Characterisation of Paper Egg Trays Used in Southwestern Nigeria

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Abstract

This study characterised paper egg trays used in Southwestern Nigeria, on the basis of physical, mechanical and proximate properties. A purposefully selected, most available and frequently used paper egg tray brands of local (*Lagos, Power, Kano and Baba)* and imported categories (*KIWO, China, UK, Malaysia and Egypt)* were obtained for characterization. The trays were of grey/white, light yellow, light brown and brown colour respectively. All tests were done in accordance with relevant technical and professional standards. The results of general characteristics show that trays with a dimension greater than 300mm is undesirable while tray cell diameter of 34mm considered average and most preferred by users; also, tray with cell diameter of 32mm and 39mm are considered lower and upper limit respectively. Imported trays are noted to have better sorption properties than the locally manufactured trays, due probably to their better fibre quality, light weight and low caliper (thickness). *Lagos* tray brand has the lowest caliper (thickness) of 1.4±0.09mm, while *Baba* brand has the highest caliper (thickness) of 2.43±0.15mm among the locally manufactured trays. *China* tray of 1.29±0.05mm has the lowest caliper while *Malaysia* tray of 1.96±0.07mm has the highest caliper among the imported trays. Moreover, the trays show diverse moisture content; the lowest being *Power* trays of 3±0.37%, while *Kano* has average moisture content of 11±0.36%. Percentage water absorption capacity (WAC) of the trays at 30 minutes of soaking is in the range of 320±0.35% (*Baba* tray) and 253±0.37% (*China* tray). It is also noted that *Baba* tray with highest caliper of 2.43±0.15mm has the highest WAC, while *China* tray of the lowest caliper of 1.29±0.04mm has the lowest WAC. Thickness swelling of the trays is in the range of 133±0.62% (*Baba* tray) and 70±0.45% (*China* tray). Bulk density of the trays shows that brown-colour trays of *Baba* and *Kano* have the highest bulk density of 0.09g/cm³ and 0.1g/cm³, respectively; while light brown trays of *Power, UK* and *Malaysia* trays have bulk density of 0.07g/cm³ respectively**.** Meanwhile, the white colour trays of *Lagos*, *KIWO*, *China* and *Egypt* trays have bulk density of 0.06g/cm³ respectively. The range of the maximum compressive load the trays can bear is 11.30±0.24KN (*Baba* tray) and 8.44±0.13KN (*China* tray). Also, *Kano and Power* are shown to have the highest tensile strength of 28.78±0.111N/mm and 28.67±0.077N/mm, respectively**;** while *China* tray has the lowest tensile strength of 26.69±0.143N/mm. Furthermore, *Lagos* tray has the highest ash content of 18.95±0.64% while *Egypt* tray has the lowest ash content of 10.07±0.39%. Likewise, *Egypt* tray has the highest percentage of organic matter of 86.29±0.48% while Lagos tray has the lowest percentage of organic matter of 77.83±0.21%. In conclusion, tray dimensions, cell diameter and general tray design are acceptability criteria. Well compressed trays (usually grey/white-colour trays) proved to have better sorption properties. Bulkiness of tray influences its water absorption, thickness swelling and compressive strength. Ash content in trays may be connected with the quality of raw material used for its manufacture.

Keywords: Egg tray brands, Paper characterisation, physical and mechanical properties, proximate analysis.

Introduction

Food packaging is a co-ordinated system of preparing food for transport, distribution, storage, retailing, and end-use with optimal cost (*Coles et al.,* 2003). More than 25% of food is wasted because of poor packaging (*WPO, 2009*). The primary package is the first-level package that directly contacts the product, contains and preserves the packaged product (*Soroka, 2008*). Paper egg trays (fig. 1), the most preferred choice by egg distributors and egg retailers in Nigeria, as primary egg-packaging items are becoming exclusive. They provide shockproof and cushion to eggs during transportation and delivery, thus, protecting the fragile shell eggs from breakage; they are supposed to be available, accessible and cheap. The hub of egg distribution in Nigeria (Ibadan), is the most adversely affected by this challenge. In their desperation to get qualitative egg trays for their business, egg distributors demand for imported trays against the local ones which is indeed injurious to economy. The situation has to be salvaged through research with the aim of devising means of getting cheaper and easily accessible egg trays for egg distribution.

Paper products, made from plant fibres, are the most commonly used packaging materials in the world. Above 95% of paper is made from wood; the remainders are agricultural by-products, such as straw, sugar cane bagasse, cotton, flax, bamboo, corn husks, and so on. Fresh and processed foods sustain both physical and environmental damage during storage and transportation. A good packaging system must be able to protect or reduce damage to the packaged contents (*Wiley J., 2014*). Moreover, with egg-tray importation into the country; a low patronage of local products is being recorded by the manufacturers. This negative response has led to closure of shops by some egg tray manufacturers. In order to reduce the prices of egg trays the trays must be durable enough to be used many times, in order to lessen their demand. This can only be achieved through the improvement of their quality by incorporating affordable and locally-available strength-enhancing and protective additives into them; as well as evaluation and improvement of their second-hand value. This will not only reduce their prices, it will also discourage importation of egg trays; boost patronage of local trays, keep local manufacturers working, create more jobs, stop capital flight, and promote eggs distribution and circulation in the country.

Packaging paper products are also examined for high mechanical strength and good barrier properties (*Balan T, 2015*); due mainly to the synthetic materials used for paper-based packaging (*Kirwan M.J., 2005*). Nearly 10% of all produced starches is globally used for surface applications like surface sizing and coating, in paper production (*Auhorn W.J., 2006*). Also, other cellulose derivatives are used as strength additives or as thickeners and binders in surface sizing and coating formulae (*Lindstrom et al, 2005*). Nevertheless, the quantity of inorganic material available in biomass should be determined as part of the total constituents, be it structural or extractable. Structural ash is bound in the physical structure of the biomass, while extractable ash can be removed through extraction (*Sluiter et al, 2005)*

Therefore, there is need to characterize selected parameters of paper egg trays (both local and imported) used in Southwestern Nigeria; as a way forward towards the production of more acceptable paper egg trays locally.

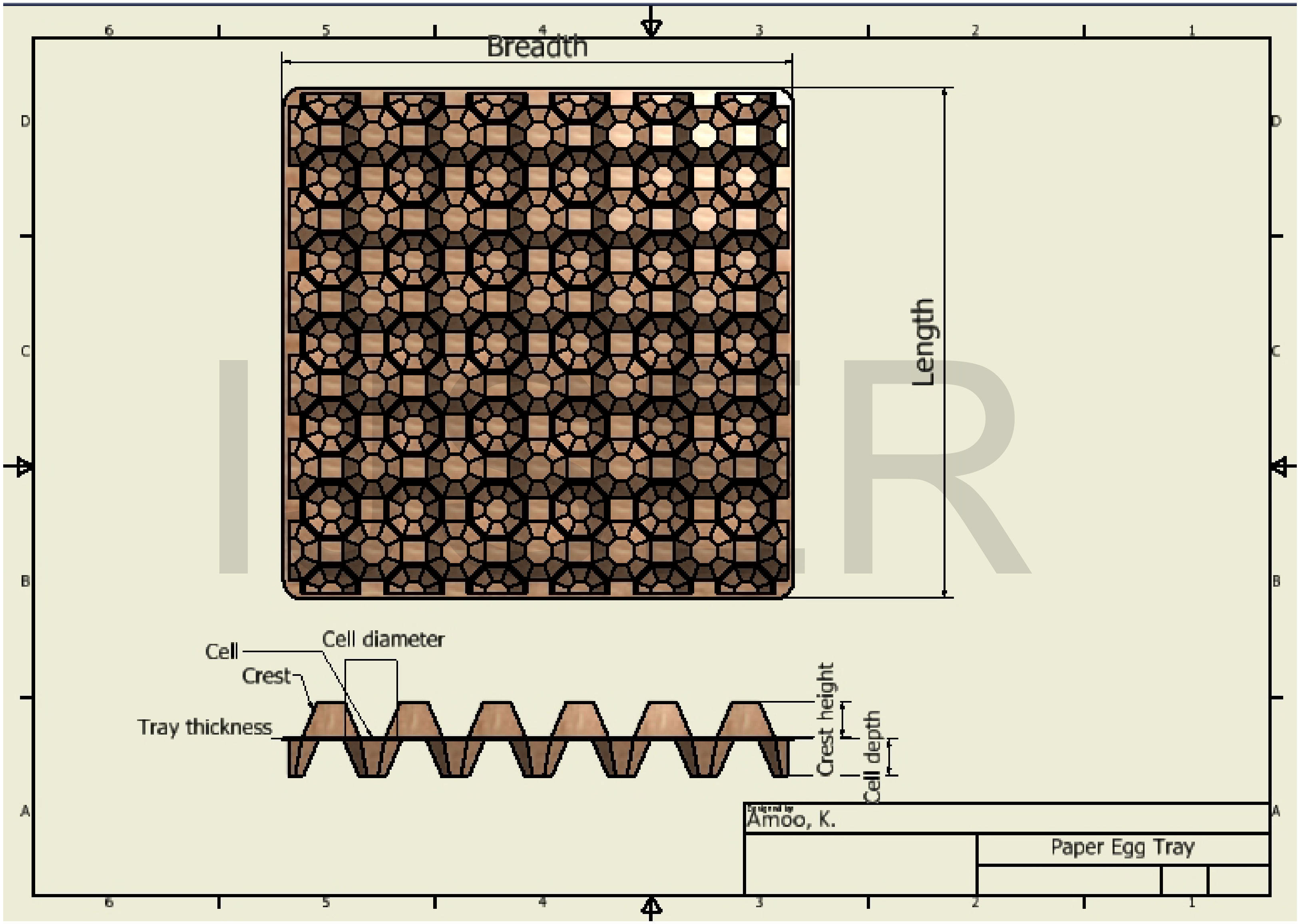

Fig 1: A Schematic 30-cell Paper Egg Tray

Material and Method

A total of 9 paper egg tray brands of local and imported categories were obtained from Ojoo Market, Ibadan, Nigeria. The selected trays were the most available and frequently used in the region. The locally manufactured trays were named *Lagos*, *Power*, *Kano and Baba*, respectively, according to the location of manufacture or manufacturer's name; while imported paper egg trays were named *KIWO*, *China*, *UK*, *Malaysia and Egypt*, respectively, based on their country of origin or name of the importer.

Determination of Physical Properties

All physical property tests were done according to relevant standards. 5 replicates of each specimen were used for the experiment.

i. Water Absorption Capacity (WAC) and Thickness Swelling (TS)

The WAC and TS were determined in accordance with ASTM D 1037, (*2012)*. The initial and final weights were recorded and the WAC and TS were calculated by the weight and thickness difference, respectively:

$$WAC=\left(\frac{W_1-W_0}{W_0}\right) \times 100$$

Where; W_1 = Final weight of specimen

W_0 = Initial weight of specimen

$$TS = \left(\frac{T_1-T_0}{T_0}\right) \times 100$$

Where; T_1 = Final thickness of the specimen

T_0 = Initial thickness of the specimen

ii Percentage Moisture Content Determination

Moisture content determination was done according to TAPPI T412 (2011). Sample selection and conditioning were according to TAPPI T402 (2013) and TAPPI T400 (2011), respectively; and the percentage moisture content calculated thus from the weight difference:

$$M.C\ (\%) = \left(\frac{M_0 - M_1}{M_1}\right) \times 100$$

Where; M_o = wet mass of the trays
M_1 = oven-dry mass of the trays

iii Caliper (Thickness) of Paper Egg Tray Determination

The test was conducted according to TAPPI T411 (2010) and other relevant TAPPI standards..

iv Determination of Basis weight of Paper Egg Tray

This was conducted according to TAPPI T410 (2013); and other relevant TAPPI standards.

v. Bulk Density Determination

The bulk density was calculated on the basis of the measured weight and the bulk volume according to ASTM D7481 (2009). Test samples were milled and a quantity of powder sufficient to complete the test was gently passed through a mechanical sieve with apertures greater than or equal to 1.0 mm, into a dry graduated cylinder of 450 ml. This was gently introduced without compacting, with 0.1 per cent accuracy. The cylinder was then carefully leveled to the nearest graduated unit. Bulk density was calculated (in g/cm^3) by the formula:

$$B.D = \left(\frac{m}{V_\circ}\right)$$

Where; m = untapped mass of the powder

V_o = volume of the powder in the cylinder

Mechanical Properties of Paper Egg Tray

Mechanical tests were done at 23ºC and 50% RH using OKH-600 Digital Display Universal Testing Machine at 0.01KN/s cross-head speed. Sample selection and conditioning were done according to relevant TAPPI standards. 5 replicates of each sample of the trays were used for the test.

i. Compressive Strength Determination

This was conducted according to TAPPI T822 (2007). Sample selection and conditioning were according to TAPPI T402 (2013) and TAPPI T400 (2011), respectively.

ii. Tensile strength Determination

The tensile characteristics of egg tray and paper-products are important in their ability to resist tearing or ruptures that are typical of the distribution environment of paper egg trays. The test was conducted according to TAPPI T494 (2006) . Sample selection and conditioning were according to TAPPI T402 (2013) and TAPPI T400 (2011), respectively.

Proximate Analysis Determination

The proximate analysis categorizes the material in terms of its moisture, volatile matter, fixed carbon and ash. Information on these properties is helpful in order to estimate their appropriateness in different processes (*Stahl et al, 2004*). Meanwhile, samples were analyzed for their proximate properties in accordance with *A.O.A.C., 2005.* All analyses were carried out in replicates.

i. Dry Matter Determination

This was done in line with Official Method 967.08 of AOAC, 2005; during which 2g of the sample was weighed into a crucible of known weight. The crucible containing the sample was then transferred into the oven to dry to a constant weight for 24 hours at 100ºC. Thereafter, the crucible was removed from the oven and transferred into a desiccator, cooled for ten minutes and weighed:

$$\% \text{ Dry Matter (DM)} = \left(\frac{W_3 - W_0}{W_1 - W_0} \right) \text{x } 100$$

Or

$$\% \text{ Moisture} = \left(\frac{W_1 - W_3}{W_1 - W_0} \right) \text{x } 100$$

$$\% \text{ Moisture} = 100 - \%\text{DM}$$

Where; Wo = weight of empty crucible

W_1 = weight of crucible plus sample

W_3 = weight of crucible plus oven-dried sample

ii. Determination of Ash Content

This was done in line with Official Method 942.05 of AOAC, 2005; during which 2g of the sample was weighed into a porcelain crucible; then transferred into the muffle furnace at 550ºC and left for about 4 hours. At 4th hour it had turned to white ash. The crucible and its content were cooled to about 100ºC in air, then to room temperature in a dessicator and weighed:

$$\text{Ash Content} = \left(\frac{Wt\,of\;ash}{Original\;\;wt\;\;of\;\;Sample_0} \right) x100$$

iii. Crude Fibre Determination

This was done in line with Official Method 958.06 of AOAC, 2005; during which 2g of the sample was weighed into the fibre flask and 100ml of 0.255N H_2SO_4 added. The mixture was then heated under reflux for 1 hour with the heating mantle. The mixture (hot) was filtered through a fibre sieve cloth. The filtrate obtained was discarded and the residue returned to the fibre flask to which 100ml of (0.313N NaOH) was added and heated under reflux for another 1 hour. The mixture was filtered again through a fibre sieve and 10ml of acetone added to dissolve any organic constituent present. The residue was later washed with 50ml of hot water on the sieve cloth before it was finally transferred into the crucible. The crucible and the residue were then oven-dried at 105ºC overnight. The oven-dried crucible containing the residue was cooled in a dessicator and later weighed to obtain the weight W_1.

The crucible with weight W_1 was again transferred to the muffle furnace for “ashing” at 550°C for 4 hours. The crucible containing white or grey ash (free of carbonaceous material) was cooled in the dessicator and weighed to obtain W_2:

$$\text{Crude Fibre} = \left(\frac{W_1 - W_2}{Wt\,of\;Sample} \right) x100$$

Results and Discussion

General Characteristics of Sample Paper Egg Trays

Appendix 1 shows the general characteristics of sample paper egg trays. The locally manufactured trays of Lagos, Power, Kano and Baba have dimensions of 297x290mm, 290x280mm, 290x285mm, and 300x300mm, respectively. KIWO, an imported tray has a dimension of 300x295mm, while other imported trays have respective dimensions that are greater than 300mm which informs the rejection of some of the imported trays by the users, because any tray dimensions larger than 300mm is too big to key in to the secondary packaging container (box carton) used for egg packaging for onward transportation. Also, the cell diameters of the trays are shown to be 36mm (Lagos), 34mm(Power), 36mm (Kano), 39mm(Baba), 32mm(KIWO), 38mm(China), 35mm(UK), 36mm(Malaysia), and 35mm(Egypt) respectively. It was however noted that Power Brand (34mm) was the most preferred in terms of cell diameter. The reason was that 34mm cell diameter was considered an average and appropriate for egg sizes found in Nigeria. 32mm was considered a lower limit while 39mm was considered an upper limit respectively.

Percentage Water Absorption Capacity of Selected Paper Egg Trays

Appendix 2 shows that Lagos, KIWO, China, and Egypt trays can survive water immersion for more than 24 hours. Power, UK, and Malaysia trays can survive water immersion for about 2 hours while Kano and Baba trays can only survive water immersion for about 30 minutes and 1 hour respectively. The reason may be connected to the fibre quality and bulkiness of the trays. Trays that are made up of more long fibres tend to stay longer in water without crumbling. Also, trays with high caliper (thickness) tend to contain more void, absorbs water and aid crumbling. Therefore, well compacted trays especially trays were noticed to survive water immersion better than bulky trays.

Physical Properties of Selected Paper Egg Trays

From Appendix 3, Lagos tray brand has the lowest caliper (thickness) of 1.4±0.09mm, while Baba brand has the highest caliper (thickness) of 2.43±0.15mm among the locally manufactured trays. Also, China tray of 1.29±0.05mm has the lowest caliper while Malaysia tray of 1.96±0.07mm has the highest caliper among the imported trays. It is observed that white-colour trays of Lagos, KIWO, China, and Egypt have lower caliper (thickness) compared to light brown-colour trays of Power, UK and Malaysia; and brown-colour trays of Baba and Kano. The reason for this may be connected with the paper type, fibre quality and quality assurance observed during their manufacture. Also, the trays show diverse moisture content; the lowest being Power trays of 3±0.37%, while Kano has average moisture content of 11±0.36%. The reason for this may be due to difficulty in drying of the products as some of the local tray manufacturers prefer sun-drying, as they lack modern oven for adequate drying of products. Meanwhile, imported trays of KIWO, China, UK, Malaysia and Egypt have higher moisture content. This may be as a result of possible moisture absorption by the trays during freight; paper products being hygroscopic. The moisture content of paper and paperboard is the quantity of water present and measurable in it and will vary according to the environment and the moisture added during manufacturing and conversion processes. This depends on relative humidity and whether the moisture was desorbed (brought into equilibrium from a higher relative humidity) or adsorbed (brought into equilibrium from a lower relative humidity) - the hysteresis effect (*smitherspira.com*)

The Percentage water absorption capacity of the trays at 30 minutes of soaking is in the range of 320±0.35% (Baba tray) and 253±0.37% (China tray). It is however, noted that Baba tray with highest caliper of 2.43±0.15mm has the highest WAC while China tray of the lowest caliper of 1.29±0.04mm has the lowest WAC.

Thickness swelling of the trays is in the range of 133±0.62% (Baba tray) and 70±0.45% (China tray). The bulk density of the specimens, which was calculated on the basis of the measured weight and the bulk volume (*SCAN-CM 46-92, 1992*), shows that brown-colour trays of Baba, and Kano have the highest bulk density of 0.09g/cm³ and 0.1g/cm³ respectively, while light brown trays of Power, UK and Malaysia trays have bulk density of 0.07g/cm³ respectively**.** The white colour trays of Lagos, KIWO, China and Egypt trays have bulk density of 0.06g/cm³ respectively**.** The higher the cellulose contents of a plant material, the better the swelling behaviour of the pulp produced from it (*Singh et al., 2011*). This shows that fibre quality has significant effect on bulk density of the trays.

Mechanical Properties of Selected Paper Egg Trays

The range of the maximum compressive load the trays can bear is 11.30±0.24KN (Baba tray) and 8.44±0.13KN (China tray) as shown in Appendix 4. It is observed from the table, that brown-colour trays of Baba and Kano have the highest compressive strength of 0.28±0.008N/mm² and 0.26±0.015N/mm², respectively. The strength to resist a load in a stationary condition is possibly the most desirable property in paper egg trays. The design of egg tray helps in withstanding stacking; and under ideal condition, paper egg-trays hold many times its own weight in stacking for long periods of time. Also, Kano and Power are shown to have the highest tensile strength of 28.78±0.111N/mm and 28.67±0.077N/mm respectively**,** while China tray has the lowest tensile strength of 26.69±0.143N/mm.

Proximate Analysis of Selected Paper Egg Trays

Appendix 5 shows that, Lagos tray has the highest ash content of 18.95±0.64% while Egypt tray has the lowest ash content of 10.07±0.39%. Ash content is a measure of the mineral content and other inorganic matter in the sample. It is an indication of the amount of filler present in the tray which may be as a result of the paper type, fibre quality and amount of additives used for the tray manufacture. High filler content means high ash content (*Kaiser E.R, 1966*). Egypt tray has the highest percentage of organic matter of 86.29±0.48% while Lagos tray has the lowest percentage of organic matter of 77.83±0.21%. This shows divergent quantity of cellulosic materials in the trays, as probably the result of the quality of raw materials used for their manufacture.

Conclusion and Recommendation

In conclusion; tray dimensions, cell diameter and tray design are important acceptability criteria. Well compacted trays (usually grey/white-colour trays) proved to have better sorption properties. Bulkiness of tray influences its water absorption, thickness swelling and compressive strength. Ash content in trays may be connected with the quality of raw material used for its manufacture.
Further research work on paper egg trays used in southwestern Nigeria is recommended.

Appendix 1: General Characteristics of Selected Paper Egg Trays

Sample Name	Dimensions L * W (mm)	Weight (g)	Cell Diameter (mm)	Cell Depth (mm)	Crest Height (mm)	Capacity (No of Eggs)	Colour	Status	Price Per Bundle (₦)	Remarks
Lagos	297x290	76±3.16	36	25	23	30	White	Local	2200	Good
Power	290x280	81.8±5.36	34	21	22	30	L.Brown	Local	2400	Very good
Kano	290x285	108.2±8.52	36	25	18	30	Brown	Local	3000	Good
Baba	300x300	101.6±5.41	39	28	14	30	Brown	Local	4500	Good
KIWO*	300x295	72.2±1.14	32	24	22	30	White	Imported	2500	Good
China*	320x305	71.4±1.36	38	25	16	30	L.Yellow	Imported	2600	Fair/Rejected
UK*	305x305	80.1±1.2	35	25	19	30	L.Brown	Imported	2900	Fair/Rejected
Malaysia*	310x305	78.6±1.82	36	26	20	30	L.Brown	Imported	2900	Fair/Rejected
Egypt*	310x310	73.3±1.17	35	24	22	30	White	Imported	2650	Fair/Rejected

*= Name of importer or country of origin

Appendix 2: Percentage Water Absorption Capacity of Selected Paper Egg Trays

Tray Name	10min	20min	30min	1hr	2hr	3hr	24hr
Lagos	271	274	277	278	278	278	278
Power	279	283	291	293	293	NA	NA
Kano	270	281	285	NA	NA	NA	NA
Baba	278	290	320	321	NA	NA	NA
KIWO*	256	258	260	261	261	261	261
China*	249	252	253	253	253	253	253
UK*	254	257	258	258	258	258	NA
Malaysia*	248	251	253	255	255	255	NA
Egypt*	257	259	261	261	261	261	261

*= Name of importer or country of origin

Appendix 3: Physical Properties of Selected Paper Egg Trays

Tray Name	Caliper (mm)	%Moisture Content	%WAC @30min	%Thickness Swelling@30min	Bulk Density(g/cm³)
Lagos	1.4±0.09	4±0.39	277±0.41	78±0.41	0.06
Power	2.17±0.09	3±0.37	291±0.38	119±0.51	0.07
Baba	2.43±0.15	7±0.37	320±0.35	133±0.62	0.09
Kano	2.07±0.21	11±0.36	285±0.46	126±0.58	0.10
KIWO*	1.33±0.05	7±0.40	260±0.36	69±0.48	0.06
China*	1.29±0.05	7±0.35	253±0.37	70±0.45	0.06
UK*	1.92±0.04	6±0.35	258±0.35	82±0.48	0.07
Malaysia*	1.96±0.07	6±0.36	253±0.39	85±0.43	0.07
Egypt*	1.34±0.06	7±0.38	261±0.38	72±0.42	0.06

*= Name of importer or country of origin; WAC= Water Absorption Capacity

Appendix 4: Mechanical Properties of Selected Paper Egg Trays

Sample Name	Max. Compressive Load (KN)	Compressive Strength (N/mm²)	Max. Tensile Force (KN)	Tensile Strength (N/mm)
Lagos	9.50±0.21	0.24±0.007	8.30±0.02	27.95±0.067
Power	10.15±0.15	0.25±0.005	8.31±0.032	28.67±0.077
Kano	10.47±0.43	0.26±0.015	8.35±0.025	28.78±0.111
Baba	11.30±0.24	0.28±0.008	8.34±0.025	27.81±0.087
KIWO*	9.43±0.02	0.24±0.001	8.29±0.023	27.64±0.084
China*	8.44±0.13	0.21±0.003	8.14±0.044	26.69±0.143
UK*	10.20±0.14	0.26±0.004	8.39±0.021	27.52±0.068
Malaysia*	10.15±0.07	0.25±0.002	8.35±0.044	27.38±0.143
Egypt*	9.44±0.014	0.24±0.0004	8.32±0.031	26.83±0.099

*= Name of importer or country of origin

Appendix 5: Proximate Analysis of Sample Paper Egg Trays

Sample Name	Moisture Content** (%)	Dry Matter (%)	Ash Content (%)	Crude Fibre (%)	Organic Matter (%)
Lagos	3.22±0.14	96.78±0.14	18.95±0.64	30±0.06	77.83±0.21
Power	3.23±0.31	96.77±0.31	18.36±0.49	35.6±0.83	78.41±0.18
Kano	3.74±0.57	96.26±0.57	16.4±0.65	29±0.08	79.86±0.04
Baba	3.7±0.24	96.3±0.24	10.1±0.85	29.6±0.27	86.2±0.30
KIWO*	3.6±0.08	96.4±0.08	10.14±0.34	33.8±1.15	86.26±0.40
China*	3.32±0.38	96.68±0.43	15.34±0.51	32.3±0.92	81.34±0.25
UK*	3.46±0.41	96.54±0.42	11.56±0.43	34.6±0.56	84.98±0.16
Malaysia*	3.57±0.33	96.43±0.36	10.98±0.36	31.4±0.47	85.45±0.39
Egypt*	3.64±0.12	96.29±0.13	10.07±0.39	33.6±0.36	86.29±0.48

**=conditioned Moisture Content; *= Name of importer or country of origin

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