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# Fibre Characteristics of Paper and Paper Egg Tray Used In Southwestern Nigeria

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***Abstract:*** **Fibre characteristics of paper and paper egg tray (locally manufactured and imported brands) used in Southwestern Nigeria was investigated. 14 different brands of paper and paperboard were selected to cover the available varieties of paper and paperboard for egg tray production. Paper samples were obtained from identified paper egg tray producing establishments, printing press and other sources in the region. A total of 9 paper egg tray brands of local and imported categories were also obtained for characterization based on users' recommendation. 25mm by 25mm of each test specimen was put in test tube containing warm water of 50ºc, for 24 hours. Representative samples of separated fibres in the suspension were mounted on slides and measured under a Ritchert Light Microscope x80 magnification. Twenty (20) representative fibres were selected and measured in order to keep error below 5% for a 95% confidence level. Results obtained showed that sample papers and boards were made of heterogeneous fibrous materials; and their fibre quality compromised. Local paper egg trays were made of comparatively lower fibre quality.**

***Keywords:*** **Fibre characteristics, paper, paperboard, paper egg tray.**

## 1. INTRODUCTION

Paper has become incredible phenomenon in both developed and developing countries like Nigeria (Onilude, 2011). The variability of raw materials is a general practical problem for egg tray production in Nigeria. The industry faces the challenge of guaranteeing a satisfactory strength of their products. A sustainable production of paper egg trays of consistent and acceptable quality requires comprehensive understanding of the fibrous materials being used, which are becoming more heterogeneous due to the fact that a very large proportion of the world's pulp and paper are produced using cellulosic materials produced in temperate zones. (Pokhrel C, 2010)

Besides, fibre anatomy can be used successfully as a complementary practical test to predict the performance of pulp and paper products (Adamopoulos *et al, 2006)*. This is an opportunity for cost reduction and selection of the most appropriate and inexpensive combination of waste papers for a specific purpose. This can be achieved by identifying the effects of different types and morphological characteristics of fibres from recovered pulps on the quality of paper egg trays, which are hitherto not sufficiently reported. Paper quality depends greatly on the fibre characteristics and pulping technique used. Fibre morphological indices that determine the quality of paper are: fibre length, fibre diameter, lumen width, cell wall thickness, the relative fibre length (slenderness ratio), runkel ratio, coefficient of flexibility and rigidity coefficient (Frimpong-Mensah, 1992).

## 2. MATERIALS AND METHOD

**Sample selection:**

14 different brands of paper and paperboard brands were selected to cover the available varieties of papers and paperboards in the country, at the moment, for egg tray production. They were obtained from identified paper egg tray producing establishments, printing press and other sources, within Southwestern Nigeria. The samples were then sorted, and their actual weight (grammage) determined according to TAPPI T410. Also, a total of 9 paper egg tray brands of local and imported categories were also obtained for characterization based on users' recommendation.

**Fibre Characterization:**

Samples of paper, paperboard and paper egg trays were prepared for fibre anatomy. 25mm by 25mm of each test specimen was put in test tube containing warm water of 50ºc, for 24 hours. Representative samples of separated fibres in the suspension were then mounted on slides and measured under a Ritchert Light Microscope x80 magnification. Twenty (20) representative fibres were selected and measured in order to keep error below 5% for a 95% confidence level in accordance with Jorge et al,( 2000).

Fibre length (FL), fibre diameter (FD), lumen width (LW), and cell-wall thickness (CT) were measured from each representative sample; and derived values of morphological indices i.e. slenderness ratio, runkel ratio, elasticity coefficient and rigidity coefficient; were also determined in accordance with the approach adopted by Kirci (2006) as shown in the equations below.

Slenderness Ratio (SR) = $\frac{FL}{FD}$…………………… (1)

Runkel Ratio (RR) = $2\left(\frac{CT}{LW}\right)$…………………… (2)

Elasticity Coefficient (EC) = $\left(\frac{LW}{FD}\right)$x 100………… (3)

Rigidity Coefficient (RC) = $\left(\frac{CT}{FD}\right)$ x 100………… (4)

## 3. RESULTS AND DISCUSSION

***Grammage Determination:***

Grammage of selected paper samples was determined according to TAPPI T410; and the result shown in table 1. From the table, *Office paper, Newsprint*, *Chipboard*, and *Manila Card* have actual grammage of 77.22±1.73 g/m², 43.48±0.85 g/m², 246.88±2.24 g/m², and 246.92±2.28 g/m² respectively, as against the manufacturers' grammage of 80 g/m², 45 g/m², 250 g/m², and 250 g/m², respectively. All 14 paper samples weighed recorded less grammage than as claimed by the manufacturers/ suppliers. This suggests that quality of paper and paperboard being supplied/ imported to Nigeria might have been compromised.

***Fibre Length of Samples:***

Fibre length of the samples was measured by aligning the representative fibre sideways to the calibrated ruler in the microscope, and is measured from one end to the other; known to be the available number of bonding sites of a respective fibre to form an interwoven network of fibres. However, tables 2 and 3 show the average fibre length of selected paper, paperboard, and paper egg tray brands. Table 2 shows that *Newsprint* brand, amongst paper brands, has the longest fibre length of 2.30±0.72mm and followed by *Matt paper* of 1.25±0.86mm, as also shown in fig. 1. *Cardboard* and *Chipboard* brand has average fibre length of 1.29±0.83mm and 1.18±0.50mm respectively, amongst paperboard brands, as indicated in fig.2. Also, *Lagos tray* and *Malaysia tray* has fibre length of 1.34±0.61mm and 2.28±0.95mm, amongst local and imported trays respectively, as shown in fig. 3 and 4 below.

Long fibres are preferred for manufacture of paper because they give a more open and less uniform sheet structure (Oluwadare and Ashimiyu, 2007). It influences the physical and mechanical properties of the cellulosic material and is also associated with its toughness, workability and durability (Parameswaran and Liese 1976, Espiloy, 1987). Short fibres lack formation of good surface contact and fiber-to-fiber bonding (Ogbonnaya *et al*. 1997). This and others are pointers to the notion that hardwood pulps are lower in paper strength due to the shortness of their fibres (i.e <2mm) than those of softwoods with longer fibres. Also, papers produced from short fibres are shown to have low mechanical strength and tearing resistance (Ververis *et al*. 2004). Otherwise, fibre length is not the only factor that influences the strength of paper products; there are other contributing factors of paper strength (Annergren, *et al.* 1963; Horn, 1974).

***Fibre Diameter of Samples:***

From tables 2 and 3, *Newsprint, Cardboard, Baba tray* and *UK tray* has the largest average fibre diameter of 41.06±11.27µm, 24.43±8.93 µm, 27.23±11.81 µm, and 29.58±11.21 µm, amongst paper, paperboard and paper egg tray brands respectively. Fibre diameter is usually measured across the fibre length by placing the calibrated ruler present in the microscope at the middle of the fibre, in horizontal direction (Jang et al, 2002).

***Lumen Width of Samples:***

Tables 2 and 3 show that *Newsprint* (28.15±0.98 microns), *Cardboard* (18.16±7.60 microns), *Lagos tray* (15.35±8.38 microns) and *UK tray* (19.53±9.35 microns) has the widest lumen width amongst paper, paperboard and paper egg tray brands respectively.

Lumen width is the hollow space of the cell from the first wall side to the second wall side. It is also the diameter of the interior cavity, determined in a transverse direction. Fibre lumen width affects the beating of pulp in the sense that; the larger the fibre lumen width, the better will be the beating of pulp due to the penetration of liquids into vacant spaces of the fibres. Fibres with large lumen and thin walls tend to collapse during paper making with enhanced inter-fibre bonding and as a result enhance their strength properties (Panshin, and de Zeeuw, 1980).

***Cell wall Thickness of Samples:***

From tables 2 and 3, *Newsprint*, *Chipboard*, *Baba tray* and *China tray* brands has cell-wall thickness of 6.45±3.29 microns, 4.36±1.94 microns, 4.67±2.24 microns and 5.48±1.77 microns, respectively. Cell wall thickness is calculated by subtracting the lumen width from the fibre diameter and dividing difference by two. Fibres with thick cell-wall are reported to have negative influence on the bursting strength, tensile strength and folding endurance of paper. The paper is also bulky, uneven and having large number of void volume; while, paper made from fibres with thin cell-wall are dense and having good formation. Fibre cell wall thickness is influenced by the tree's age. Its proportion varies in trees. Matured wood have fibres with thick cell-wall while juvenile wood fibres are thin walled (Gbadamosi, 2001).

***Slenderness Ratio of Samples:***

From tables 2 and 3, it is shown that all samples except *Baba tray* (30.55±12.40) has slenderness ratio that is less than 33, amongst paper, paperboard, and paper egg tray brands. Slenderness ratio is the ratio of the fibre length to its diameter; and a determinant of tearing property of pulp and paper. Slenderness ratio of cellulosic material more than 33 is considered to be good for pulp and paper production. It also affects the flexibility and resistance to rupture of the fibres and paper product made there from. (Xu et al., 2006)

***Runkel Ratio of Samples:***

Also from tables 2 and 3, *Newsprint* (0.46±0.35), *Manila card* (0.27±0.26), *Power tray* (0.46±0.35) and *UK tray* (0.51±0.39), are among the samples with appreciable runkel ratio.

The runkel ratio is the ratio of fibre cell-wall thickness to its lumen; and this determines the suitability of a cellulosic material for pulp and paper production. Runkel ratio is directly affected by cell wall thickness, and not really by lumen diameter (Ona T. et al, 2001). Runkel ratio is also related to paper conformability, pulp yield and fiber density. High runkel ratio fibres produce bulkier paper than fibres with low runkel ratio. Wood species that is meant for pulp and paper production must have its runkel ratio to be less than 1 (Kpikpi, 1992). According to Eroglu, (1980), the fibres with a Runkel ratio above 1 are considered as having thick cell-wall, and are stiffer, less flexible and form bulky paper products of lower bonded area, and the cellulose obtained from this type of fibres is least suitable for paper making. When Runkel ratio is equal to 1, cell wall has medium thickness and cellulose obtained from this type of fibre is suitable for paper manufacture. When the ratio is less than 1, cell wall is thin and cellulose obtained from these fibres is most appropriate for paper production.

***Elasticity and Rigidity Coefficient of Samples:***

From tables 2 and 3, *Manila card* has average elasticity coefficient of 79.9±13% which falls within the category of highly elastic fibres, while other samples are within the elastic fibres category. The elasticity coefficient (co-efficient of flexibility), typically expressed in percentage, is calculated from the ratio of lumen width to its fibre diameter. Elasticity coefficient gives the bonding strength of each fibre and by and large, the tensile strength and bursting properties (Emerhi E.A, 2012). It also determines the degree of fibre bonding in paper sheet (Sharma *et al.* 2013). Elasticity Co-efficient (flexibility ratio) is categorized into four groups (1) High elastic fibres are those having elasticity coefficient greater than 75%. (2) Elastic fibres are those having elasticity ratio between 50-75%. (3) Rigid fibres are those having elasticity ratio between, 30-50%. (4) Highly rigid fibres are those having elasticity ratio less than 30% (Bektas, *et al.*, 1999).

Rigid fibres do not have enough elasticity and are unsuitable for paper production; therefore they are usually used for fibre plate, and cardboard production. This is because high rate of rigidity coefficient is reported to negatively affect tensile, tear, burst, and double fold resistance of paper (Akgul and Tozluoglu, 2009).

**Table1: Brands of Paper Used for the Experiment**

| S/No | Brand Name | Factory Grammage ($g/m^2$) | Actual Grammage ($g/m^2$) | Description |
|---|---|---|---|---|
| 1 | Kraft liner | - | - | Used in packaging carton making |
| 2 | Office Paper | 80 | 77.22±1.73 | Used for office work, printing of hand bill, jotter etc; has grammage of 60 $g/m^2$, 70 $g/m^2$, 75 $g/m^2$, and 80 $g/m^2$ . |
| 3 | Conqueror | 80 | 76.52±2.23 | Rough on one side and moderate on the other; has grammages of 80 $g/m^2$ and 100 $g/m^2$; used mainly for letterheads making. |
| 4 | Carbonless | 40 | 39.34±0.32 | Used for printing of receipt, bank slips and others that requires carbon paper; has the lowest grammage among printing paper brands (40$g/m^2$). |
| 5 | Matt Paper | 130 | 127.66±1.63 | Smooth on both sides; has grammages of 115 $g/m^2$, 130 $g/m^2$, 135 $g/m^2$, 150 $g/m^2$, and 180 $g/m^2$ respectively; used for calendar printing, handbill, magazine etc. |
| 6 | Bond Paper | 80 | 77.06±2.18 | Used for printing of reading books, note books, etc; has grammages of 50 $g/m^2$, 56 $g/m^2$, 60 $g/m^2$, 70 $g/m^2$, 75 $g/m^2$, 80 $g/m^2$, and 100 $g/m^2$ respectively. |
| 7 | Newsprint | 45 | 43.48±0.85 | Has grammages of 45 $g/m^2$ and 50 $g/m^2$; used for printing of newspaper, duplicate of receipt and exercise books. |
| 8 | Unbleached Kraft | 60 | 57.46±0.93 | Has grammage of 60 $g/m^2$; used in making cover of printing paper, and making of postal envelope. |
| 9 | Glossy Paper | 130 | 128.86±0.85 | Same as Matt paper, but is glossy on both sides; has grammages of 90 $g/m^2$, 115 $g/m^2$, 130 $g/m^2$, 135 $g/m^2$, 150 $g/m^2$, and 180 $g/m^2$ respectively. |
| 10 | Chipboard | 250 | 246.88±2.24 | Smooth on one side, but rough on the other; having grammages of 200 $g/m^2$, 210 $g/m^2$, 250 $g/m^2$, 300 $g/m^2$ and 350 $g/m^2$ ; used in making cover of exercise books, containers/cartons for beverages and school chalks. |
| 11 | Cardboard | 180 | 178.08±1.63 | Has grammages of 150 $g/m^2$ and 180 $g/m^2$, and is used in making exercise book cover, outdoor bills etc |
| 12 | Matt Card | 250 | 247.88±1.84 | Smooth on both sides; has grammages of 250 $g/m^2$, 300 $g/m^2$,350 $g/m^2$ and 400 $g/m^2$ respectively; used in making scratch card and certificates. |
| 13 | Pelican Card | 250 | 247.28±1.67 | Glossy on only one side, and rough on the other; has grammages of 180 $g/m^2$ ,210 $g/m^2$ , 230 $g/m^2$ ,250 $g/m^2$ 300 $g/m^2$ and 350 $g/m^2$; used in business card, book cover, calendar, invitation card, certificates, and photographic paper. |
| 14 | Manila Card | 250 | 246.92±2.28 | Has grammage of 250 $g/m^2$ and is used in making exercise book cover, office file/folder, hospital card etc |

**Table 2: Average Fibre Characteristics of Sample Paper and Paperboard Brands**

| Brand Name | Fibre Length (mm) | Fibre Diameter (µm) | Lumen Width (µm) | Cell wall Thickness (µm) | Runkel Ratio | Slenderness Ratio | Elasticity Coefficient (%) | Rigidity Coefficient (%) |
|---|---|---|---|---|---|---|---|---|
| Kraft liner | 1.20±0.63 | 22.80±9.21 | 15.40±8.61 | 3.70±0.95 | 0.48±0.34 | 52.46±15.52 | 67.56±12.74 | 16.22±6.37 |
| Office Paper | 0.94±0.34 | 19.02±5.59 | 10.76±5.29 | 4.13±1.89 | 0.91±0.54 | 50.39±12.12 | 55.77±14.09 | 22.12±7.04 |
| Conqueror Paper | 0.89±0.20 | 18.56±4.35 | 10.05±3.26 | 4.26±1.09 | 0.85±0.33 | 47.91±13.06 | 54.12±8.29 | 22.94±4.14 |
| Carbonless Paper | 0.93±0.18 | 18.51±3.16 | 10.05±1.82 | 4.23±1.06 | 0.84±0.26 | 50.14±11.62 | 54.27±6.33 | 22.87±3.16 |
| Matt Paper | 1.25±0.86 | 21.98±3.98 | 13.87±3.68 | 4.05±1.09 | 0.58±0.29 | 56.82±37.01 | 63.11±10.41 | 18.45±5.21 |
| Bond Paper | 0.90±0.16 | 15.61±5.21 | 9.74±4.43 | 2.93±1.43 | 0.60±0.27 | 57.71±37.01 | 62.42±12.26 | 18.79±6.13 |
| Newsprint | 2.30±0.72 | 41.06±11.27 | 28.15±10.98 | 6.45±3.29 | 0.46±0.35 | 55.90±22.10 | 68.57±13.38 | 15.71±6.69 |
| Unbleached Kraft | 1.22±0.70 | 24.28±6.24 | 16.22±6.05 | 4.03±1.21 | 0.50±0.28 | 50.25±19.30 | 66.81±11.56 | 16.60±5.78 |
| Glossy Paper | 1.20±0.77 | 21.73±5.00 | 13.52±4.09 | 4.11±1.36 | 0.61±0.22 | 55.14±36.60 | 62.21±8.42 | 18.90±4.21 |
| Chipboard | 1.18±0.50 | 22.59±5.87 | 13.87±5.69 | 4.36±1.94 | 0.63±0.50 | 52.28±16.85 | 61.40±13.75 | 19.30±6.88 |
| Cardboard | 1.29±0.83 | 24.43±8.93 | 18.16±7.60 | 3.14±1.20 | 0.35±0.17 | 52.92±28.35 | 74.32±8.54 | 12.84±4.27 |
| Matt Card | 0.94±0.52 | 21.62±8.19 | 13.36±7.00 | 4.13±1.78 | 0.62±0.33 | 43.28±17.29 | 61.79±13.26 | 19.10±6.63 |
| Pelican Card | 0.83±0.19 | 19.33±6.12 | 11.83±5.74 | 3.75±0.71 | 0.63±0.29 | 42.77±16.35 | 61.21±9.85 | 19.39±4.93 |
| Manila Card | 0.98±0.48 | 15.71±6.22 | 12.39±5.53 | 1.66±1.16 | 0.27±0.26 | 62.44±19.88 | 78.90±13.00 | 10.55±6.50 |

**Table 3: Average Fibre Characteristics of Selected Local and Imported Paper Egg Trays**

| Brand Name | Fibre Length (mm) | Fibre Diameter (µm) | Lumen Width (µm) | Cell wall Thickness (µm) | Runkel Ratio | Slenderness Ratio | Elasticity Coefficient (%) | Rigidity Coefficient (%) |
|---|---|---|---|---|---|---|---|---|
| Lagos Tray | 1.34±0.61 | 22.75±8.67 | 15.35±8.38 | 3.70±1.19 | 0.48±0.37 | 59.01±27.47 | 67.49±13.67 | 16.26±6.84 |
| Power Tray | 1.16±0.53 | 22.34±9.10 | 15.30±7.20 | 3.52±1.51 | 0.46±0.35 | 51.83±25.04 | 68.49±11.68 | 15.75±5.84 |
| Kano Tray | 1.02±0.63 | 20.91±6.91 | 13.46±6.52 | 3.72±0.83 | 0.55±0.28 | 48.90±16.42 | 64.39±10.69 | 17.80±5.34 |
| Baba Tray | 0.72±0.35 | 27.23±11.81 | 17.9±10.36 | 4.67±2.24 | 0.78±0.81 | 30.55±17.40 | 63.35±18.28 | 18.32±9.14 |
| China Tray* | 1.35±0.83 | 26.83±10.28 | 15.86±10.06 | 5.48±1.77 | 0.69±0.82 | 50.44±23.21 | 59.13±15.80 | 20.44±7.90 |
| UK Tray* | 1.93±1.08 | 29.58±11.22 | 19.53±9.35 | 5.02±2.27 | 0.51±0.39 | 65.19±44.27 | 66.03±14.48 | 16.98±7.24 |
| Malaysia* | 2.28±0.95 | 26.21±11.13 | 15.91±8.34 | 5.15±2.78 | 0.65±0.50 | 86.93±34.25 | 60.70±17.59 | 19.65±8.79 |
| Egypt Tray* | 1.81±1.13 | 24.02±10.55 | 13.87±6.86 | 5.07±2.64 | 0.73±0.42 | 75.48±38.95 | 57.75±15.17 | 21.13±7.58 |
| KIWO Tray* | 1.81±1.13 | 24.94±9.04 | 15.91±7.87 | 4.51±1.78 | 0.57±0.47 | 72.68±37.94 | 63.80±13.85 | 18.10±6.92 |

*=imported Paper Egg Tray bearing the name of importer or country of origin

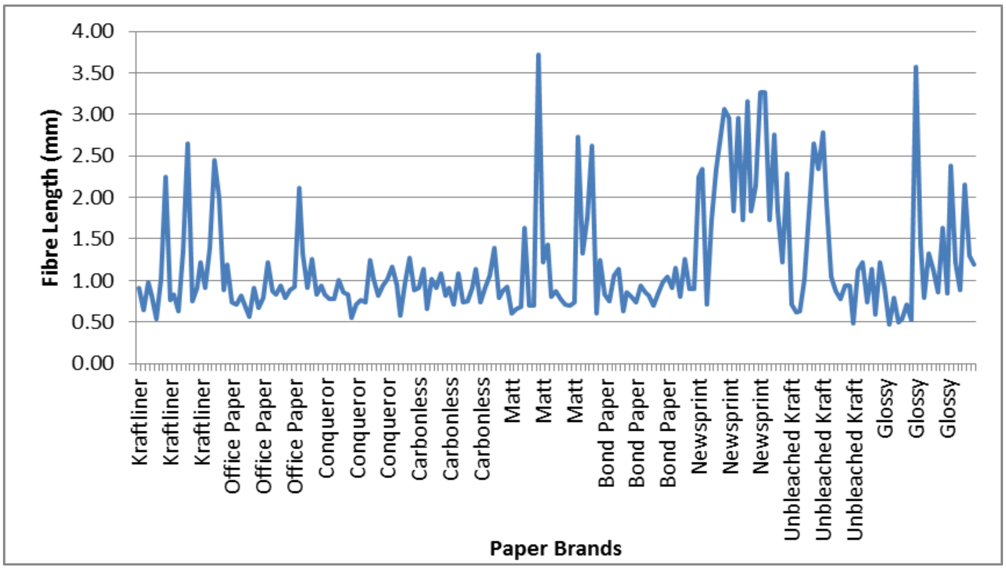


**Fig. 1: Comparison of Fibre Length of Sample Paper Brands**

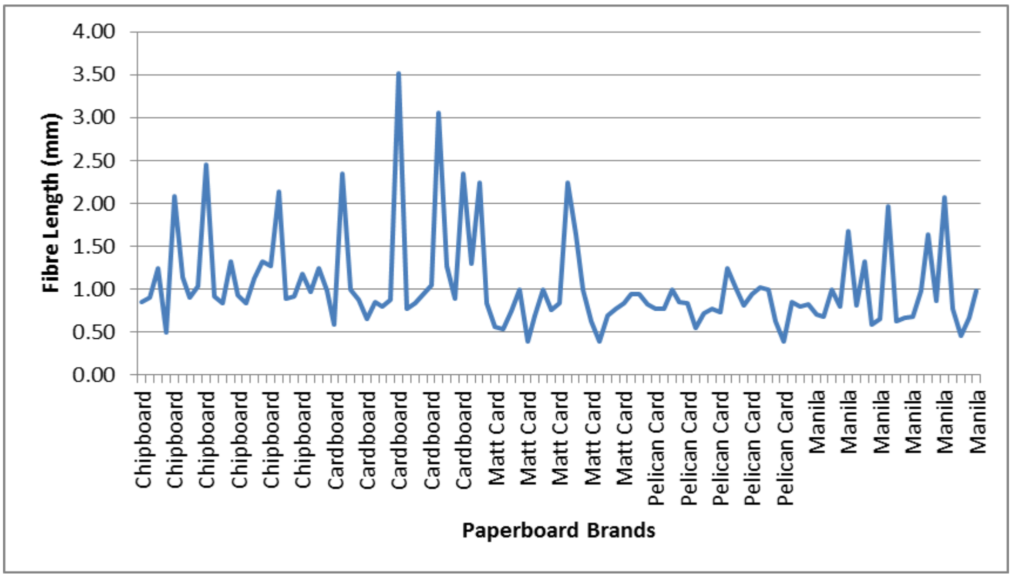


**Fig. 2: Comparison of Fibre Length of Sample Paperboard Brands**

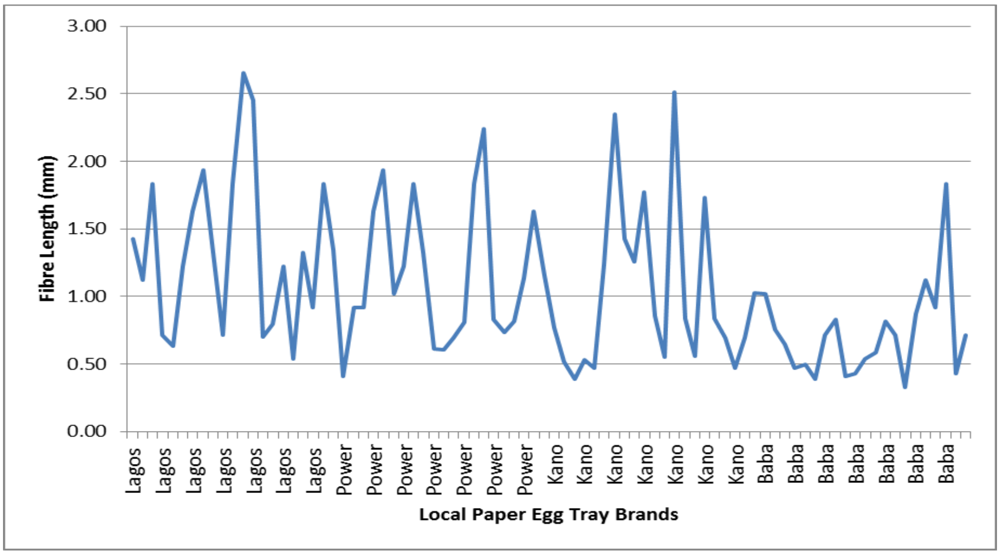


**Fig. 3: Comparison of Fibre Length of Sample Local Egg Trays**

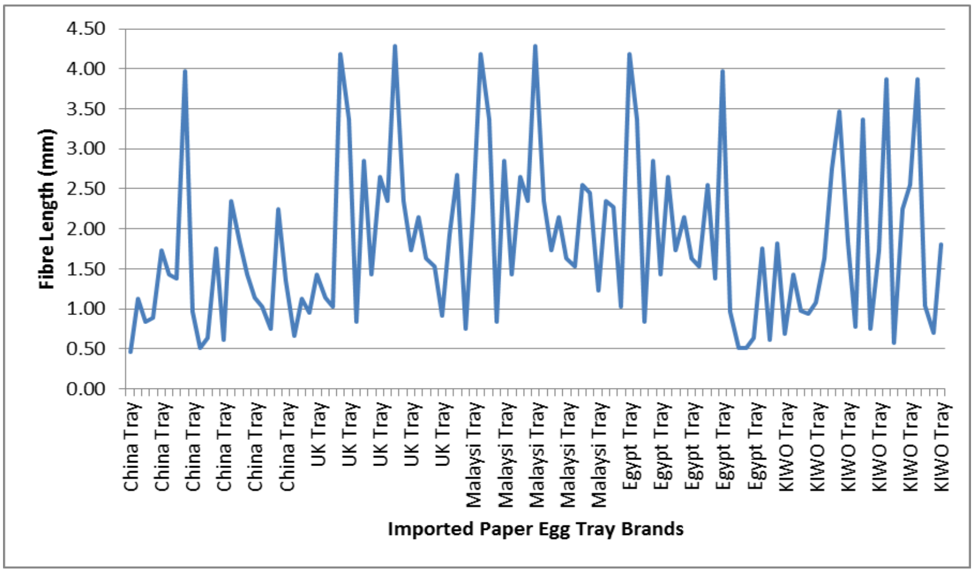


**Fig. 4: Comparison of Fibre Length of Sample Imported Egg Trays**

## 4. CONCLUSION

Based on the available results, it is noted that sample papers and boards are made of heterogeneous fibrous materials; and their fibre quality compromised. Local paper egg trays are discovered to be made of comparatively lower fibre quality. It is therefore suggested that *'Newsprint', 'Kraft' paper, 'Chipboard, and 'cardboard'* brands will be suitable for paper egg tray production, as a result of their fibre characteristics.

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