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Effect of postharvest period on disease progression and proximate composition of *Irvingia* species fruit waste

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Abstract: *Irvingia species are important fruit trees. Although the microbial postharvest quality of its fruits have been studied, the potential relationship between postharvest disease and the proximate composition of its fruit are yet unknown. Hence in this research, changes that occur in postharvest Irvingia fruit wastes on the 0^{th} , 3^{rd} and 6^{th} days after harvest (DAH) was assessed with respect to brownish-black rot disease and proximate components. Results showed that brownish-black rot disease advanced significantly ($P\leq 0.05$) as DAH increased. Mean weighted percentage brownish-black rot disease on 0^{th}, 3^{rd} and 6^{th} DAH were 2.37%, 22.24% and 87.86% respectively. Mean percentage moisture was 82.99% followed by dry matter (16.91g), Carbohydrate (15.00g), fibre (0.67g), protein (0.63g), ash (0.49g) and lipids (0.10g). Whilst differences in % moisture, dry matter and lipid with respect to DAH were not significant (P=0.05), differences in protein, ash, fibre, and carbohydrate contents were significant. Brownish-black rot disease was significantly, positively related to carbohydrate (r2 = 0.69; Pearson correlation coefficient = 0.83) whilst being significantly, negatively related to fibre (r2 = 0.92; Pearson correlation coefficient = -0.82), ash (r2 = 0.68; Pearson correlation coefficient = -0.96) and protein (r2 = 0.73; Pearson correlation coefficient = -0.86), respectively. Postharvest holding periods led to nutritive degradation of Irvingia fruits' proximate composition. Fruits should either be consumed soon after harvest or processed under infection-free conditions to lengthen their storage life and preserve their proximate and nutritional quality.*

Keywords: *Irvingia gabonensis, Proximate composition, Brownish-black rot disease, Nutritional quality of fruits.*

I. Introduction

Irvingia species are economically important fruit tree that grows in the wild forests of most West and Central African countries (Harris, 1996; Lowe et al., 2000). Two species, I. gabonensis and I. wombolu are predominant in Nigeria and are commonly called bush mango or African mango because of their mango-like fruits (Matos et al., 2009; Ngodi et al., 2005). The fruits are ellipsoidal, 4-7cm long, green when unripe and yellow when ripe with a fleshy mesocarp (Etebu, 2013). The proximate composition of food which has been variously reported to include its content of protein, carbohydrates, fat and oil, moisture and dietary fibre (Onimawo and Egbekun, 1998; Ihekoronye and Ngoddy, 1985) have been mostly studied with respect to the kernels of Irvingia fruits. The kernels of the fruits are considered to be the most valuable component for various reasons. They are rich source of fat, oil and protein and are used widely as condiment in thickening of sauce (Matos et al., 2009). The market for the products of Irvingia kernels is reportedly very robust, with Cameroun, Nigeria and Côte d´Ivoire being major sources in local and international trade (Ayuk et al. 1999). In addition to its nutritional and economic benefits, the kernel is highly valued for its health and medicinal benefits (Duguma et al., 1990; Ndoye et al., 1997). In particular, studies have shown that extract from the kernel of I. gabonensis caused a significant reduction in body weight among obese people in Cameroon (Ngondi et al., 2005).

These nutritional, economic and medicinal benefits explain why the kernels/nuts have attracted so much attention to the exclusion of other parts of the fruit. The fleshy part which constitute over 80% of the fruit are often discarded as waste, after the kernels are extracted, and left to rot in dumps, water bodies, pits or nearby bushes (Etebu, 2012; Ladipo et al., 1996). However, some reports in literature indicate that the fleshy pulp of Irvingia fruits have been used as feed for pigs, and in the production of fruit drinks, wine, jam and other syrups (Ayuk, 1999; Leakey et al., 2003; Okafor, 1985; Shiembo et al., 1996). Also, some Workers have clearly shown that the fleshy pulp of fresh Irvingia fruits, like the kernels; contain several nutritionally beneficial substances such as carbohydrates, proteins, lipids, vitamins etc (Onimawo et al., 2003). As impressive as these findings are, they do not indicate the fate of these substances as postharvest storage period increases. The major set-back militating against the use of the fleshy component of postharvest Irvingia fruits is their short shelf life after harvest; known to harbor several fungi and bacteria whilst in storage (Etebu, 2012, 2013; Etebu and Tungbulu, 2015; Joseph and Aworh, 1992).

Whilst the effect of storage days on *Irvingia* postharvest disease have been studied severally under the different conditions (Etebu, 2012, 2013; Joseph and Aworh, 1992), the effect of storage period and postharvest disease on the proximate composition of *Irvingia* fruit pulp are yet unknown. Hence in this research, the changes

that occur in postharvest *Irvingia* fruit wastes after harvest was assessed with respect to brownish-black rot disease and proximate composition. Findings from this work would avail us the prerequisite information to further assess the systematic decay of *Irvingia* fruit wastes after harvest, and to know when food substances of interest may be extracted or exploited for beneficial use.

II. Materials and Methods

Samples collection and Experimental design

Irvingia fruits were harvested from a natural forest situated in Amassoma town (Lat. 4°58′09″N Long. 6°06′34″ E) of Bayelsa state, Nigeria. A total of 900 fresh and green fruits were randomly selected and split with a machete to extract the kernel, and the pericarp which is usually considered waste by locals were thereafter separated into three replicates (300 fruits per replicate). A quadrant measuring about 3m × 1m having three equal compartments (representing three replicates) of 1m x 1m was constructed and fruits wastes from each replicate were spread in the three equal compartments of the quadrant respectively. The quadrant was barricaded at the sides with nets to exclude reptiles and the fruits were left to decay for 6 Days after harvest (DAH).

Postharvest disease assessment

At the onset (representing day 0) of the experiment 10 fruits were randomly selected each from all three replicates and their postharvest spoilage status were individually assessed based on brownish-black rot disease symptom described by Etebu (2012), and the average disease score of 10 fruit wastes (representing one replicate) was recorded as the score for each replicate. Assessment of postharvest spoilage status of the fruits was repeated on the 3rd and 6th days after harvest (DAH) respectively. Severity of postharvest spoilage was determined visually by the proportion of fruit area affected by brownish-black rot disease and expressed in percentage as according to Etebu et al. (2003, 2009).

Moisture content: Moisture content assessment was hinged on the principle of weight loss of *Irvingia* fruit pulp due to the evaporation of water and was performed according to AOAC (2000). Briefly, 5g of *Irvingia* pulp was weighed and placed in a crucible of constant weight, and dried at 105°C (60°C?) for 24 hours. After drying, the sample was allowed to cool; the weight measured regularly until a constant weight was obtained. The loss in weight represented the moisture content, and was calculated from the formula

$$\textbf{\% Moisture} = \frac{\textbf{A - B}}{\textbf{C}}$$

Where

A = weight of sample (*Irvingia*) before drying
B = weight of sample (*Irvingia*) after drying
C = weight of sample (*Irvingia*) after drying and cooled to constant weight

Ash content: Ash content in samples was considered as the inorganic residue of a sample after the organic matter has been burnt up. Assessment of ash content of *Irvingia* fruit wastes was based on the procedure described by AOAC (2000). Briefly, 2g of *Irvingia* pulp was measured into a crucible of known weight in a muffle furnace and ignited at 550°C for 15hrs after which it was cooled to room temperature in a desicator, after which the ash was re-weighed. Ash content was thereafter calculated from the formula

$$\textbf{\% Ash} = \frac{\textbf{Weight of Ash}}{\textbf{Weight of Sample (}\textbf{\textit{Irvingia}}\textbf{)}} \times 100$$

Crude fibre: This is the organic residue of a sample after being treated under standardized conditions with light petroleum, boiling dilute H_2SO4, boiling dilute NaOH solution, dilute HCI, alcohol and ether. Its assessment was undertaken as described by AOAC (1986).

Procedure: Fifty millilitre of water and 1.25% of tetraoxosulphate (VI) acid (H_2SO_4) were added unto 2g of defatted *Irvingia* fruit pulp in a well calibrated beaker. The volume was thereafter made up to 200ml with water and heated to boiling for 30 minutes. After this, the mixture was filtered hot through Buchner funnel with the aid of a suction pump. The residue was washed severally with hot water until it was acid free (became neutral to litmus paper). The residue was then transferred into the 400ml beaker and 50ml of 1.25% NaOH was added and the volume made up to 200ml with distilled water. The mixture was then brought to boiling for 30 minutes. During this period, boiling water was repeatedly added from time to time to maintain the 200 ml level and rewashed through Buchner funnel to collect the precipitate until it was free from NaOH. Finally, the residue was

washed twice with 95% ethanol dried in an oven at 100°C to a constant weight and thereafter cooled in a dessicator. The crude fibre content was calculated from the formula

$$\textbf{\% Crude Fibre} = \frac{\textbf{Weight of fibre}}{\textbf{Weight of defatted sample (}\textit{Irvingia}\textbf{)}} \times 100$$

Protein content determination: Protein content was determined in the form of Total nitrogen using the kjeldahl method adopting the procedure described by AOAC (1986). It comprised of three steps – Digestion, distillation and titration.

Digestion: Half a gram of *Irvingia* fruit sample was gently heated for 1hr in a long-necked digestion flask containing 5ml of concentrated tetraoxosulphate (VI) acid (H_2SO_4) and Kjeldahl catalysts (1.5g $CuSO_4$; 1.5 Na_2SO_4 anti bumps chips). The heating was continued for about 4-5hrs until a clear bluish digest was obtained. Thereafter, the digest was cooled and quantitatively transferred into a 50ml standard flask and made up to the 50ml mark with distilled water.

Distillation: Ten millilitre of this digested *Irvingia* fruit sample solution was treated with 10ml of 40% NaOH in a Kjedahl distillation flask and was gently brought to boiling for 30 minutes. The resultant gas (ammonia) was collected in a conical flask containing 10ml of 5% boric acid into which 2ml of the mixed indicator (methyl red and methylene blue) was added. The boric acid mixed indicator solution turned green as ammonia was distilled into it. Also, a blank control was set up wherein all the procedure was repeated with all analytes except the 0.5g of *Irvingia* sample.

Titration: A 50ml burette was filled with 0.1M HCl solution and the distillate was titrated. The protein content of *Irvingia* fruit wastes was thereafter obtained by multiplying percentage nitrogen by 6.25 being the Gravimetric factor of protein conversion (Vincente et al., 2009)

$$\text{\% Nitrogen} = \frac{(B - A) \times Molarity\ of\ NaOH \times 0.014}{W}$$

Where

B = titre value of blank

A = titre value of sample

W = weight of sample used

% protein = % Nitrogen x conversion factor

Crude fat: Crude fat was assessed using the soxhlet extraction method as described by Osborne and Voogt (1978) and AOAC (1986). Five gram of oven dried *Irvingia* fruit sample was weighed into a thimble, and about 200ml of petroleum ether was poured into a previously weighed round bottom flask containing weighed anti bumping granules. The Soxhlet extractor and the thimble with its content was fitted into the flask and heated slowly until the solvent in the extractor was decolourised. The thimble was removed and air dried, and the extracted lipid in the flask was concentrated using rotary evaporator. This was further dried in a desicator and then weighed. The amount of lipid extracted was obtained from difference between the weight of the flask before and after the extraction. Percentage lipid content was calculated from

$$\textbf{\% Lipid} = \frac{\textbf{Weight of Extract}}{\textbf{Weight of Sample (}\textit{Irvingia}\textbf{)}} \times 100$$

Carbohydrate content: The carbohydrate content of *Irvingia* fruit pulp was determined by subtracting the sum of the other five proximate components (moisture, crude fibre, crude protein, ash, crude fat) from 100.

Data analysis: Brownish-black rot disease was arcsine transformed according to Gomez and Gomez (1984). Also, Percentage moisture was square root transformed. The transformed data alongside other data were subjected to ANOVA using Generalized Linear Model of SPSS version 16.0 Statistical software. Correlation/regression analyses were performed between brownish-black rot disease of *Irvingia* fruits and the different proximate components. Mean disease and proximate content data were further subjected to Tukey's mean separation test. Mean transformed set of data were thereafter de-transformed (weighted) and discussed hereunder alongside other parameters. Comparison of disease and proximate composition was made with respect to days after harvest, and the relationships between disease and proximate composition were discussed

III. Results and discussions

Brownish-black rot disease

Response of *Irvingia* fruit wastes left to rot in open field conditions after harvest was characterized by brownish-black rot disease (Fig. 1). *Irvingia* fruits are climacteric; being able to ripen after harvest even when they are detached from the parent tree. Ripening processes of fruits are influenced by physiological changes that render the fruits susceptible to microbial attack (Prusky and Keen, 1993). Several microorganisms have been shown to associate with diseased postharvest *Irvingia* fruits. In particular, fungal species such as Aspergillus, Penicillium, Botrytis, Rhizopus, Mucor have been implicated with postharvest *Irvingia* fruits (Joseph and Aworh, 1991; Etebu, 2012, 2013). Aworh and Joseph (1991) categorically showed, through Koch's postulate, that the primary causal agent of brownish-black rot disease of postharvest *Irvingia* fruits was the fungus Botrytis species. A few bacterial species whose partial 16S rRNA gene sequences shared $\geq$ 99% DNA sequence similarity with Bacillus species, Enterobacter species, Oceanobacillus profundus, Enterobacter cloacae and Staphylococcus cohnii have also been shown to be associated with decaying *Irvingia* fruit wastes (Etebu and Tungbulu, 2015)

Severity of postharvest disease was observed to be dependent on the number of days after harvest (DAH). DAH signifies the number of days the fruit wastes were left to decay in the open field after harvest. Disease progressed significantly ($P \leq 0.05$) as DAH increased (Table 1). Mean weighted brownish-black rot disease scores on 0^{th}, 3^{rd} and 6^{th} DAH were 2.37%, 22.24% and 87.86% respectively. Findings from this present work was comparable to results of previous works, and postharvest disease symptoms more or less towed the same pattern of occurrence previously observed in some earlier works (Joseph and Aworh 1991, 1992; Etebu, 2012). In a nutshell, fruit wastes of *Irvingia* gabonensis were observed to be completely green at harvest with very few patchy specks of dark colourations without rot. However, the rate of disease development of *Irvingia* fruits was clearly faster in this work than previous works reported. For example whilst Etebu (2012) showed that mean weighted percentage brownish-black rot disease symptoms on *Irvingia* fruits left in an open field after three days of harvest was only 0.63%, results in this work showed that as much as 22.24% surface area of fruit wastes left under similar conditions and for the same number of days after harvest developed same degree of disease symptoms. The difference in rate of development of the disease would have been occasioned by the different ways in which the fruits were treated prior to storage in the open field. Whilst Etebu (2012) worked on whole *Irvingia* fruits, this present work was carried out with split fruit that are usually considered as wastes after the kernels are extracted. So whilst it took up to 12 days to record over 70% surface area of whole fruit tissues turning into a brownish-black rot (Etebu 2012), fruit wastes examined in this work took only 6 days to record same level of decay. The increase in rate and magnitude of disease symptoms in this work could be further attributed to wounds inflicted on the fruit wastes in course of kernel extraction. Such wounded portions of the fruit would have served as infection locus for disease and spoilage microorganisms to easily gain entry into the fruit tissues to cause infection (Palou et al., 2013).

Percentage area of *Irvingia* fruit waste overtaken by brownish-black rot disease symptom increased progressively and significantly ($P \leq 0.05$) from day 0 to the 3rd, and 6th days after harvest. Although this trend is largely similar to results observed in previous works, it would be of note to mention that the brownish-black rot postharvest disease symptoms of *Irvingia* fruits observed in this former work did not change significantly ($P \leq 0.05$) between day 0 and 3 after harvest. This again further reiterates the enormous impact of wounds or injury on postharvest fruits as they relate to postharvest infections.

Proximate composition

The nutritional content of *Irvingia* fruits varied between proximate parameters measured. Of the 100g of *Irvingia* fruit wastes assessed in this work, weighted mean percentage moisture across all DAH was 82.99% followed by dry matter (16.91g), Carbohydrate (15g), fibre (0.67g), protein (0.63g), ash (0.49g), and fats and lipids (0.10g) (Table 1). Onimawo and associates (2003), in their pioneering work reported that *Irvingia* pulp contained moisture (80%), protein (1.09%), fat (1.06%), ash (0.8%), fibre (0.4%) and carbohydrate (10.7%). The water content of *Irvingia* fruit pulp obtained in this work is comparable to the results obtained by Onimawo et al, 2003 for the same fruit. The water content of *Irvingia* fruits were also similar to that of mango (Mangifera indica) which has been shown to be 80% (Mamiro et al. 2007). Mangoes are used in Nigeria for the production of mango juice and with or without the peel for making jam (Achinewhu, 1983). Furthermore, the extraction rate of juice from I. gabonensis fruit pulp has been reported to be 75% and the sugar concentration of its juice is about the same with those of pineapple and orange (Akubor, 1996).

Although the results of this present work were largely similar to results obtained by Onimawo et al (2003), there are some obvious differences. For example whilst the protein and fat contents obtained in this work were 0.63g and 0.10g per 100g of *Irvingia* fruit pulp, respectively, Onimawo et al (2003), for the same mass of fruit recorded 1.09g and 1.06g as protein and fats contents respectively. These differences could have arisen from differences in the health status of the fruits as at the time of investigation, the storage period of the

fruits or conditions under which they were stored prior to assessment. Findings of this present work show that number of storage days after harvest has significant impact on both the health status and proximate composition of fruits. Whilst differences in % moisture, dry matter and lipid with respect to DAH was not significant at the 5% probability level, nutritional parameters such as protein, ash, dietary fibre and carbohydrate were significantly ($P \leq 0.05$) influenced by the number of days the fruit wastes were left to decay in the open after harvest (Table 1).

Protein for example was observed to decrease from 0.75g/100g of *Irvingia* fruit (0.75%) at DAH (0) to 0.61g/100g of fruit (0.61%) at DAH (3) and 0.53g/100g of fruit (0.53%) at DAH (6) (Table 1). The difference in protein content on DAH (0) was significantly higher in comparison to its content on the 3rd and 6th DAH but the difference in protein content between the 3rd and 6th DAH was not significant. These results clearly show that *Irvingia* fruit pulp has low protein content irrespective of the storage days after harvest. This was expected because fruits are generally low in protein; accounts for less than 1% of the fresh weight of fleshy fruits (Kader and Barret, 2005; Nixwell et al., 2013), but findings reported by Onimawo et al (2003) from a work done over a decade ago indicated that the protein content of *Irvingia* fruits were as much as 1.09%. The nutritional value of any given food is said to be defined by its protein content and protein energy (Gopalan et al., 2000). This difference in protein contents of *Irvingia* fruits between these works could be attributed to variety of factors, some of which would include, difference in *Irvingia* species, growth conditions of fruit trees, soil conditions, storage conditions prior to assessment etc. Variability in biochemical composition has been reported to limit the industrial use of crops (Guéguen, 1991). Although variability in crops is known to be influenced by genotypic and phenotypic factors (Turner et al., 1990), it would be interesting to assess the protein content of postharvest *Irvingia* fruits across different geographical locations with a view to studying the potential effect of environmental and climatic conditions on its nutritional value.

Similar to protein, the ash content of postharvest *Irvingia* fruit wastes assessed in this work decreased from 0.56g per 100g of fruit waste on DAH (0) to 0.53g and 0.39g fruit on the 3rd and 6th DAH respectively. Whilst ash content of the fruit on DAH (0) was significantly higher than it was on the 6th DAH, difference in ash content of the fruits between DAH (0) and DAH (3) was not significant at 5% probability level.

Ash is the inorganic residue left in a food material after water and organic matter are removed through heat application. The organic matter is therefore a measure of the total amount of minerals in a food. As such the ash content of a food material is an index of the quality of the food. High total ash content in a food material indicates the presence of impurities and by extension a low quality food (Mbogo et al., 2010). Results on ash content of *Irvingia* fruit pulp obtained from this work was slightly lower than figures reported by Onimawo et al (2003). The variation in ash content of *Irvingia* fruits assessed in this work and earlier studies may have been occasioned by differences in growing conditions of the fruit tree, postharvest handling and storage conditions prior to determination of its nutritional quality.

The fibre content was assessed as part of the nutritional quality indices measured in this work. Results showed that fibre content per 100g of *Irvingia* fruit pulp decreased from 0.71g on DAH (0) to 0.69g and 0.60g on the 3rd and 6th DAH respectively. Measure of Tukey's Honestly Significant Differences (HSD) in fibre content with respect to DAH followed exactly same pattern similar to Ash (Table 1). Whilst fibre content of *Irvingia* fruit on DAH (0) was significantly higher than it was on the 6th DAH, difference in fibre content of fruits between DAH (0) and DAH (3) was not significant at 5% probability level. Dietary fibres are the sum total of plant polysaccharides indigestible by mammalian endogenous digestive enzymes (Theander et al., 1994). Though indigestible by humans and other mammals they play very important role in the general wellbeing of an individual's physiological processes. In particular, fibre relieves constipation by enhancing the water holding functionality of faeces, and its consumption has often been linked to a decreased incidence of heart related disease and colon cancer (Kader and Barrett, 2005). *Irvingia* fruits are known to have a laxative effect among consumers, and this has been attributed to its fibre content (Ngodi et al., 2005). Findings of a recent work has also muted the possibility of bacteria as being partly responsible for the free bowel movement amongst consumers of raw *Irvingia* fruits (Etebu and Tungbulu, 2015). The fibre content of *Irvingia* fruits observed in this study is within the reported range of 0.5 to 1.5% (fresh weight) known amongst fruits (Kader and Barrett, 2005). The results, irrespective of the storage period was, however, higher than the value reported by Onimawo et al (2003) who worked on the same fruit. The difference in fibre content between this present work and the earlier work by Onimawo and Associates done in 2003 could be attributed to species differences of the fruits analysed.

Irvingia species predominant in Nigeria are of two species, I. gabonensis (sweet and edible) and I. wombolu (bitter and inedible). Prior to 1975, *Irvingia gabonensis* and *Irvingia wombolu* were clumped together as one species, Irvingia gabonensis (Aubry-Lecomte ex O'Rorke). However, Okafor (1975) noted the existence of two forms (sweet and bitter varieties). He named the one having a sweet and edible pulp as *I. gabonensis* var. *gabonensis* whilst the other form which has a bitter and inedible pulp was named *I. gabonensis* var. *excelsa*. Following this recognition and distinction by Okafor in 1975, Harris (1996) revised the taxonomy of the

Irvingiaceae, splitting *I. gabonensis* var *excelsa*, from *I. gabonensis* var *gabonensis*, to create Irvingia wombolu Vermoesen. The sweet species is now simply named Irvingia gabonensis while the bitter one is *Irvingia wombolu*. However, studies on *Irvingia* have often failed to identify species along this taxonomic line, and as a result figures for I. wombolu are sometimes erroneously recorded for I. gabonensis (Atangana et al., 2001). It would be worthwhile to assess the nutritional qualities of I. gabonensis and I. wombolu to compare their differences where they exist. A relatively recent comparative study on these two species of *Irvingia* with respect to fruit size, weight and brownish-black rot disease revealed statistically significant ($P \leq 0.05$) differences (Etebu, 2013). Also, the fungal population and relative amounts of various phytochemicals were also varied between the two species.

Carbohydrate content was dependent on DAH. Its content on the day of harvest was 14.45g per 100g of fresh fruit pulp. This value increased to 15.12 and 15.42 on 3rd and 6th DAH, respectively. Whilst the carbohydrate content of *Irvingia* fruit waste on 0th DAH was significantly ($P \leq 0.05$) different from those assessed on 3rd and 6th DAH, the difference in carbohydrate content between the latter two DAHs was not significant. Carbohydrates are the most abundant and widely distributed proximate component derived from plants; responsible for the structural framework, texture, taste, and food value of a fresh fruit. Carbohydrate content typically range between 10 to 25% of fresh fruit weight, but changes in carbohydrate contents are common phenomenon amongst fruits, particularly climacteric fruits, during ripening (Kader and Barrett, 2005). Ripening brings about a decrease in starch and an increase in sugar content amongst most fruits (Doreyappy-Gowda and Huddar, 2001). Starch which occur in relatively high amounts in unripe fruits are hydrolyzed during ripening to sugars such as fructose, glucose and sucrose (Kudachikar et al., 2001). As with other organic matter, carbohydrate content was expected to decrease with increase in DAH. It is common knowledge that as postharvest period increases fruits would naturally deteriorate as a result of several inherent biological processes such as respiration (Kader and Barrett, 2005). During respiration, complex carbohydrates are broken down to simpler forms and expectedly, stored food reserves of fruits would get depleted in the process.

IV. Relationship between Brownish-black rot disease and proximate composition

Findings of this present work revealed a relationship between brownish-black rot disease and different proximate components. Correlation-regression analyses between disease and moisture and lipids were not significant (Data not shown). However, significant relationship between disease and the rest proximate components (protein, ash, fibre and carbohydrate) were obtained (Figures 2-5), indicating that the amount of these fruit constituents is dependent on the disease /health status of the fruit prior to assessment.

In particular, results showed that postharvest disease is inversely, significantly ($P<0.01$) related to protein content of *Irvingia* fruits ($r^2 = 0.73$, Pearson correlation coefficient = -0.86) (Fig. 2). This means conditions that facilitate progression of disease of *Irvingia* fruits after harvest would also lead to reduction of protein content of its fruits. In corroboration of this finding, Adeniyi et al (2014) working with healthy and diseased *Irvingia* seeds (kernels) had observed that protein contents were significantly higher amongst healthy seeds than diseased ones. This present work showed that protein content of *Irvingia* fruits decreased as storage days (DAH) increased (Table 1). Close analysis of results from this work and others seem to suggest that storage period in itself alone may not significantly influenced the amount of protein in postharvest fruits. For example, Oyewole (2014) whilst working with microorganisms associated with deterioration of stored banana observed that the protein content was higher in fruits stored for longer periods. In the same article, the Researcher further reiterated that postharvest diseases of fruits cause losses in terms of quantity and quality. Also, Nweke and Ibiam (2012) had earlier on showed that fruits with soft rot disease have correspondingly low protein content in their pulp when compared to healthy fruits. From the ongoing, it would suffice to say that postharvest *Irvingia* fruit wastes must be stored under conditions that would reduce postharvest disease if the overall nutritional quality of its fruit is to be maintained.

Also similar to protein, results from this present work further showed that brownish-black rot disease of *Irvingia* fruit wastes was observed to be inversely correlated to ash content of the fruit ($r^2 = 0.68$; Pearson correlation coefficient = -0.96) (Fig. 3). This means that an increase in severity of brownish-black rot disease results to a significantly, corresponding reduction in ash content of the *Irvingia* fruit pulp. Several Workers who simply compared the ash content of healthy and diseased fruits showed that diseased fruits, in contrast to findings of this present work, had higher ash content than healthy fruits (Nweke and Ibiam 2012; Esiegbuya et al 2013). These variations in result patterns further confirms that changes in postharvest fruits are governed by a suite of factors, some of which includes plant type, plant growing conditions, prevalent diseases, postharvest handling and storage etc .

Brownish-black rot disease of postharvest *Irvingia* fruit wastes, was observed to be significantly ($P<0.01$), inversely related to its fibre content ($r^2 = 0.92$; Pearson correlation coefficient = -0.82**) (Fig. 4). This also means that the fibre content of postharvest *Irvingia* fruits would decrease as brownish-black rot disease increases and vice versa. Nweke and Ibiam (2012) whilst working with Annona muricata (commonly called

soursop) showed that fruits plagued by soft rot disease had relatively reduced amounts of fibre content in their fruit pulp, amongst other nutritionally valued indices, compared to the their healthy counterparts. Fungi found to be associated with soft rot disease of this plant were reported to include Rhizopus stolonifera, Aspergillus niger and Colletotrichum gloeosporoids. Similarly, fungal species found to be associated with brownish-black rot disease of postharvest disease of *Irvingia* fruits include Aspergillus, Penicillum, Rhizopus, Mucor, Botrytis etc (Etebu, 2012, 2013; Joseph and Aworh, 1991, 1992). Dietary fibres are derived from fruit cell walls made of cellulose, hemicellulose, pectin and lignin substances (Kader and Barrett, 2005), and fungi associated with postharvest disease of *Irvingia* are likely to have degraded the fibre content of the fruits. This assumption is predicated on two reasons based on findings of some previous works. Firstly, several fungal species are known to degrade plant polysaccharides that make up the dietary fibre content of plant fruits (Kader and Barrett, 2005; Van den Brink and de Vries, 2011). Secondly, some recent works have shown that increase in brownish-black rot disease of *Irvingia* fruits is positively related to fungal population associated with the disease (Etebu, 2013). It therefore follows that the decrease in fibre content may have been occasioned by an increase in fungal population which whilst facilitating the degradation of the fruits dietary fibre also led to increase in brownish-black rot disease severity. This possibly explains the significant ($P \leq 0.01$) inverse relationship between brownish-black rot disease and fibre content of *Irvingia* fruit waste obtained in this present work.

It is interesting to note that of all proximate component indices assessed in this work, only carbohydrate had a significantly ($P \leq 0.05$) positive relationship with brownish-black rot disease which in itself increased with increase in days after harvest (Fig. 5, Table 1). This simply means that an increase in brownish-black rot disease of postharvest *Irvingia* leads to an increase in carbohydrate content of its fruits. This is the first work, to the best of our knowledge, where correlation-regression analysis between brownish-black rot disease of postharvest *Irvingia* and its carbohydrate content has been done. Earlier works wherein the apparent effect of postharvest diseases on proximate composition of fruits are studied, the focus have more or less been comparison between healthy and diseased fruits. Comparative studies between healthy and diseased fruits of different plant have always shown that the former fruits contain significantly higher amounts of carbohydrates than the latter (Nweke and Ibiam, 2012; Ekundayo and Okigbo, 1991). In particular, Nweke and Ibiam (2012) showed that healthy fruits of Annona muricata contained a higher amount of carbohydrate content than those plagued with soft rot disease. In their submission, they opined that the biochemical activities of pathogens causing disease of fruits would result to digestion, degradation and dissolution of the fruit tissue into a mush (watery rot), this in turn, would result to a relative reduction in the protein, fat, fibre and carbohydrate contents of the infected fruits (Nweke and Ibiam, 2012).

From the ongoing, brownish-black rot disease of postharvest *Irvingia* fruit was expected to be negatively related to its carbohydrate content as it was with other proximate components (Fig. 1). This expectation, notwithstanding, the corresponding increase in total carbohydrate with increase in disease severity of postharvest *Irvingia* fruits may be explained as follows. The severity of brownish-black rot disease of postharvest *Irvingia* fruits has been previously linked to an increase in fungal population (Etebu, 2013). That being the case, it could be that reducing sugars also got increasingly accumulated during pathogenesis as DAH increased which could have led to an increasing amount of total carbohydrate content of the fruits. A recent work on the effect of storage period on the chemical composition of Abelmoschus esculentus (okra) tacitly gave credence to this possibility (Fagbohun and Faleye 2012). Although the Workers did not assess the postharvest disease of okra fruits in their studies, they observed that the fungal population, as well as carbohydrate content increased as storage period progressed.

V. Conclusion

This present work further establishes the nutritional benefits of *Irvingia* fruit consumption as has been observed by previous Workers. In addition, it reveals the effect of postharvest disease of *Irvingia* fruit on its proximate composition. Whilst the composition is not affected, the quantities of the components are significantly depleted by disease. We recommend that fleshy *Irvingia* fruits intended for consumption may have to be thoroughly washed and consumed soon after kernels are extracted owing to its short life span. Alternatively, the fleshy edible pericarp often treated as waste may have to be processed into consumable forms to both lengthen its storage life and preserve the nutritional quality of the fruit waste.

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Fig. 1: Postharvest Irvingia fruit waste

From Left - Right: Fresh fruits ready for kernel extraction; Fresh fruits; Fleshy pulp of fruit; and fruits showing Brownish-black rot symptoms

Table 1: The fate of brownish-black rot disease and proximate composition of Irvingia fruit wastes after harvest

	Mean Brownish-black rot disease		Mean Proximate components measured per 100g of *Irvingia* fruit wastes							
			% Moisture							
DAH	ArcSine	Weighted	SQRT	Weighted	Dry matter (g)	Protein (g)	Lipid (g)	Ash (g)	Fibre (g)	Carbohydrate (g)
0	8.85^{a}	2.37	9.13^{a}	83.36	16.57^{a}	0.75^{b}	0.12^{a}	0.56^{b}	0.71^{b}	14.45^{a}
3	28.14^{b}	22.24	9.10^{a}	82.81	17.03^{a}	0.61^{a}	0.09^{a}	0.53^{b}	0.69^{b}	15.12^{b}
6	69.61^{c}	87.86	9.10^{a}	82.81	17.13^{a}	0.53^{a}	0.09^{a}	0.39^{a}	0.60^{a}	15.42^{b}
Grand mean	**35.53**	**37.49**	**9.11**	**82.99**	**16.91**	**0.63**	**0.10**	**0.49**	**0.67**	**15.00**

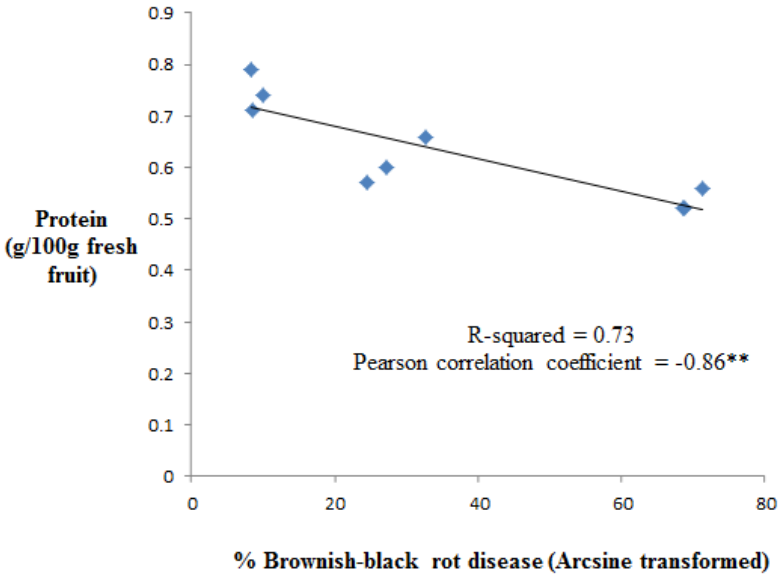

Fig. 2: Relationship between brownish-black rot disease and protein content of postharvest Irvingia fruit

** Indicates significant negative relationship at $P \leq 0.01$

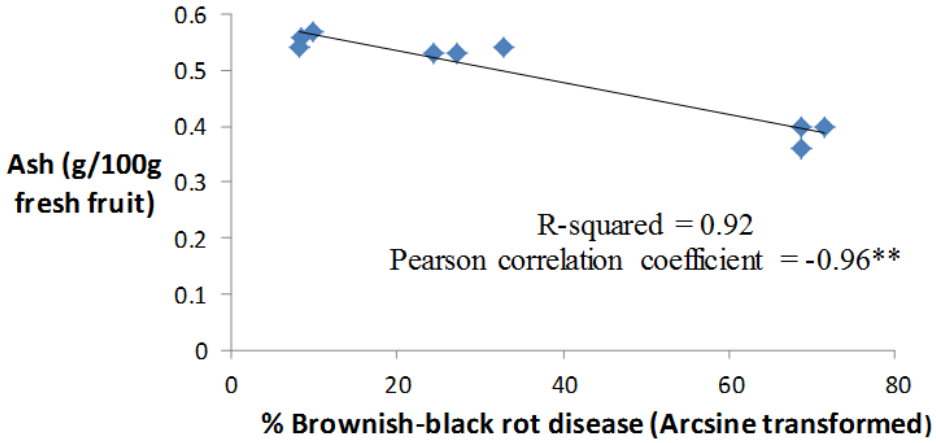

Fig. 3: Relationship between brownish-black rot disease and ash content of postharvest Irvingia fruit

** Indicates significant negative relationship at $P \leq 0.01$

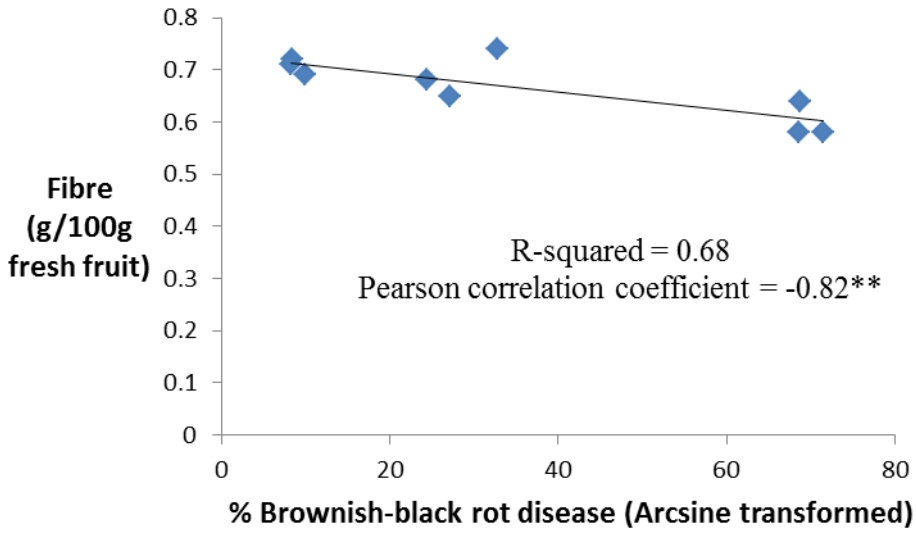

Fig. 4: Relationship between brownish-black rot disease and fibre content of postharvest Irvingia fruit
****** Indicates significant negative relationship at $P \leq 0.01$

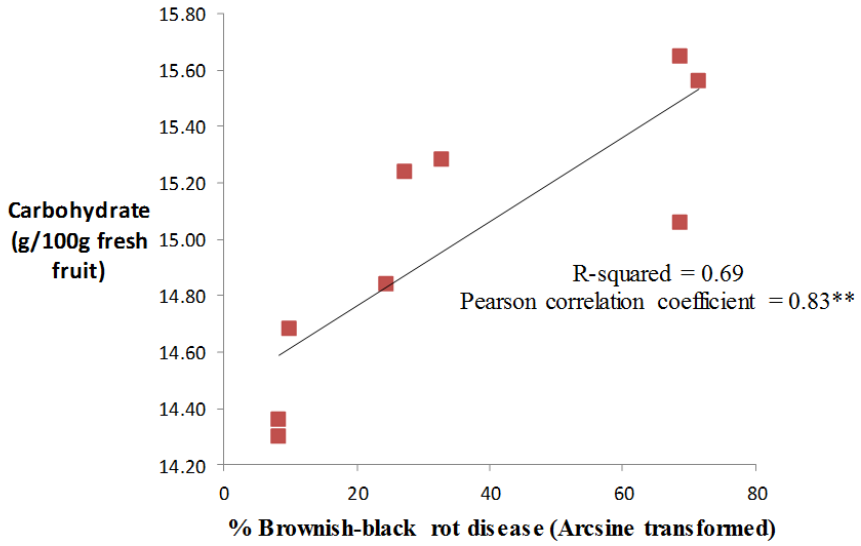

Fig. 5: Relationship between brownish-black rot disease and carbohydrate content of postharvest Irvingia fruit
****** Indicates significant positive relationship at $P \leq 0.01$