The effect of treatment methods and storage conditions on postharvest disease and fungal quality of *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) kernels

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Abstract

Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) are especially valued for their fat and protein rich kernels but are often contaminated, while in storage, by spoilage fungi that are potentially hazardous to human and animal health. Hence in this research, the postharvest disease and fungal quality of *Irvingia* kernels was studied. Freshly harvested *Irvingia* kernels were subjected to three treatment methods (sun-dried, 0.9% NaCl and 3% $KHCO_3$) and stored in both sealed and open bags for 28 days. Results showed that fungal population and postharvest disease incidence of *Irvingia* kernels in storage were dependent on treatment methods, storage conditions and storage days. Overall mean log cfu of fungi on Sun-dried *Irvingia* kernels (5.60) was significantly ($P \leq 0.05$) lower than those treated with 0.9% NaCl (5.95) or 3% $KHCO_3$ (5.99). Incidence and severity of diseased *Irvingia* kernels stored in sealed bags were significantly ($P \leq 0.05$) lower than those stored in open bags. Disease incidence and severity of *Irvingia* kernels increased significantly ($P \leq 0.05$) as storage period increased. Eight species of fungi *Aspergillus niger* (26.60%), *Rhizopus stolonifer* (21.28%), *Aspergillus flavus* (19.15%), *Penicillium* species (10.64%), *Mucor* species (8.51%), *Candida tropicalis* (5.32%), *Phytophthora* species (4.26%) and *Fusarium oxysporum* (4.26%) were isolated from the kernels after 28 days of storage. Results further showed that *A. flavus*, *Penicillium* and *Fusarium* species, known to produce mycotoxins were not isolated from kernels treated with NaCl or sun-dried and stored in sealed bags. It is therefore advisable to store *Irvingia* kernels in sealed bags after drying them under direct sun or treating with 0.9% NaCl.

Keywords: *Irvingia gabonensis*, Postharvest disease, Postharvest treatment, spoilage fungi, storage.

1. INTRODUCTION

Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) is a highly, economically important tree native to most tropical forests in West and Central Africa (Harris, 1996; Lowe *et al.,* 2000). In West Africa, *I. gabonensis* tops the list of non-timber forest products being clamoured for domestication (Ndoye *et al.,* 1997; Agbogidi and Okonta, 2003; Leakey *et al.,* 2003); and it is fast becoming the tree of choice in agroforestry practices (Okafor, 1985, 1991; Okafor, *et al.,* 1996; Leakey, 1999; Koyejo and Omokhua, 2001).

I. gabonensis is sometimes called bush mango or African mango because the trees bear mango-like fruits (Matos *et al.,* 2009). The fruits are broadly ellipsoid, about 4-7cm long, green when unripe and yellow when ripe with a fleshy mesocarp. The fruit pulp is juicy although the taste varies between sweet and bitter (Etukudo, 2000; Etebu, 2013), and has been shown to have great industrial potentials ranging from the preparation of juices, jams and jellies to wine and soap making (Okafor, 1985; Shiembo *et al.,* 1996; Leakey *et al.,* 2003). The juicy fruit pulp of *I. gabonensis* is rich in vitamin C and is widely consumed as a dessert fruit or snack throughout Western and Central Africa (Ejiofor, 1994; Leakey and Newton 1994). The fruit is sometimes also fed to pigs (Ayuk *et al.* 1999). Locals consume the fleshy mesocarp of *Irvingia gabonensis* fruits (Okafor, 1975; Leakey, 1999; Fajimi *et al.*, 2007), especially while they split the fruits to extract the kernels.

Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) is especially valued for their fat and protein rich kernels which serves as a sauce thickening agent and oil (Matos *et al.,* 2009). In addition to its nutritional and economic benefits, *I. gabonensis* is highly valued for its health and medicinal benefits (Duguma *et al.,* 1990; Ndoye *et al.,* 1997; Van, 2010), and agricultural potentials. Studies have shown that seed extract of *I. gabonensis* caused a significant reduction in body weight among obese people in Cameroon (Ngondi *et al.,* 2005). These benefits make the market for the products of *Irvingia* kernels very robust and economically valuable. In Cameroon alone, the trade of *Irvingia* kernels to other African countries has been valued at US$ 260,000 per annum (Ndoye *et al.,* 1997). The humid lowlands of Cameroun, Nigeria and Côte d΄Ivoire have been identified as the major sources of *Irvingia gabonensis* kernels in local and international trade (Ayuk *et al.* 1999).

A major setback in the sales and consumption of *Irvingia* kernels is their susceptibility to postharvest spoilage fungi with their attendant health risks. Several studies have shown that *Irvingia* kernels displayed on shelves for sales in Nigerian markets are often contaminated with spoilage fungi (Adebayo-Tayo *et al.,* 2006; Iyayi *et al.,* 2010). Furthermore studies carried out by Adebayo-Tayo and associates (2006) showed that fungal contaminated *Irvingia* kernels are potentially harmful to those who consume them. In particular, they observed that fungal contaminated kernels possess aflatoxin.

Aflatoxins are produced primarily by the fungi *Aspergillus flavus* and *A. parasiticus* (Wu and Khlangwiset 2010), and these fungi have been shown to grow on *Irvingia* kernels displayed for sales in Nigerian markets (Iyayi *et al.,* 2010). Consumption of high levels of aflatoxin in food has been reported to have caused illness among several hundreds of Kenyans in 2004, and leaving 125 people dead (Lewis *et al.* 2005; Strosnider et al. 2006). It has been estimated that more than 5 billion people in developing countries worldwide are at risk of chronic exposure to aflatoxins through contaminated foods (Strosnider *et al.* 2006). Postharvest conditions such as storage, transportation, and food processing, amongst others; have been implicated as predisposing factors that enables *A. flavus* and *A. parasiticus* produce aflatoxins in contaminated food (Wu and Khlangwiset 2010).

It becomes imperative therefore to handle postharvest *Irvingia* kernels in ways that would minimise postharvest fungal contamination. Hence in this work the effect of simple treatment methods and storage conditions on disease and fungal quality of postharvest *Irvingia* kernels was studied. Findings of this work would potentially increase the market value of *Irvingia* kernels and would also reduce health risk of people that consume *Irvingia* kernels.

2. Materials and methods

2.1 Incidence and severity of postharvest disease of *Irvingia* kernels in storage

Forty eight (48) cups of freshly harvested *Irvingia* seeds were bought from locals in Amassoma, Southern Ijaw Local Government Area (4°42'N 5°58'E) of Bayelsa state, Nigeria, just minutes after harvest (a cup contained about 60 seeds and weighed between 148 - 150g). The seeds were divided into three sets of sixteen cups per set and treated differently. The first set of 16 cups was sun-dried for 2 days; exactly the way locals treat harvested seeds traditionally, and were thereafter packed in sixteen separate clear polythene bags (1 cup of 60 kernels per bag). The resultant 16 bags were then further divided into two groups (8 cups per group). One group were sealed and marked sealed whilst the other group of 8 bags were left unsealed. Both groups of sealed and unsealed *Irvingia* kernels were then stored for 28 days at room temperature. On the 14th day of storage four bags were separately selected at random from the sealed and unsealed groups of kernels. Thereafter, 10 kernels were randomly taken from each bag and the kernels from each bag were separately assessed for percentage incidence and severity of postharvest disease due to fungal contamination. The kernels contained in the remaining bags were assessed for the same parameters on the 28th day of storage.

The second set of 16 cups of *Irvingia* kernels (weighing about 2.37 kg) were mixed with 22g of NaCl (amounting to 0.9%) and dried in the oven at 37°c for 2 hours. Thereafter the kernels were packaged and stored as previously described for kernels dried under the sun. Data was also collected after 14 and 28 days of storage as previously described.

The third group of 16 cups of *Irvingia* kernels (weighing about 2.37 kg) were mixed with 112g of potassium bicarbonate (amounting to 3%) and dried in the oven at 37°c for 2 hours. Thereafter the kernels were also packaged and stored as previously described for kernels dried under the sun. Data was also collected after 14 and 28 days of storage as described.

Postharvest disease of *Irvingia* kernels was identified by the appearance of brownish to black colouration on the kernels. Percentage incidence of infected kernels was determined by dividing the number of discoloured kernels divided by 10 and multiplied by 100. Severity of postharvest fungal infection of individual kernels was determined by the ratio of infected area and expressed as percentage. The mean score of 10 kernels from a bag for each of the parameters was considered to represent a replicate. Fungal population data was log transformed whilst percentage data were arcsine transformed according to Gomez and Gomez (1985), and all data sets were subjected to ANOVA using Generalized Linear Model of SPSS version 16.0 Statistical software. Mean percentage data were further subjected to Tukey's mean separation test and discussed with respect to treatment methods, storage conditions and period.

2.2 Assessing fungal population and quality of treated *Irvingia* kernels during storage

All kernels from all replicates of a given treatment previously assessed for postharvest disease incidence and severity were mixed to form a composite mixture and vigorously stirred in 200ml of sterile water to dislodge fungal mycelium. Thereafter, 1ml of fungal suspension was serially diluted and plated in 3 replicates onto potato dextrose agar (Oxoid Ltd, Hampshire, UK) previously prepared according to manufacturer's prescription, and integrated with 50µg ml^{-1} each of streptomycin and tetracycline according to Etebu et al. (2003). The plates were thereafter incubated at ambient room temperature for 3 days. At the end of 3 days colony forming units were counted and the fungal population was expressed as colony forming units per nut of *Irvingia* fruit. Colonies were thereafter repeatedly subcultured after every three days onto newly prepared agar plates until pure cultures were obtained. Fungal colonies were thereafter transferred onto Sabouraud dextrose agar (Oxoid Ltd, Hampshire, UK) and incubated in a sporulating chamber under black light for 3 days (adapted from Etebu et al., 2005), and identified based on macroscopic and microscopic examination according to Alexopoulos (1962) and Barnett and Hunter (1972).

3. Results and discussion

3.1 Incidence and severity of postharvest disease of *Irvingia* kernels in storage

Irvingia kernels were prone to postharvest fungal spoilage while in storage. Incidence and severity of postharvest disease of *Irvingia* kernels in storage were influenced differently by the different factors studied. Whilst incidence of disease was dependent on all factors (treatment methods, storage conditions and storage period) investigated, severity of postharvest disease was dependent on storage conditions and period, but not treatment methods (Tables 1 and 2). Niranjana et al (2009) whilst working on Mango (*Mangifera indica*) showed that the way and manner the fruits are treated prior to storage affects both the storage life as well as postharvest disease incidence on the crop whilst in storage. Results from this present work corroborate findings of previous work done on other fruits. Various workers had shown in earlier works that storage disease incidence among fruits increases with increasing storage duration (D' hallewin and Schirra, 2000; Abd-El-Aziz & Mansour, 2006, Etebu, 2012a,b). In line with these findings results from this present work showed that storing postharvest *Irvingia* kernels in sealed polythene bags (38.54) significantly ($P \leq 0.05$) reduced the incidence of postharvest disease incidence than those stored in open polythene bags (47.12) (Table 2). Also, incidence of disease of *Irvingia* kernels in storage increased significantly ($P \leq 0.05$) as storage period increased (Table 2). Mean Arcsine transformed percentage incidence of disease was 31.82 after 14 days of storage, this increased significantly to 53.84 after 28 days.

Although mean Arcsine transformed percentage incidence of postharvest disease of *Irvingia* kernels dried under the sun prior to storage was significantly ($P \leq 0.05$) lower (38.30) than those treated with $KHCO_3$ (46.68), its effect on postharvest disease incidence was not significantly different from kernels treated with 0.9% NaCl (43.51) (Table 2). Like sun drying, common salt (NaCl) is added to food primarily for purposes of preservation and is adjudged to effectively prevent food spoilage due to microorganisms. It is able to prevent the growth of spoilage microorganisms through a variety of ways, some of which includes, decreasing the amount of water in foods available for microbial growth and chemical reactions (Fennema, 1996, Potter and Hotchkiss, 1995), kills microbial cells through osmotic shock (Davidson, 2001), retards microbial growth by interfering with cellular enzymes (Shelef and Seiter, 2005).

Differences in disease severity was not significant ($P=0.05$) among *Irvingia* kernels treated differently prior to storage (Tables 1 and 2). Similar results have been reported in previous works. In particular, Etebu et al., (2003) working on postharvest fungal quality of selected chewing sticks observed that disease severity of the chewing sticks were not differentially affected by the way in which they were processed prior to storage. Similarly, these workers further showed that whether chewing sticks were stored in sealed or unsealed polythene bags made no significant differences with respect to postharvest fungal disease severity. This notwithstanding, they advised that chewing sticks should be sealed in polythene for purposes of good marketing standards.

3.2 Fungal population of postharvest *Irvingia* kernels in storage

Irvingia kernels were colonized by fungi and are prone to postharvest spoilage in storage. Fungal population of kernels whilst in storage were observed to be dependent on treatment methods, storage conditions and storage days (Table 1). Overall mean log colony forming units of fungi on *Irvingia* kernels previously sun-dried prior to 28 days of storage was 5.60 (Table 2). This population of fungi was significantly ($P \leq 0.05$) lower as compared to *Irvingia* kernels treated with 0.9% NaCl (5.95) and 3% $KHCO_3$ (5.99). Whilst sodium is known to inhibit the growth of several plant pathogens (DePasqualle and Montville, 1990), the use of solar energy through direct sun drying is one of the oldest method employed in the drying and preservation of agricultural surpluses (Jain and

Tiwari 2003; Berinyuy et al., 2012). The use of direct sun drying is still very much in vogue notwithstanding the documented preference of solar drying (Simate, 2003; Janjai et al.,1994), essentially because very little capital is required on the expenditure of equipment (Latapi and Barret, 2006; Berinyuy et al., 2012). Direct Sun drying is quite easy and straightforward. Basically, agricultural produce are usually spread on the ground or platforms often with no pre-treatment and are turned regularly until sufficiently dried so that they can be stored for later consumption. Discolouration and fungal attack are major determinants of *Irvingia* quality in marketing (Ladipo, 1999). *Irvingia* kernels become discoloured due to fungal attack if they are not dried soon after harvest. These assertions in tandem with results obtained from this work makes drying of *Irvingia* kernels prior to storage an essential requirement to sustain a good and acceptable quality of postharvest *Irvingia* kernels in storage.

It is pertinent to note that sun-dried *Irvingia* kernels had a significantly lower fungal population than kernels treated differently in this present work, only when the basis for comparison were *Irvingia* kernels stored in open polythene bags. Whilst sun-dried and sealed *Irvingia* kernels had a significantly ($P \leq 0.05$) lower fungal population than those treated with $KHCO_3$ and stored in similar conditions, differences in fungal population between those treated with NaCl and sealed and those sun-dried and stored sealed were not significantly ($P \leq 0.05$) different (Table 3). This shows that one has to take both treatment method and storage conditions into consideration in adopting ways to preserve *Irvingia* kernels in storage.

Fungal population of postharvest *Irvingia* kernels in storage was also generally dependent on storage condition and period. Whilst the mean log fungal colony forming units of kernels stored in sealed polythene bags were 5.64, those stored in open polythene bags were as much as 6.06 being significantly ($P \leq 0.05$) higher (Table 2). The storage of agricultural products, especially grains, in sealed containers has been recommended because storing grains in tight containers causes a drastic reduction in oxygen and an increase in carbon dioxide which helps to reduce both insects and fungal activities (Soffe, 2011). The *Irvingia* kernels were not surface sterilized before plating unto relevant culture medium, and this accounted for the high number of fungi recorded in this work. Locals generally do not wash or clean *Irvingia* kernels bought from the market before cooking same. They simply ground the kernels with all the attendant fungal contaminations after purchase and use thereafter.

Results from this work further showed that fungal population on postharvest *Irvingia* kernels in storage increased significantly ($P \leq 0.05$) as the storage period increased (Table 2). Mean cfu of *Irvingia* kernels after 14 and 28 days of storage were 5.74 and 5.96 respectively. Etebu (2012b) working on postharvest spoilage of *Irvingia* fruits also asserts that fungal population increased with increase in storage period. Also, Obette et al (2011) working on selected fruits and vegetables showed that fungal and bacterial populations increased correspondingly as storage days increased.

3.3 Fungal quality of postharvest *Irvingia* kernels in storage

Postharvest *Irvingia* kernels were contaminated by different species of fungi in varying frequencies. On the overall *Aspergillus niger* (26.60%), *Rhizopus stolonifer* (21.28%), *Aspergillus flavus* (19.15%), *Penicillium* species (10.64%), *Mucor* species (8.51%), *Candida tropicalis* (5.32%), *Phytophthora* species (4.26%) and *Fusarium oxysporum* (4.26%) were isolated from the kernels after 28 days of storage (Table 4). Fungi are one of the major causes of spoilage of postharvest agricultural produce in storage, and fungi isolated from *Irvingia* kernels in this present work have also been found to be associated with variety of other crops by several workers (Amadi and Adeniyi, 2009; Adebayo-Tayo et al. 2006; Akintobi et al. 2011; Fagbohun et al. 2011). *Aspergillus niger*, *Rhizopus stolonifer*, *Aspergillus flavus*, *Penicillium* species and *Mucor* species observed in this work to have been isolated more frequently from *Irvingia* kernels in storage has long been recognised to be most common group of fungi that infects grains after harvest and grows on them during storage (Adams, 1977; Agrios, 1978).

The contamination of *Irvingia* kernels in storage was observed to be influenced by pre-storage treatment method. Whilst *Mucor* sp., *A. niger, A. flavus* and *R. stolonifer* were isolated from *Irvingia* kernels irrespective of the pre-storage treatment methods, the isolation of *C. tropicalis, Penicillium* and *Phytophthora* species were dependent on pre-storage treatment methods. *Penicillium* and *Phytophthora* species were not isolated from kernels that were sun-dried prior storage. Similarly, *Candida tropicalis* was not isolated from kernels treated with NaCl prior to storage (Table 4). Furthermore, *Candida tropicalis* alongside *Phytophthora* species was not isolated from kernels that were treated with $KHCO_3$ prior to storage. Different treatment methods may have affected the chemical composition and physical composition of the kernels differently, and these differences would be responsible for the variation in the fungal species that were able to colonize the kernels during storage. For example, Ekpe et al. (2007) working on the effect of processing methods on *Irvingia* kernels showed that proximate analysis differed

significantly ($p > 0.05$) between the processed product and fresh *Irvingia* seeds in crude protein, fat, ash and dietary fibre contents.

All eight fungal species were isolated from kernels after 14 and 28 days of storage. The proportion of fungi isolated was relatively the same during this period of storage except *Mucor* and *Penicillium* species. Whilst *Mucor* species reduced in relative proportion by about 50% between 14 and 28 days of storage, *Penicillium* increased in relative proportion within the same period by about 50% (Table 4).

Aside loss of quality of stored products, one very important effects of postharvest spoilage of stored agricultural produce is the potential production of mycotoxins, and members of *Aspergillus*, *Penicillium* and *Fusarium,* amongst a few other genera, are considered to be the main representatives of mycotoxigenic fungi (Amadi and Adeniyi, 2009). The relatively high frequency of incidence of *Aspergillus* and *Penicillium* species on stored *Irvingia* kernels observed in this present work therefore calls for serious concern. Moreso, an earlier study undertaken by Adebayo-tayo and associates (2006) showed that aflatoxins (a type of mycotoxin) were detected in *Irvingia* kernels shelved for sale in Eastern Nigeria.

Results from this present work further showed that the effect of pre-storage treatment methods on postharvest fungal species is dependent on the condition in which the kernels were stored after treatment (Table 5). Results showed that *Mucor* species, *A. flavus* and *F. oxysporum* were isolated only from kernels that were stored in unsealed polythene bags irrespective of pre-storage treatment method (Table 5). *A. niger* was isolated from kernels treated with NaCl or $KHCO_3$ irrespective of how they were stored (sealed or unsealed bags). The case was different with kernels that were sun-dried prior to storage. For this set of kernels *A. niger* contamination was observed only when they were stored sealed. Similarly, *Rhizopus stolonifer* was also isolated from kernels that were sun-dried only when they were thereafter stored in sealed bags. In contrast, *C. tropicalis* was isolated only from kernels that were stored in unsealed polythene bags, but only when the kernels were sun-dried prior to storage. This fungus was not isolated from *Irvingia* kernels during storage when they were treated with NaCl or $KHCO_3$ irrespective of the storage conditions (Table 5). *Phytophthora* species on the other hand was isolated only from kernels treated with NaCl and stored in sealed bags. Contamination of *Irvingia* kernels in storage by *Penicillium* species was also dependent on both pre-storage treatment method and storage conditions. The fungus grew in sealed bags only when the kernels were previously treated with $KHCO_3$. *Irvingia* kernels that were either treated with NaCl or sun-dried and thereafter stored in sealed bags did not show contamination with *Penicillium* species. Whilst kernels that were sun-dried or treated with $KHCO_3$ and stored in unsealed bags also did not get contaminated with *Penicillium*, the case was different with kernels previously treated with NaCl and then stored under similar storage conditions. As much as 31.25% of fungi isolated from kernels treated with NaCl and stored in unsealed bags were *Penicillium* species (Table 5)

4. Conclusion

Any pre-storage treatment method that would reduce the fungal population on stored *Irvingia* kernels, and prevent the production of mycotoxin would be welcome as this would guarantee the health and safety of a whole lot of people that consume the kernels. Results from this work showed that most of the groups of fungi implicated with production of mycotoxins (*A. flavus*, *Penicillium* species, and *Fusarium*) were not isolated when the kernels were first treated with NaCl or sun-dried and stored in sealed polythene bags. Furthermore, these sets of *Irvingia* kernels treated with NaCl or sun-dried and stored in sealed polythene bags also had lower fungal population compared to those treated the same way but stored in open bags. Aside from the fact that *Irvingia* kernels stored in sealed polythene bags seemed to have prevented the growth potential mycotoxigenic fungi, storing *Irvingia* kernels in sealed containers would portend good marketing standards. It is therefore recommended that pre-storage *Irvingia* kernels be sun-dried or treated with 0.9% NaCl and stored in sealed polythene bags.

References

Abdel-El-Aziz, S. and Mansoor SF (2006). Some safe treatment for controlling post-harvest diseases of Valencia orange (*Citrus sinensis* L.) fruits. *Annals Agric. Sci*. **44**: 135-146.

Adams JM (1977). A review of the literature concerning losses in stored Cereals and pulses. *Trop. Sci.* **19** (1): 1-27.

Adebayo-Tayo BC, Onilude, AA, Ogunjobi, AA, Gbolagade, JS and Oladapo MO (2006).

Detection of fungi and aflatoxin in shelved bush mango seeds (*irvingia spp.*) stored for sale in Uyo, Eastern Nigeria. *Electron. J. Environ. Agric. Food Chem.* **5** (5): 1569 - 1574

Agbogidi OM and Okonta BC (2003). Role of women in community forestry and

environmental conservation. In: Proceedings of FAN Conference held in Calabar. Akindele SA and Popoola L (eds), 6-11th Oct., 2003. 159-163.

Agrios NG (1978). *Plant Pathology.* Academic Press, New York, 703p.

Akintobi AO, Okonko IO, Agunbiade SO, Akano OR and Onianwo O (2011). Isolation and identification of fungi associated with the spoilage of some selected fruits in Ibadan, South Western Nigeria. *Acad. Arena*, **3:** 1-10

Alexopoulos, C. Y. (1962). *Introduction to mycology*, (2nd ed.). John Wiley and Sons Inc. New York, p. 613

Amadi, JE and Adeniyi DO (2009). Mycotoxin production by fungi isolated from stored grains. *Afr. J. Biotech.* **8:** 1219 - 1221

Ayuk, ET, Duguma B, Franzel S, Kengue J, Mollet SM, Tiki-Manga T, Zenkekeng P (1999).

Uses, management and economic potentials *Irvingia gabonensis* in the humid lowlands of Cameroon. *For. Ecol. Manage*. 113: 1-9

Barnett, H. L., & Hunter, B. B. (1972). Illustrated General of Imperfect fungi, 3rd edition. Burgess Publishing Co. Minnesota, p.241

Berinyuy, JE, Tangka, JK and Fosto GMW (2012) Enhancing natural convection solar drying of high moisture vegetables with heat storage. *Agric. Eng. Int: CIGR J.* **14:** 141 - 148

D'hallewin, G. and Schirra M (2000). Structural changes of epicuticular wax and storage

response of 'Marsh' grapefruits after ethanol dips at 21 and 50°C. *Proc. 4th Int. Conf. on Postharvest*, pp. 441-442.

Davidson PM (2001). Chemical preservatives and natural antimicrobial compounds, In: Food

microbiology: Fundamentals and frontiers. (Eds. Doyle MP, Beauchat LR and Montville TJ). Washington, DC: ASM Press.

DePasqualle DA and Montville TJ (1990). Mechanism by which ammonium bicarbonate and ammonium sulfate inhibit mycotoxigenic fungi. *Appl. Envtal. Microbiol.* **56:** 3711-3717

Duguma B, Tonye T, Depommier D (1990). Diagnostic survey on local multipurposes trees/shrubs. Fallow systems and livestock in Southern Cameroon. CRAF Working paper, No. 60.

Ejiofor, MAN (1994). Nutritional values of Ogbono (*Irvingia gabonensis* var. *excelsa*). ICRAF-IITA Conference on *Irvingia gabonensis*; Ibidan, Nigeria; May 1994.

Ekpe, O. Umeh, I and Eka O. (2007). Effects of a typical rural processing method on the proximate composition and amino acid profile of bush mango seeds (*Irvingia gabonensis*). *Afr. J. Food Agric. Nutr. Dev.* **7:** 164-171

Etebu, E. (2012a). Postharvest pathology and phytochemicals of *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) fruits and wastes. *Agric. Sci. Res. J. 2*(6), 285-294.

Etebu, E (2012b). Differences in fruit sizes, postharvest pathology and phytochemicals between *Irvingia gabonensis* and *Irvingia wombolu*. *Sustain. Agric. Res.* **2** (1): 52-61. http://dx.doi.org/10.5539/ sar.v2n1p52.

Etebu, E., Pasberg-gauhl, C., Gauhl, F., & Daniel-Kalio, L. A. (2005). Effect of light and sealing patterns on sporulation and growth of *Mycosphaerella fijiensi*s. *InfoMusa, 14*(1), 24-25.

Etebu, E., Tasie, A. A., & Daniel-Kalio, L. A. (2003). Post-harvest fungal quality of selected chewing sticks. *Oral dis, 9*(2), 95-98. http://dx.doi.org/10.1034/j.1601-0825.2003.00803.x

Etukudo I (2000). *Forests our divine treasure*. Dorand Publishers Fajimi O, Sarumi MB,

Olayode MN, Gamra EO and Sanusi SI (2007). *In-vitro* propagation of *Irvingia gabonensis*. *Afr. .J. Biotechnol.* 6(8): 976-978.

Fagbohun E, Anibijuwon I, Oluwole E and Lawal O (2011). Fungi associated with spoilage of dried coca beans during storage in Ekiti State of Nigeria. *J. Microbiol. Biotech. Food Sci.* **2:** 204-214

Fajimi, O., Sarumi, M.B., Olayode, M.N., Gamra, E.O. and Sanusi, S.I. (2007). *In-vitro* propagation of *Irvingia gabonensis*. *Afr. J. Biotech.* **6**: 976-978.

Fennema OR (1996). Food chemistry. 3rd ed. New York: Marcel Dekker; 1996

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* 2nd edition. John Wiley and Sons, N.Y, p. 680.

Harris, D. J. (1996). A revision of the *Irvingiacea* in Africa. *Bulletin du Jardin Botanique National de Belgique, 65*, 143-196. http://dx.doi.org/10.2307/3668184

Iyayi IM, Adewumi, ERK and Nassang AL (2010). Microbial spoilage of *Irvingia* kernels in Benin City, Nigeria. *Arch. Appl. Sci. Res.* **2** (5):168-176

Jain D and Tiwari GN (2003). Thermal aspects of open sun drying of various crops. *Energy,* **28** (1): 37–54.

Janjai S, Esper A, and Muhlabauer W. (1994), A procedure for determining the optimum collector area for solar paddy drying system. *Renewable Energy* **4**(4): 409–416.

Koyejo, A. O., & Omokhua, G. (2001). Propagation studies on *Irvingia wombulu (syn. Excelsa*) Ex. Okafor and agroforestry specis. In: Proceedings of FAN Conference held in Abuja, 17th -21st Sept., 2001. pp. 183-187.

Ladipo DO (1999). The development of quality control standards for ogbono (*Irvingia gabonensis* and *Irvingia wombolu*) kernels: Efforts towards encouraging organized and further International trade in a nwfpof west and Central Africa. In : (FAO). Non-wood forest products of Central Africa: Current research issues and prospects for conservation and development. 299pp *www.fao.org/docrep/x2161e/x2161e26.htm* Retrieved on 17th October, 2012

Latapi, G and Barret DM (2006). Influence of pre-drying treatments on quality and safety of sun-dried tomatoes. Part II. Effects of storage on nutritional and sensory quality of sun-dried tomatoes pretreated with sulphur, sodium metabisulfite, or salt. *J. Food Sci.* **71:** 32 - 37

Leakey R, Newton A (1994). Domestication of tropical trees for timber and non-timber products. *MAB Digest* 17: 67-68.

Leakey, R. R. B. (1999). Farmers top priority fruit trees. *Agrofor. Today, 11*(3-4), 11-15.

Leakey, R., Schrecheriberg, K., and Tchoundjev, Z. (2003). The participatory domestication of West African indigenous fruits. *Int. For. Rev., 5*, 338-347. http://dx.doi.org/10.1505/IFOR.5.4.338.22652

Lewis, L., Onsongo, M., Njapau, H., Schurz-Rogers, H., Luber, G., Kieszak, S., Nyamongo, J., Backer, L., Dahive, A., Misore, A., DeCock, K., Rubin, C and the Kenya Aflatoxicosis Investigation Group (2005)"Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in eastern and central Kenya," *Environ. Health Perspect.* **113**(12): 1763–1767.

Lowe, A. J. A., Gillies, C. M., Wilson, J., and Dawson, I. K. (2000). Conservation genetics of bush mango from central/west Africa: Implications from random amplified polymorphic DNA analysis. *Mol. Ecol, 9*, 831-841. http://dx.doi.org/10.1046/j.1365-294x.2000.00936.x

Matos, L., Nzikou, J. M., Matouba, E., Pandzou-Yembe, V. N., Mapepoulou, T. G., Linder, M., and Desobry S (2009). Studies of *Irvingia gabonensis* seeds kernels: Oil technological applications. *Pak. J, Nutr, 8*, 151-157.

Ndoye, O., Pérez, M. R., and Eyebe, A. (1997). The markets of non-timber forest products in the humid zone of Cameroon. Network No, 22 Rural Development Forest Network, Overseas Development Institute, London.

Ngondi, J. L., Oben, J. E., & Minka, S. R. (2005). The effect of *Irvingia gabonensis* seeds on body weight and blood lipids of obese subjects in Cameroon. *Lipids in health and Disease, 4*, 12-15. http://dx.doi.org/10.1186/1476-511X-4-12

Niranjana P, Gopalakrishna RKP, Sudhakar RDV and Madhusudhan B (2009). Effect of controlled

atmosphere storage (CAS) on antioxidant enzymes and DPPH-radical scavenging activity of mango (*Mangifera indica*) cv. Alphonso. *Afr. J. Food, Agric. Nutr. Dev.* **9** (2): 779-792

Obetta SE, Nwakonobi TU and Adikwu OA (2011). Microbial effects on selected stored fruits and vegetables under ambient conditions in Makurdi, Benue state, Nigeria. *Res. J. Appl. Sci. Eng. Technol.* **3:** 393-398

Okafor, J. C. (1975). Varietal delimination in *Irvingia gabonensis* (*Irvingiaceae*). *Bulletin du Jardin Botanique Nationale de Belgique, 45*(1-2), 211-221. http://dx.doi.org/10.2307/3667601

Okafor, J. C. (1985). Selection and improvement of indigenous tropical fruit tree: Problems and prospects. *J. Forest Res., 1*, 87-95.

Okafor, J. C. (1991). Improving edible species of forest products. *UNASYLVA, 165*, 17-23.

Okafor, J. C., Ejkiofor, M., & Okolo, H. C. (1996). Development and utilisation of disappearing and under utilised edible wood forest species of southeastern Nigeria. Final Technical Report of Project Grant No. 7536. Biodiversity Support Programme. WWF, Washington, D. C.

Potter NN and Hotchkiss JH (1995). *Food science.* Food science texts series. 5th ed. New York: Chapman & Hall.

Shelef LA and Seiter J. (2005). Indirect and miscellaneous antimicrobials, In: Antimocrobials in food. (eds. Davidson PM, Sofos JN and Larry BA).3rd edition. Boca Raton, FL: Taylor and Francis. 573–598.

Shiembo PN, Newton AC, Leakey RRB (1996). Vegetative propagation of *Irvingia gabonensis*, a West African fruit tree. *For Ecol. Manage.* 87: 185-192

Simate IN (2003). Optimization of mixed-mode and indirect-natural convection solar dryers*. Renewable Energy*. **28:** 435–453.

Soffe RI (2011). *The Agricultural Notebook*. 20th edition. John Wiley and Sons. 768pp

Strosnider H, Azziz-Baumgartner E, Banziger M, Bhat RV, Breiman R, Brune M, DeCock K, Dilley A, Groopman J, Hell K, Henry SH, Jeffers D, Jolly C, Jolly P, Kibata GN, Lewis L, Liu X, Luber G, McCoy L, Mensah P, Miraglia M, Misore A, Njapau H, Ong C, Onsongo MTK, Page SW, Park D, Patel M, Phillips T, Pineiro M, Pronczuk J, Schurz Rogers H, Rubin C, Sabino M, Schaafsma A, Shephard G, Stroka J, Wild C, Williams JT, Wilson D (2006). “Workgroup Report: Public Health Strategies for Reducing Aflatoxin Exposure in Developing Countries.” *Environmental Health Perspectives*, **114:**1989-1903.

Van M (2010). *Irvingia* potentials. *J. Ethnopharmacol*. **4**: 280-285

Wu F and Khlangwiset P. (2010). Health economic impacts and cost-effectiveness of aflatoxin reduction strategies in Africa: Case studies in biocontrol and postharvest interventions. . *Food Additives & Contaminants* **27**:496-509.

Table 1: Summary of ANOVA results showing the effect of treatment methods and storage conditions on postharvest fungal population, percentage disease incidence and severity

		Mean Square		
Factors	Degree of freedom	Fungal population	% Incidence of disease	% Severity of disease
Treatment methods (TM)	2	0.56**	215.00*	5.27ns
Storage conditions (SC)	1	1.55**	662.03**	424.29**
Storage period (SP)	1	0.43**	4365.25**	715.12**
Interactions				
TM * SC	2	0.24*	109.53ns	85.58ns
TM * SD	2	0.05ns	38.86ns	3.24ns
SD * SC	1	0.01ns	78.09ns	0.65ns
TM * SC * SD	2	0.02ns	79.72ns	14.38ns

*Differences significant at 5% probability level
**Differences significant at 1% probability level
Ns Differences not significant at 5% probability level

Table 2: The effect of treatment methods, storage conditions and storage period on fungal population and quality of *Irvingia* seeds during storage

Factors	Mean log CFU	% incidence of PHD^y	% severity of PHD^y
Treatment methods			
Sun-dried	5.60^a	38.30^a	37.73^a
NaCl	5.95^b	43.51^{ab}	38.04^a
$KHCO_3$	5.99^b	46.68^b	39.00^a
Storage conditions			
Sealed	5.64^a	38.54^a	34.82^a
Unsealed	6.06^b	47.12^b	41.69^b
Storage Periods			
14 days	5.74^a	31.82^a	33.80^a
28 days	5.96^b	53.84^b	42.71^b

CFU – Colony forming units

^{y} - Arcsine transformed

PHD – Postharvest disease

Different letters denotes significant differences at $p \leq 0.05$

Table 3: The interactive effect of treatment method and storage conditions on fungal population of *Irvingia* kernels in storage

	Mean Log fungal CFU	
Treatment method	Sealed	Unsealed
Sun-dried	5.44^{a}	5.75^{abc}
NaCl	5.59^{ab}	6.32^{d}
$KHCO_3$	5.88^{bc}	6.08^{cd}

CFU – Colony forming units

Different letters denotes significant differences at $p \leq 0.05$

Table 4: The effect of treatment methods and, storage conditions and period on percentage frequency of fungi associated with postharvest *Irvingia* kernels in storage

Factors	*Mucor sp.*	*Aspergillus niger*	*Aspergillus flavus*	*Penicillium sp.*	*Rhizopus stolonifer*	*Candida tropicalis*	*Phytophthora sp.*	*Fusarium oxysporum*
<u>Treatment methods</u>								
Sun-dried	12.00	20.00	28.00	0.00	20.00	20.00	0.00	0.00
NaCl	8.82	26.47	17.65	14.71	20.59	0.00	11.76	0.00
$KHCO_3$	5.71	31.43	14.29	14.29	22.86	0.00	0.00	11.43
<u>Storage conditions</u>								
Sealed	0.00	42.22	0.00	11.11	37.78	0.00	8.89	0.00
Unsealed	16.33	12.24	36.73	10.20	6.12	10.20	0.00	8.16
<u>Storage period</u>								
14 days	6.98	25.58	18.60	13.95	20.93	4.65	4.65	4.65
28 days	9.80	27.45	19.61	7.84	21.57	5.88	3.92	3.92
Overall	8.51	26.60	19.15	10.64	21.28	5.32	4.26	4.26

Table 5: The interactive effect of treatment methods and storage conditions on the Percentage frequency of fungi associated with postharvest *Irvingia* kernels in storage

Factors	*Mucor sp.*	*Aspergillus niger*	*Aspergillus flavus*	*Penicillium sp.*	*Rhizopus stolonifer*	*Candida tropicalis*	*Phytophthora sp.*	*Fusarium oxysporum*
Sealed								
Sun-dried	0.00	50.00	0.00	0.00	50.00	0.00	0.00	0.00
NaCl	0.00	16.67	0.00	0.00	22.22	0.00	11.11	0.00
$KHCO_3$	0.00	41.18	0.00	29.41	29.41	0.00	0.00	0.00
Unsealed								
Sun-dried	20.00	0.00	46.67	0.00	0.00	33.33	0.00	0.00
NaCl	18.75	12.50	37.50	31.25	0.00	0.00	0.00	0.00
$KHCO_3$	11.11	22.22	27.78	0.00	16.67	0.00	0.00	22.22

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