significance (WHO, 2010). Stainless steels are also a group of iron based alloys containing at least 10.5% chromium and a maximum of 1.2% carbon. Stainless steel is perfectly good for packaging food as the taste and appearance remain unchanged. The release of appreciable quantities of metals such as Cr, Ni and Fe and consequent excessive intake of these metals can cause health hazards (Langard and Norseth, 1986; WHO, 1991). Packaging materials must be such that any potential transfer to foods does not raise safety concerns, change the composition of the food in an unacceptable way or have adverse effects on the taste and or odour of the foods (Marsh and Bugus, 2007). Accominotti *et al*. (1998) measured the chromium and nickel levels in meals cooked in stainless steel pans; two tested pans contained 17 and 18% of chromium.

Recently, food packaging has gained a widespread importance in food safety due to the possibility of migration of chemicals from food contact materials, while keeping foods safe from contamination and retaining the nutritional and sensory properties of foods. The increasing use of synthetic materials in the packaging and cooking of *moi-moi* has called for definitive information on the composition of the finished product as regards to the food safety and quality of the *moi-moi* produced, as high temperature encountered during the cooking process may induce thermal decomposition products, that can migrate into the *moi-moi* and cause undesirable changes. Therefore, the objective of this study is to determine the impact of different packaging materials on the sensory and chemical properties of *moi-moi*. The results from this study will help to make informed decisions on the appropriate packaging material for *moi-moi*.

Materials and Methods

Materials procurement

The materials used for the preparation of *moi-moi* are Beans (Cowpea, 600g), Vegetable oil (25ml), salt(1.5g), onions (25g), magi cubes (2g), pepper (20g), different packaging materials like; Uma (*Thaumacoccus daniellii*) leaf, aluminium foil, aluminium cans, nylon bags, plastic plate and stainless steel plate. The materials used for the preparation were purchased from Ndoro Oboro periodic (weekly) market, Ikwuano Local Government Area, Abia State, Nigeria.

Sample preparation

The method described by Enwere (1998) with slight modification was used in the preparation of the *moi-moi* samples. The beans were sorted to remove dirt and soaked in water (1:3 by volume) for 10 minutes after which the beans coat was manually removed by rubbing in between the palms and washed. The de-coated beans were wet milled with pepper and onion into a paste. The other ingredients (salt, seasoning cube, vegetable oil and water) were mixed into the cowpea paste, the mixture was stirred and poured into six different packaging materials; broad leaves, plastic plate, stainless steel plate, nylon, aluminium can and aluminium foil with each one replicated three times and they were steamed in the same pot for 45 minutes at 100^{o}C.

Determination of Proximate Composition of Moi-moi

Proximate analyses of the *moi-moi* were carried out as described by Onwuka (2018). These include the moisture content, ash, crude protein, crude fat, crude fibre and carbohydrate.

Determination of Heavy Metals

The heavy metals were determined as described by APHA (1995). Heavy metals such as Lead (Pb), Zinc (Zn), Nickel (Ni), Cadmium (Cd) and Aluminium (Al) were determined using Atomic absorption spectrophotometer (AAS).

Determination of Volatile Organic Compounds

The Volatile Compounds were analyzed using the method described by Ezhilan and Neelamegam, (2011). One gram (1g) of the *moi- moi* sample was extracted using diethyl ether (1:10, w/v) for five times. The obtained solution was filtered and the solvent of filtrate removed by evaporating in a water bath at 40^{o}C. Then the extractum was diluted with 1ml of anhydrous ethyl alcohol: n-hexane (1:1, v/v) and filtered using a wattman filter paper. This was injected into GC/MS (HEWLETT 5890 SERIES 11) for analysis. The temperature was programmed from 200^{o}C to 300^{o}C at a rate of 4^{o}C min^{-1} with 10 minutes hold. Injection was at 200°C. The carrier gas was Helium with a constant flow at 1ml/min. Mass method used was Electron Ionization with ionization voltage of (EI+) 70 eV for m/z value 50 to 300 with a scan time of 0.3sec and interscan delay of 0.1sec. Interpretation on mass-spectrum GC-MS was conductedusing the database of National Institute Standard and Technology (NIST) having more than 62,000 patterns. The spectrum of the unknown components was compared with the spectrum of known components stored in the NIST library. The name, molecular weight and structure of the components of the test materials were ascertained.

Sensory Evaluation of the Moi-moi

The *moi-moi* samples produced were subjected to sensory test by 20 panellists using the 9 point hedonic scale as described by Iwe (2010). Sensory parameters such as appearance, texture, aroma, taste, and overall acceptability were evaluated.

Statistical Analysis of Data

The data from this study were statistically analyzed using one way analysis of variance (ANOVA) and the means separated by Duncan's new multiple range test (DNMRT) using the Statistical Package for Social Sciences (SPSS) version 16 at 5% ($P<0.05$) acceptable level.

Results and Discussion

Effect of packaging materials on Proximate Composition of moi-moi

The effect of packaging materials on Proximate Composition of *moi-moi* is presented in Table 1.

Table 1 Proximate Composition of the *moi-moi* samples

Sample	Moisture (%)	Protein (%)	Fat (%)	Crude Fiber (%)	Ash (%)	CHO (%)
Stainless steel	66.38^{d}±0.06	1.55^{b}±0.04	3.74^{a}±0.70	9.65^{a}±0.55	1.33^{a}±0.01	17.77^{a}±0.07
Plastic plate	70.89^{b}±0.51	1.59^{b}±0.18	3.52^{ab}±0.10	6.61^{b}±0.66	1.35^{a}±0.01	14.74^{b}±0.57
Leave	72.11^{a}±0.10	2.22^{a}±0.28	2.29^{c}±0.15	7.77^{ab}±0.36	0.92^{b}±0.10	15.52^{ab}±0.98
Al can	69.26^{c}±0.29	1.40^{b}±0.23	2.61^{c}±0.28	9.21^{ab}±0.63	1.47^{a}±0.28	16.07^{ab}±0.01
Nylon	69.53^{c}±0.35	2.04^{a}±0.21	2.78^{bc}±0.20	7.22^{ab}±1.64	1.58^{a}±0.18	16.86^{ab}±1.52
Al foil	71.28^{b}±0.26	1.31^{b}±0.03	2.73^{bc}±0.18	7.44^{ab}±1.54	1.32^{a}±0.04	15.93^{ab}±01.63

Values are means of duplicate determinations± standard deviation. Means along a column with different superscripts are significantly different at (p< 0.05). Where Al can= Aluminium can and Al. foil = Aluminium foil

The moisture content of the samples ranged from 66.38% in *moi-moi* packaged with stainless steel to 72.11% in *moi-moi* packaged in Leave. The moisture contents of *moi-moi* packaged in plastic plate and aluminium foils were not significantly ($p>0.05$) different, likewise *moi-moi* packaged in aluminium can and nylon. However, significant difference ($p< 0.05$) exists between the moisture content of other *moi-moi* samples. The difference observed in the moisture content of the samples could be as a result of the kind of packaging material used since all the *moi-moi* samples were made from the same mix. The moisture content of the samples is higher than that (50.10%-55.10%) reported by Okwunodulu *et al*. (2019) for *moi-moi* made from cowpea seeds. However, it compared well with that (62.65%-71.26%) reported by Ikechukwu *et al*. (2018) for *moi-moi* from cowpea-maize flour blends. High moisture content in *moi-moi* packaged with leave and aluminium foil could be because of the low moisture barrier of these packaging materials causing water to penetrate thus increasing the moisture content. *Moi-moi* packaged in stainless steel had the lowest moisture content; this could be as a result of more moisture loss from *moi-moi* in stainless steel than any other packaging materials, because stainless steel conducts heat faster and as such causing faster moisture loss.

The crude protein content of the *moi-moi* samples ranged from 1.31% in *moi-moi* cooked in aluminium foil to 2.22% in *moi-moi* cooked in leaves. A similar observation was made by Aniebet and Olanrewaju (2018), who reported that *moi-moi* packaged in banana leaves had higher protein content than *moi-moi* in other packaging materials. There was no significant ($p>0.05$) difference between the protein content of *moi-moi* packaged in stainless steel, plastic plate, aluminium can and aluminium foil. There was also no significant ($p> 0.05$) difference between protein content of *moi-moi* in leaves and that packaged in nylon. The crude protein content of the samples is very much lower than 31.5% and 34.46% reported by Adeyeye *et al*. (1995) and Aniebet and Olanrewaju (2018), however it is similar to 4.81%-4.98% reported by Okwunodulu *et al*. (2019). The protein content of *moi-moi* packaged with leaves was significantly ($p< 0.05$) higher than the rest of the *moi-moi* samples, this could be as a result of possible migration of some proteins from the leaves into the *moi-moi* sample during cooking, hence increasing the protein content (Chinedu *et al*., 2014; Dosumu and Akinnuonye, 2015).

The fat content ranged from 2.29%-3.74%, with highest value observed in the *moi-moi* packaged in stainless steel and the lowest observed in *moi-moi* packaged with leaves. Low fat content of the samples packaged with leave could be because water can penetrate into the leaves thus causing some quantity of fat to leach into the cooking water. The ash content ranged from 0.92%-1.58%, with highest value observed in *moi-moi* packaged in nylon and the lowest result observed in *moi-moi* in leaves. The ash content of *moi-moi* packaged with leaves was significantly ($p< 0.05$) lower than the rest of the *moi-moi* samples. Ash content of a sample represents the inorganic residue (minerals) left after ignition or complete oxidation of organic matter (Onwuka, 2018). The low ash content observed in *moi-moi* wrapped in leaves could be as a result of leaching of minerals from *moi-moi* into the cooking water.

Effect of packaging materials on Heavy Metals Composition of moi-moi

The mean concentrations of Lead, Cadmium, Nickel, Zinc and Aluminium in *moi-moi* cooked with different packaging materials are presented in Table 2.

Table 2: Heavy Metal Composition of the *moi-moi* samples

Sample	Nickel(mg/l)	Zinc(mg/l)	Cadmium(mg/l)	Aluminium(mg/l)	Lead(mg/l)
Stainless steel	0.031^{e}±0.00	0.027^{a}±0.03	0.078^{b}±0.01	0.687^{c}±0.00	0.009^{c}±0.00
Plastic plate	0.017^{a}±0.01	0.003^{c}±0.00	0.040^{d}±0.01	0.001^{e}±0.01	0.036^{a}±0.01
Leave	0.025^{c}±0.01	0.002^{c}±0.01	0.031^{f}±0.01	0.002^{e}±0.01	0.021^{b}±0.01
Al. can	0.026^{d}±0.00	0.020^{b}±0.00	0.053^{c}±0.01	1.727^{b}±0.01	0.036^{a}±0.01
Nylon	0.021^{b}±0.01	0.002^{c}±0.00	0.045^{d}±0.01	0.063^{d}±0.01	0.036^{a}±0.01
Al. foil	0.335^{f}±0.01	0.018^{b}±0.01	0.092^{a}±0.01	1.794^{a}±0.00	0.026^{b}±0.01

Values are means of duplicate determination± standard deviation. Means with different superscripts are significantly different at (p< 0.05)

The nickel content of the *moi-moi* samples ranged from 0.017 (in *moi-moi* cooked with plastic plate) to 0.335 mg/l (in *moi-moi* cooked with Aluminium foil). The variation in the nickel content observed could be due to packaging materials. The nickel level of the *moi-moi* samples is very low compared to 0.82 mg/kg - 2.87 mg/kg reported for some commercial yam products in South Korea (Mee-Young *et al*., 2013). Severe lung damage has been recorded following acute exposure to nickel carbonyl (WHO, 1991). Another reported health effect is; allergic skin reactions (Nielsen and Menne, 1993). Exposure to nickel can also cause increased risk of laryngeal cancer, kidney cancer and cancer of the prostrate (WHO, 1991).

Zinc content of the *moi-moi* samples ranged from 0.002mg/l (in *moi-moi* cooked in leaves and nylon) to 0.027mg/l (in *moi-moi* cooked in stainless steel). The level of zinc observed in *moi-moi* packaged in stainless steel and aluminium can and aluminium foil was significantly higher than that in other samples. However, it was still below the permissible limit of 1.5 mg/kg for zinc in foods (WHO, 1999). The zinc level in these samples is also very low compared to 0.190mg/l – 2.280 mg/l reported for some selected Nigerian beverages (Ogundele *et al*., 2015). Zinc is an essential trace element found in almost all food and portable water; it is found in forms of salts or organic complexes (Ogundele *et al*., *ibid*). Zinc has the least toxicity effects among other minerals and its deficiency in a diet can cause health problems (Ukom *et al*., 2019). It is recommended at level of 15mg/day for men and 12mg/day for women (ATSDR, 1994).

The cadmium content ranged from 0.031mg/l (in moi-moi cooked with leaves) to 0.092mg/l (in *moi-moi* cooked in aluminium foil). According to FAO/WHO, 0.007 mg/kg body weight is recommended for cadmium (JECFA, 2004). It is safe to say that regular use of aluminium foil as packaging material possess a chance of increasing cadmium accumulation in the body. Accumulation of cadmium in the body affects negatively several organs like; liver, kidney, lungs, bones, placenta, brain and the central nervous system (Castro-Gonzalez and Mendez-Armenta, 2008).

The Aluminium content of the *moi-moi* samples ranged from 0.001mg/l (in *moi-moi* packaged in plastic plate) to 1.794mg/l (in *moi-moi* packaged in Aluminium foil). The aluminium content of the samples packaged in aluminium can and aluminium foil were significantly higher than that of the other samples. The high content of aluminium in the samples packaged in aluminium can and aluminium foil could be an indication that aluminium could have migrated into the sample from the packaging materials since all the *moi-moi* samples were from the same mix (Stahl *et al*., 2011). The provisional tolerable weekly intake for aluminium is 1mg kg^{-1} weight/week (WHO, 1997). The aluminium content of the samples was below the permissible limit. Soluble aluminium compounds have demonstrated reproductive toxicity and developmental toxicity including decreased growth, delayed maturation and impaired neurodevelopment in experimental animals (WHO, 1997; WHO 2010).

The lead content ranged from 0.009mg/l (in *moi-moi* packaged in stainless steel) to 0.036mg/l (in *moi-moi* packaged in plastic plate, aluminium can and nylon). The lead result recorded for this study is below 0.025mg/kg body weight which is the permissible limit recommended by FAO/WHO (JECFA, 2004). Lead as a heavy metal has been reported to be highly toxic and their presence in foods is not to be accepted even in trace quantities (Ogunkunle *et al*., 2014).

Effect of packaging materials on Sensory properties of moi-moi

The sensory scores of *moi-moi* produced using different packaging materials are presented in Table 3.

Table 3: Sensory Evaluation of *Moi-moi*

Sample	Appearance	Texture	Aroma	Taste	Gen. Accept
Stainless steel	$7.75^{a}\pm0.64$	$7.65^{ab}\pm0.59$	$7.55^{ab}\pm0.76$	$7.30^{b}\pm1.08$	$7.60^{b}\pm0.82$
Plastic plate	$7.00^{b}\pm0.97$	$7.35^{ab}\pm0.99$	$7.30^{bc}\pm0.92$	$7.35^{b}\pm0.88$	$7.65^{b}\pm0.67$
Leave	$6.85^{b}\pm1.08$	$7.85^{a}\pm0.81$	$8.10^{a}\pm0.79$	$8.15^{a}\pm0.81$	$8.30^{a}\pm0.73$
Al. can	$7.35^{ab}\pm0.81$	$7.20^{b}\pm0.89$	$7.00^{bc}\pm1.17$	$7.10^{b}\pm0.97$	$7.15^{bc}\pm0.93$
Nylon	$7.70^{a}\pm1.23$	$7.05^{b}\pm1.10$	$6.85^{c}\pm0.75$	$7.05^{b}\pm0.95$	$7.05^{c}\pm0.95$
Al. foil	$7.25^{ab}\pm1.25$	$7.40^{ab}\pm0.82$	$7.45^{bc}\pm0.95$	$7.55^{b}\pm0.76$	$7.30^{bc}\pm0.57$

Values are means of duplicate determinations± standard deviation. Means with different superscripts are significantly different at (p< 0.05)

The appearance rating ranged from 6.85-7.75, with highest rating observed in the *moi-moi* in stainless steel and the lowest observed in *moi-moi* packaged with leaves. There was no significant (*p>0.05)* difference between *moi-moi* packaged in stainless steel, nylon, aluminium can and aluminium foil. There was also no significant (*p>0.05)* difference between *moi-moi* packaged in plastic plate and leaves. The low appearance rating observed in *moi-moi* packaged with leaves could be as a result of leaching of some colorants from the leaves into the *moi-moi* during cooking, altering the colour. Appearance is one of the first indicators of quality; it contributes and influences the market value. The texture scores of the samples ranged from 7.05-7.85, with the highest score observed in the *moi-moi* packaged in leaves and the lowest observed in *moi-moi* packaged in nylon. There was no significant (*p> 0.05)* difference between the texture scores of *moi-moi* packaged in leaves and the *moi-moi* packaged in plastic plate, stainless steel and aluminium foil but it varied significantly (*p< 0.05)* with the rest of the *moi moi* samples. Chinedu *et al*. (2014) reported that leaves contain carbohydrate which upon hydrolysis may migrate into *moi-moi*, then gelatinize and in turn enhance texture of the *moi-moi*.

The taste scores of the *moi-moi* samples ranged from 7.05-8.15, with highest score observed in the *moi-moi* packaged with leaves and the lowest score observed in *moi-moi* packaged with nylon. The result shows that leaves impart more acceptable flavour in *moi-moi* than the other packaging materials used in this study; this could be because some essential oils could have migrated into the sample, thus the higher perceived flavour and taste in the *moi-moi* packaged in leaves (Dosumu and Akinnuonye, 2015).Taste is a determining factor of consumer acceptance.

The General acceptability rating ranged from 7.05-8.30, with highest rating observed in *moi-moi* packaged in leaves and the lowest rating observed in *mio-moi* packaged in nylon. The general acceptability of *moi-moi* packaged in leaves was significantly ($p< 0.05$) higher than the rest of the *moi-moi* samples, however, the *moi-moi* samples were all acceptable to the panellists.

Volatile Compounds in moi-moi cooked in different packaging materials

The volatile components of *moi-moi* are shown in Table 4. A Total of seventy seven (77) volatile compounds were found in the *moi-moi* samples. These compounds are of various groups; hydrocarbons, acids, ketones, esters, alcohols and terpene. Esters were the dominant constituents; it constitutes over 50% of the total volatiles in the *moi-moi* samples. The *moi-moi* packaged in nylon had highest amount of volatile organic compounds, followed by *moi-moi* in plastic plate, while the least was *moi-moi* in aluminium foil. The variation in the number of volatile compounds in the *moi-moi* samples could be due to the variation in the packaging materials, since all the *moi-moi* samples were prepared from the same mix.

Some of the acids observed in the samples are similar to the acids discovered in leaves and seeds of *P. guineense*, they include; acetic acid, dodecanoic acid, eicosanoic acid (Jirovetz *et al*., 2002). Acetic acid and butanoic acid are used in various industries as flavouring agents (Ojinnaka *et al*., 2016). Carboxylic acids found present in this study are; butanoic acid, 4-chloro-, 1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-4a,7b-dihydroxy-3(hydroxymethyl)-1,1,6,8-tetram, docosahexaenoic acid, 1,2,3-propanetriyl ester, 9,12,15,-Octadecatrienoic acid, 2-phenyl-1,3-dioxan-5-yl ester, 8,11,14-eicosatrienoic acid, methyl ester (Z,Z,Z), 11,13-Dihydroxy-tetradec-5-enoic acid, methyl ester, dodecanoic acid, 1a,2,5,5a,6,9,10,10a-octahydro-5a-hydroxy-4-(hydroxymethyl)-1,1,7,9-tetramethyl-6,11-dioxo. Most of carboxylic acids are used in production of polymers. Some of them for example decanoic acid and dodecanoic acid are found in palm oil (Wikipedia, 2020), hence must have been present in the *moi-moi* samples from vegetable oil. The *moi-moi* packaged in stainless steel had highest concentration of carboxylic acids and this could be because it had the highest fat content among all the samples due to minimal leaching; most of these carboxylic acids are from fat.

One of the compounds present in the *moi-moi* packaged in leaves was morphinan-4,5-epoxy-3,6-di-ol, 6,-[7-nitronenzofuran-4-yl]amino; this volatile compound is a by-product of polychlorinated dibenzo-furans (PCDFs) (Wenjing *et al*., 2019) used as pesticide by farmers and must have found its way into the *moi-moi* from the leave used in packaging it. Exposure to such compounds, usually at high levels may cause various health problems such as cancer, birth defects, endocrine disruption and cardio vascular diseases (Wenjing *et al*., *ibid*). Tungsten dicarbonylbis(η-4-2-methylenecycloheptanone)[1,2-bis(dimethylphosphino)ethane was present in the *moi-moi* sample packaged in leave and nylon, tungsten has been shown to act by antagonizing the action of essential trace element molybdenum and copper. All tungsten compounds are regarded as being highly toxic (Hille, 2002). Decanoic acid esters; dodecanoic acid, 1a,2,5,5a,6,9,10,10a-octahydro-5a-hydroxy-4-(hydroxymethyl)-1,1,7,9-tetramethyl-6,11-dioxo and decanoic acid, 1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-4a,7b-dihydroxy-1,1,6,8-tetramethyl-5-oxo-3-[(1-oxodecyl)o were present in the moi-moi samples packaged in Aluminium can, they are used in the manufacture of esters for artificial fruit flavours (Adekoyeni *et al*., 2018). These volatile compounds must have been formed in the *moi-moi* samples during cooking.

Cholestane, 3, 5-dichloro-6-nitro-, (3β 5α, 6β) was found in all the *moi-moi* samples and it has anticancer activity. This compound may have been formed in the *moi-moi* samples during the preparation.

Hematoporphyrin was found in the *moi-moi* packaged with leave and aluminium can, it is a porphyrin prepared from hemin and a derivative of protoporphrin(ix), where the two vinyl groups have been hydrated to alcohols (Evstigneeva *et al*., 1977). They are used as antidepressant and antipsychotic (O'Neil and Maryadele, 2001). 8,11,14-Eicosatrienoic acid, methyl ester (Z,Z,Z) was found in the *moi-moi* packaged with plastic plate, it has been reported to have anti-cancer and cardio protective activity (Vijaya-Baskar and Elango, 2018). Trilinoleinis a volatile compound present in *moi-moi* packaged in plastic plate. It is a triglycerol with linoleic acid as the fatty acid residue at all 3 esterified positions of glycerol and has been shown to improve erythrocyte deformability, inhibit platelet aggregation, exhibit anti-inflammatory and anti-oxidant activities (Chan *et al*., 2005)

10-Acetoxy-2-hydroxy-1,2,6a,6b,9,9,12a-heptamethyl 1,3,4,5,6,6a,7,8,8a,9,10,11,12,12a,12b,13,14b-octadecahydro that was present in the *moi-moi* packaged in nylon is likely to be a product of triacetin. Triacetinis was used for manufacturing food contact plastics until 2009 (Panseri, 2014). This compound must have migrated from nylon into the *moi-moi*. Tricaetin possess antifungal properties and is generally recognized as safe (GRAS) by Food/Drug Administration (FDA) (Sendon-Garcia *et al*., 2006). Desoline is an alkaloid that was identified in *moi-moi* packaged in stainless steel and nylon. It has been reported to have both curare-like effect and a ganglion blocking effect and is used to relief muscle tension (Shao *et al*., 2018). It is not clear the source of this compound. Rhodoxanthin found in *moi-moi* packaged in Al can is a red carotenoid found in small quantities in a variety of plants. As a food additive, it is used under the E number E161f as a food colouring (Hudon *et al*., 2012). Most of the volatile organic compounds gotten from this study do not have any existing toxic information available from past epidemiological studies or animal experiments thus their safety limits are not available.

Table 4: Volatile Compounds composition of *moi-moi* produced using different packaging materials

Compounds	Steel	Plastic plate	Leave	Al. can	Nylon	Al. foil
Hydrocarbons						
Cholestane, 3,5-dichloro-6-nitro-, (3β 5α, 6β	39.0	61.1	61.5	27.9	31.7	13.5
5H-Cyclopropa(3,4) benz (1,2-e)azulen-5-one, 3,9, 9a tris(acetyloxy)methyl-2-chloro-1-1a,1b, 2,3,4	33.67	30.35	36.4	37.0	37.1	-
Alcohols						
Ethanol, 2-(9,12-octadecadienyloxy)-, (Z,Z)	12.0	-	-	-	-	22.7
Cis-inositol tri-n-octanrboronate	22.1	-	-	-	-	-
Ketones						
1, 12 Dicarbadodecarborane, 2-benzimidazol-1-yl	39.3	58.9	-	-	-	47.9
α-Cortolone, 4TMS derivative	7.05	-	-	-	-	-
Terpenes						
Delsoline	28.8	-	-	-	39.4	-
Molybdenum, dicarbonyl-(η-4-pinocarvone)-N,N,N',N'-tetramethylenediamine	33.5	-	-	-	23.5	-
Molybdenum, tricarbonyl-(η-Z-Z-cyclootene)-(η-4-norbornadiene)	67.9	-	21.2	-	-	-
Phorbol	-	31.5	-	-	28.2	-
Esters						
Prost-13-en-1-oic acid, 9-(methoxyimino)-11,15-bis[trimethysily)oxy]-, trimethylsilyl ester, (8,xi.,12,xi)	12.1	-	-	-	-	-
Butanoic acid, 4-chloro-, 1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-4a, 7b-dihydroxy-3(hydroxymethyl)-1,1,6,8-tetram	25.2	-	-	-	-	-
N,N'-Pentamethylenebis[s-3-aminopropyl thiosulfuric acid]	8.87	17.8	-	-	-	-
Docosahexaenoic acid, 1,2,3-propanetriyl ester	9.60	-	-	16.6	-	-
2-(5-(5-[Cyano-(9,9-dimethyl-1,4-dioxa-7-aza-spiro[4,4] non-7-en-8-yl)-methylene]-3,3-dimethylpyrrolidin-2-ylide	11.20	-	-	-	-	-
9,12,15,-1Octadecatrienoic acid, 2-phenyl-1,3-dioxan-5-yl ester	29.7	-	-	-	-	-
2,5-Dichloro-3,6-bis-(1-methyl-1H-benzoimidazol-2-yl)-tetrepthalic acid, dimethyl ester	38.9	-	28.3	-	-	-
2, 4, 6-Decatrienoic acid, 1a,2,5,5a,6,9,10,10a-octahydro-5, 5a-dihydroxy-4-(hydroxymethyl)-1,1,7,9-tetramethy-1	30.9	-	-	-	58.7	-
2,4,6,8-Tetradecatetraenoic acid, 9a-(acetyloxy)-1a,1b,4,4a,5,7a,7b,8,9,9a-decahydro-4a,7b-dihydroxy-3-(hydro	-	-	-	-	52.0	-
3-Hydroxy-1(4-(13-[4-(3-hydroxy-3-phenylacrlyoyl) pheny]tridecyl)-phenyl)-3-phenylprop-2-en-1-one	46.5	-	-	-	-	-
Androstan-19-ol-3-one, 17-acetoxy-4,4-dimethyl	15.5	-	-	-	-	-
α-D-Galactopyranoside, methyl 2,6-bis-O-(trimethylsilyl)-,cyclic butylboronate	-	-	-	-	7.48	-
7,8-Epoxylanostan-11-ol, 3-acetoxy	-	-	-	54.2	12.4	-

2-Nonadecanone 2.4-dinitrophenylhydrazine	-	-	-	-	10.4	-
3-Aza-2-(4-chlorophenyl)-1,1-dicyano-3-(1-methylpyrrolidin-2-yliden)propene	-	-	-	-	7.34	-
Chlortetrecycline	-	-	-	-	10.8	-
Glucobrassicin	-	-	-	-	10.3	-
Thiocolchicine	-	-	-	-	8.0	-
Card-20(22)-enolide, 3-[(2,6-dideoxy-4-O-β-D-glucopyranosyl-3-O-methyl-β-D-ribo-hexopyranosyl)oxy]-5,14-dih	-	-	-	-	10.9	-
10-Acetoxy-2-hydroxy-1,2,6a,6b,9,9,12a-heptamethyl-1,3,4,5,6,6a,7,8,8a,9,10,11,12,12a,12b,13,14b-octadecahydro	-	-	-	-	3.15	-
D-glucopyranoside, (3β,22α, 25S)-22,25-epoxy-3-methoxyfurost-5-en-26-yl 2,3,4,6-tetra-Omethyl	-	-	-	-	26.2	-
Z,Z-3,15-Octadecadien-1-ol acetate	-	8.36	-	-	28.5	-
Lupulon	-	-	-	-	11.0	-
Tungsen(0), tetracarbonyl-(phenylmethoxycarbene)(η-2-E-cycloctene)	-	-	-	-	37.8	-
Osimum chloride, (η-5-pentamethylcyclopentadienyl)-(trimethylphosphine)-(triphenylphosphine)	-	-	-	-	29.6	-
Tungsen, dicarbonylbis(η-4-2 methylenecycloheptanone)[1,2-bis(dimethylphosphino)ethane]	-	-	72.2	-	98.2	16.4
Pregn-4-ene-3,11,20-trione, 6,17,21-tris[(trimethylsilyl)oxy]-,3,20-bis(O-methyloxime),(6β)	-	-	-	-	52.3	-
Aconitane-1,7,8,14-tetrol,20-thyl-6,16-dimethoxy-4-(methoxymethyl)-,(1α,6β,14α,16β)	-	-	-	-	18.1	-
Demeclocycline	-	-	30.5	-	-	-
17a-Ethyl-3β-methoxy-17a-aza-D-homoandrost-5-ene-17-one	-	19	18.6	-	-	-
Decanoic acid, 1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-4a,7b-dihydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-5-ox	-	-	12.7	-	-	-
Acetic acid, 17-acetoxy-3-hydoxyimino-4,4,13-trimethyl-hexadecahydrocyclopenta(a)phenanthren-10-ylmethyl ester	-	-	36.6	-	-	-
Morphinan-3,14-diol,4,5-epoxy-,(5a)	-	-	15.5	-	-	-
Morphinan-4,5-epoxy-3,6-di-ol,6-(7-nitrobenzofurazan-4-yl]amino			30.2			
Hematoporphyrin	-	-	31.3	36.3	-	-
Isoquinoline, 1,2,3,4-tetrahydro-1-(4-bromophenyl)-6,7-dimethoxy	-	-	11.8	-	-	-
(5β)pregnane-3,20β-diol,14,18α-[4-methyl-3-oxo-(1-oxa-4-azabutane-1,4-diyl)]-, diacetate	-	24.4	-	-	-	9.87
6-Azacholest-4-en-7-one, 6-benzyl-3α-hydroxy	-	-	-	-	-	8.11
1H-2,8a-Methanocyclopenta[a]cyclopropa[e]cyclodecen-11-one,1a.2.5.5a.6.9.10.10a-octahydro-5,5a,6,trihydro						6.63
4-Apo-β,psi.-carotenoic acid, methyl ester	-	-	-	-	-	17.8
D-Homo-24-nor-17-oxachola-20,22-dien-16-one,1,3,7-tris(acetyloxy)-	-	-	-	-	-	30.2

14,15:21,23-diepoxy-4,4,8-trimethyl-,(1α						
11α-Hydroxyprogesterone, trimethylsilyl ether, bis(O-methyloxime)	-	-	-	22.4	-	-
Rhodoxanthin	-	-	-	23.73	-	-
Dodecanoic acid, 1a,2,5,5a,6,9,10,10a-octahydro-5a-hydroxy-4-(hydroxymethyl)-1,1,7,9-tetramethyl-6,11-dioxo	-	-	-	15.9	-	-
Docosanoic acid, 1,2,3-propanetriyl ester	-	-	-	16.6	-	-
Decanoic acid, 1,1a,1b,4,4a,5,7a,7b,8,9-decahydro-4a,7b-dihydroxy-1,1,6,8-tetramethyl-5-oxo-3-[(1-oxodecyl)o	-	-	-	25.9	-	-
3H-cycloprop(1,2)cholesta-1,4,6-trien-3-one, 1-carboethoxy-1-cyano-1β,2β-dihydro	-	-	-	37.0	-	-
Cyclopenthiazide	-	-	-	20.6	-	-
4aα,4bβ-Gibbane-1,1,10β-tricarboxylic acid, 4a,7-dihydroxy-8-methylene-, 1α,4a-lactone, dimethyl ester	-	-	-	15.8	-	-
12, 13-Dimethoxy-3-methyl-2.8-diazatricyclo[8.4.0.0(2,6)] tetradeca 1(14), 3,5,10,12-pentaene-9-thione	-	15.3	-	-	-	-
Trilinolein	-	18.4	-	-	-	-
Rhodopin	-	50.5	-	-	-	-
7-Pentyl-6,7,8,9-tetrahydro-5H-fluorene-2-carbonitrile		23.8				
Bis(μ-propynyl)-bis(cyclopentadienyl)zirconium-bis (t-butylycyclopentadienyl)zirconium	-	4.02	-	-	-	-
2,6-Bis[2-[2-S-thiosulfuroethylamino]ethoxy]pyrazine	-	28.8	-	-	-	-
Isoxazole, 5-[3,3-dicyano-1-cyclohrxylidene-2-morpholino-prop-2-enyl)] -3-p-methoxyphenyl	-	26.0	-	-	-	-
10-Heptadecen-8-ynoic acid, methyl ester (E	-	8.56	-	-	-	-
7-Chloro-1,3,4,10-tetrahydro-10-hydroxyl-1-[[2-[2-propenylamino] ethyl]imino]-3-[3-(fluoromethyl)phenyl]-9(2H)-a	-	15.4	-	-	-	-
8,11,14-Eicosatrienoic acid, methyl ester (Z,Z,Z)	-	7.94	-	-	-	-
11,13-Dihydroxy-tetradec-5-enoic acid, methyl ester	-	17.6	-	-	-	-
9,12-Hexadecadienoic acid, methyl ester	-	10.4	-	-	-	-

Conclusion

The results from this study indicate that packaging materials have significant effects on the proximate, heavy metals, sensory and volatile compounds composition of *moi-moi* produced from the same bean slurry. Some positive effects observed include improvement in taste and texture observed in *moi-moi* packaged in leaves, presence of volatile compounds that may have beneficial effects and retention of some nutrients observed in *moi-moi* packaged in stainless steel, aluminium can and plastic plates. However, heavy metals such as Nickel, Cadmium and Aluminium were observed to be higher in *moi-moi* packaged in aluminium can, aluminium foil and stainless steel, even though within permissible limit, care must be taken to avoid accumulation. It is therefore recommended that these factors be considered in choosing packaging materials for *moi-moi* preparation.

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