The Design and Fabrication of a Recycled Paper Egg Tray Machine

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Abstract

Turning wastepaper materials to different packaging materials is important to effectively manage the associated problem involved with its disposal and also to conserve our forest reservation. The imported machines for egg tray production processes are capital intensive, complex to operate, largely power dependent and also difficult to repair and maintain. Hence there is a need to find a local alternative to solve these problems. This paper therefore gives a brief description of the design and fabrication of a 30 cavity wastepaper egg tray machine of size 10 with transfer and counter moulds producing 12 egg trays/hour with a vacuum pump rating of 1.64kW using an already mechanically disintegrated pulp. The machine consist of slurry vat, mould, counter mould , the lowering mechanism , electric motor and vacuum pump. The geometry of the slurry vat include a 10 litre cylindrical vessel of 5mm vessel fixed with lowering mechanism controlling the movement of the mould and counter mould in the slurry vat. The design capacity is 12 egg trays/hour and the total estimated cost of the machine is $200 and it works on the principle of vacuuming the pulp slurry when the consistency is about 5%. The features of this pulp moulding machine consist of simple structure, easy operation and maintenance, low investment cost and larger application range.

Keywords: wastepaper, egg tray, machine and mould.

Introduction

Nature has given the egg a natural package which is the shell. Despite its relative strength, the egg is an extremely fragile product and even with the best handling methods, serious losses can result from shell damage. Economical marketing generally requires that eggs be protected by the adoption of specialized packaging and handling procedures. Packaging is an important component in delivering quality eggs to buyers. It embraces both the art and science of preparing products for storage, transport and eventually sale. Packaging protects the eggs from microorganisms; natural predators; loss of moisture; tainting; temperatures that cause deterioration and possible crushing while being handled, stored or transported (Anonymous, 2007, Egg marketing, Pg 53). There has been a recorded improvement in poultry production sub sector in Nigeria with its share of Gross Domestic Product (GDP) increasing in absolute terms (Ojo, 2003).Poultry eggs and meat contribution of the livestock share of the GDP increased from 26% in 1995 to 27% in 1999 (CBN, 1999). Three major types of poultry management systems namely extensive, semi-intensive and intensive are common in tropical countries. In virtually all rural areas poultry production is carried out on small-scale under the extensive or traditional and semi-intensive systems. The number of small scale poultry farms out-weighs the commercial farms in Nigeria. (Ovwigho et al, 2009) . Experts have identified a lot of constraints to poultry production; part of these is lack of adequate packing trays after egg production. However, literatures available have shown that egg trays are commonly made from filler trays. Filler trays are made of wood pulp moulded to accommodate the eggs. They are constructed so that they can be stacked one on top of the other and can also be placed in boxes ready for transport.

Filler trays also offer a convenient method for counting the eggs in each box, without having to count every single egg (Anonymous, 2007). Using recycled paper reduces the pressure to plant more plantations and thus can help in the prevention of the destruction of wildlife habitats which is inevitable during the production of process of wood pulp. Recycled paper is easily the most environmentally friendly paper as it uses less chemicals, reduces landfills which cause pollution and saves energy to produce new ones.

Theoretical Considerations

Pulping is the liberation of fibres from wood so that they can be reformed into paper sheet (Onilude, 2008 and F.M.S.T. 2003). Pulp is a dry fibrous material prepared by chemical or mechanically separating fibres from wood or fibre crops. Pulp can be either fluffy or fringed into thick sheets. Pulp which is shipped and sold as pulp is referred to as market pulp. When suspended in water the fibres disperse and become more pliable. This pulp suspension can be laid down on a screen to form a sheet of paper.

Waste paper re-used: The process of recovering waste paper and remaking it into new paper products is refereed to waste paper re-used. The papers used as feedstock for making recycled paper can be grouped as follow: Pre-consumer waste and past-consumer waste. Pre-consumer waste is material which left the paper mill, which has been discarded before it was ready for consumer use. Post – consumer waste is material discarded after consumer use, such as old magazines, old newspapers are residential mixed paper. Paper suitable for recycling is known as “scrap paper”.

Pulp mould: Pulp mould is made from recycled paperboard and old newspapers. It is used to produce egg trays, food service trays and beverage carriers. Moulded pulp is often considered a sustainable packaging material, as defined by the sustainable packaging coalition, since it is produced from recycled materials, and can be recycled again after its useful life-cycle.

Vacuum filtration: The pulp moulding machine is designed to operate on the principle of vacuum filtration whereby the driving force for filtration results from the application of suction on the filtrate side of the medium. The slurry to be filtered is made up of cellulose and water. The physical and chemical properties of cellulose make them develop strong bonds and enable them to retain their shape and contours when dried. The mould has been designed to produce thirty egg tray of standard size and worthy of note is the unique manual technique of operation which is intended to keep the machine as simple as possible.

Methodology

The pulp moulding technology adopted is one in which the mould is lowered into the pulp slurry vat where the slurry is formed on the mould with the aid of the vacuum pump sucking in both the fiber and water. The mould is then lifted up, fixing into the counter-mould. The suction effect from the vacuum pump is transferred to the counter-mould where the moulded product is received, all the while, still sucking water from the product. The product is removed from the counter-mould when the suction is blocked and taken for further drying to the desired moisture content.

The parts of the pulp moulding machine can be divided into two groups namely the primary and the auxiliary parts. The primary parts are the parts that make up the machine these are the mould, the counter mould, the pulp slurry vat, and the lowering mechanism while the auxiliary part is backup of the machine, its presence is fundamental to the working of the machine. These are the vacuum pump, the electric motor and an auxiliary tank. The materials for construction were sourced from the local metal scrap market and the fabrication work took place at the welding workshop of the Maintenance department and at the Faculty of Technology, University of Ibadan.

Design Details

The Moulds: This is the template, which determines the shape of the pulp moulding. It consists of a metal sieve material formed to the desired shape of the moulded product, with a metal plate serving as its base as shown in Figures 1 and 2. There are two moulds; the suction (forming) mould and the transfer mould. Both act as a die for the other.

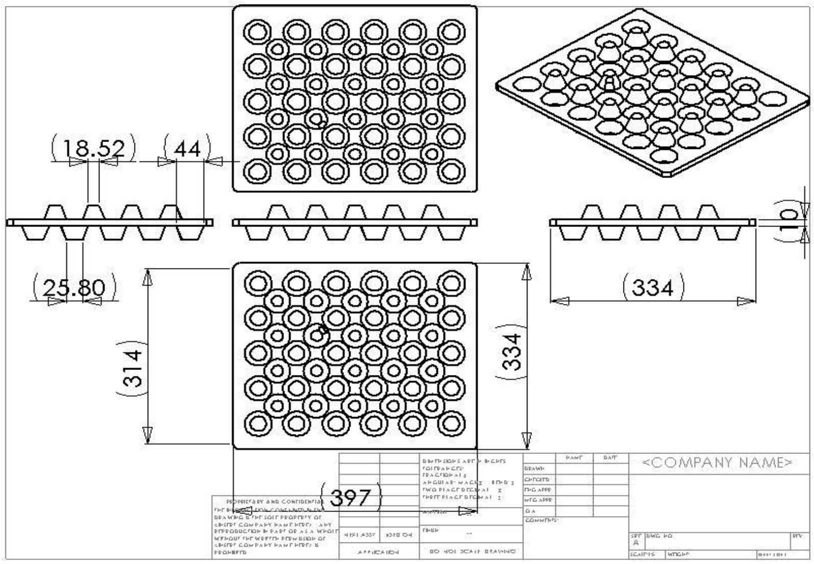

Figure 1: The Mould design

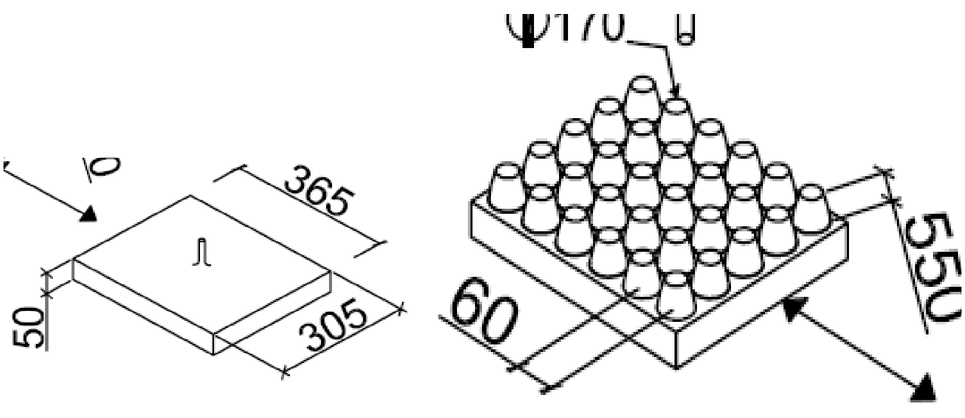

Figure 2: The Mould and Counter mould design

Considering the shape of an egg which is oval in shape, therefore the largest diameter along the axis of the egg was considered in the design (40mm) and a factor of safety of 5mm was added to the diameter. The frustum therefore has a dimension of 20mm (inverted base part) extending to 45mm and a space of 15mm between the holes as shown in Figure 3.

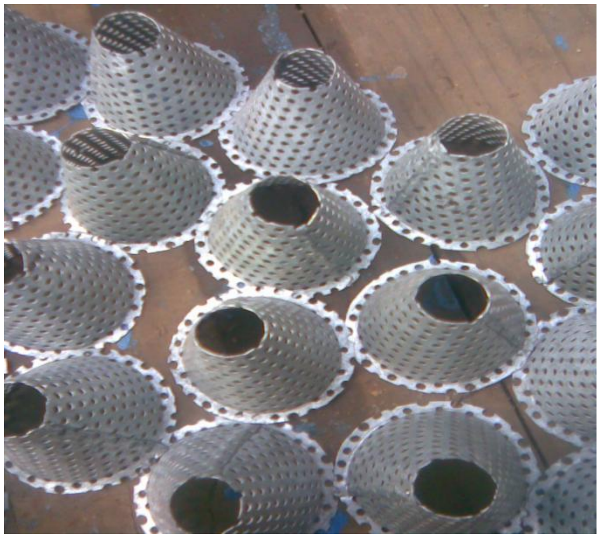

Figure 3: Opening of the frustum

Some considerations are taken as for suction mould. The internal part of the transfer mould is lined with foam for easy detachment of the pulp article when transferring.

Transfer Mould Estimations:

Using similar triangles

$$\frac{x}{10} = \frac{27+x}{22.5}$$

$$22.5x = 10x + 270$$
$$x = 21.6mm$$
$$y = 27 + 21.6 = 48.6\text{mm}$$
$$R^2 = (22.5)^2 + (48.6)^2$$
$$R = 53.2 \text{ mm}$$

The development of any right cone is a sector of a circle, since the radial surface lines are all the same true length. The angle at the centre of the sector depends on the base radius of the cone and slant height.

$$\Theta = \frac{r}{R} \times 360 = \frac{22.5}{53.2} \times 360 = 151.2^0$$

Where r and R are base radius and slant height respectively
Therefore 151.2^0 is the angle for opening the cone of the mould.

Counter Mould Estimations:

Using similar triangles

$$\frac{x}{13} = \frac{27+x}{27.5}$$
$$27.5x = 13x + 351$$
$$x = 24.21mm$$
$$y = 27 + 24..21 = 51.21\text{mm}$$
$$R^2 = (27.5)^2 + (51.21)^2$$
$$R = 58.13 \text{ mm}$$

Also, The development of any right cone is a sector of a circle, since the radial surface lines are all the same true length. The angle at the centre of the sector depends on the base radius of the cone and slant height.

$$\Theta = \frac{r}{R} \times 360 = \frac{27.5}{58.13} \times 360 = 170.31^0$$

Where r and R are base radius and slant height respectively
Therefore 170.31^0 is the angle for opening the cone of the counter mould.

Counter mould: Figures 2 and 4 is the counter mould which is located in upper part of the machine. The essence of the counter mould is to detach the moulded product from the mould for easy transfer to the drying chamber It is composed of a base box with an outlet from pressure hose to the vacuum pump. It has the same shape like that of the mould, but bigger than the mould with some centimeters which allows the mould to fix into the counter mould. The inside is paddled with the foam to prevent loss of tiny fibre so as to ensure an egg tray of smooth surface.

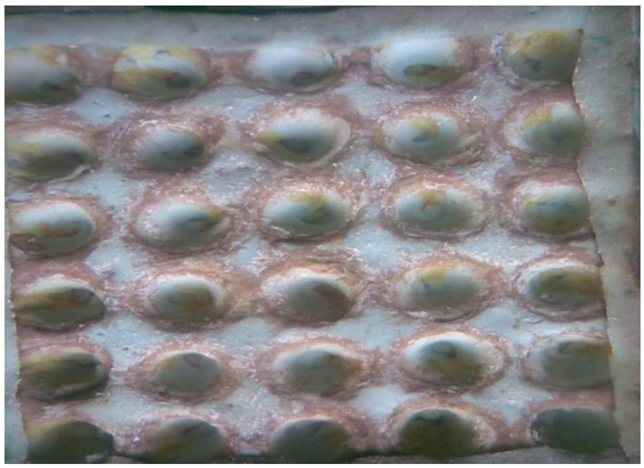

Figure 4: Counter mould

The Slurry Vat: This serves as the container for the pulp slurry to be moulded. It is the base part of the pulp-moulding machine. The vat is an open cylinder container bearing fairly dense fluid under atmospheric pressure. The cylinder is 550mm diameter and 230mm deep. This is shown in Figure 4. It is rigid enough to withstand the agitation of stock during forming. It is also expected to have sufficient volume to handle slurry of consistency between 5 and 10%.

Figure 4: Slurry vat

To calculate consistency,

$$C = \frac{F}{W} \times 100$$ *(Lavigne, 1970)-----------------------(I)*

Where,

C = Consistency (in percent) of the pulp.
F = Weight of fibrous material
W = Total weight of the pulp slurry

Mass of fibre dissolved in water = 100g
Mass of water used = 2000g
Total mass of slurry = (100 + 2000)g = 2100g
Therefore, working the consistency,

From (I),

$$C = \frac{100}{2100} \times 100 = 4.76\%$$

The consistency is therefore put at 5%.
To obtain the thickness of the slurry vat,
From the materials properties of steel, the allowable stress σ_{all} = 165MPa.
The vat is of circular cross-section, the diameter of the cross-section is calculated as follows:
The circumference of the cross-section is assumed to be outside, and not inside the perimeter of the vat. This is necessary in order to be conservative in the design.
From the figure below, the radius of the circle obtained = 275mm.

The yield strength of thin walled cylinder bearing fluid under atmospheric pressure is given as:

$$\sigma_{yield} = \frac{Pr}{t}$$ (Ryder, 2004)------------*(II)*

Where,
r= 275mm, t = thickness, P = atmospheric pressure (ℓgh)
(ℓ = 1000kg/m^3, g = 9.81m/s^2, h = 230mm)
P = (1000 X 9.81 X O.23)N/m^2
= 1962 N/m^2
σ_{yield} = 250MPa

Using a factor of safety n = 4 to accommodate forces arising from the action of the lowering mechanism,

$$\sigma_{yield} = \frac{250MPa}{4}$$
$$= 62.5MPa \equiv 6.25 \times 10^7 N/m^2$$

$$t = \frac{Pr}{\sigma_{yield}} = \frac{1962 \times 0.816}{6.25 \times 10^7}$$
$$= 5.8 \text{ X } 10^{-6}\text{m.}$$
$$= 0.0058\text{mm}$$

The Lowering Mechanism: The purpose of the lowering mechanism is for the movement of the mould into the pulp slurry vat from the counter mould and back. The mechanism itself is comprised of four long poles spanning the length through which the mould travels from the slurry vat to the counter mould. 150mm long helical springs are fixed on each pipe on which the mould rests after the pulp moulding is done. Two 7.5mm diameter pipes are fixed on either sides of the mould and attached to an overhead shaft. The overhead shaft is where manual pressure is applied to control the upward or downward movement of the mould.

Electric Motor: The electric motor is used to drive the vacuum pump. It is a single phase induction motor. The ratings of the vacuum pump to be used depend on the vacuum pump to be used, which is determined by the size of the pulp mould. However, a 2hp electric motor was used to power the vacuum pump.

Vacuum Pump: It was preferable to use a rotating vane pump, because of its ability to pump both fluid and gas rendering the use of the vacuum chamber unnecessary.

Pulp Stock Preparation: The process begins with collection of scrap paper/waste paper, in this case old newspapers, which are then converted to pulp using a Hydro-pulper. The pulp obtained is mixed with sufficient water to obtain a suspension of desired consistency, and poured into the pulp holding tank.

Wet forming of Products and de-watering: The vacuum pump is powered and vacuum builds up in the vacuum chamber. The suction mould connected to the source of sub-atmospheric pressure and is lowered into the suspension; s are deposited on the suction mould as a result of the vacuum pressure.

De-watering: The suction mould is raised from the suspension. A dewatering liquid or gas is allowed to flow through the mould, to increase the dry matter content of the moulded article.

Transfer of Wet Products: The suction mould is disconnected from the source of sub-atmospheric pressure, and is brought in contact with a transfer mould now connected to the source of sub-atmospheric pressure. The suction mould is lowered leaving behind the moulded pulp egg tray attached to the transfer mould.

Collection and drying: A collection tray is placed underneath the transfer mould while the source of sub atmospheric pressure is transferred back to the suction. The moulded article is collected on the tray, and taken out to be dried in the sun.

Results and Discussions

Egg Tray Machine Specifications

1. **Description:** Egg tray pulp molding machine
2. **Capacity:** 12 egg trays/hr
3. **Product:** size 10 of 30 cavity egg trays
4. **Process flow of batch production:**
   Waste paper (manual) – hydropulping – pulp mixing – pulp feeding – pulp molding – transferring – drying in sun – collection and stacking.
5. **Breakdown major equipment list:**
   i. hydropulper 5.6 kW
   ii. water pumps(acted as vacuum pump) 1.64 kW
6. **Raw material:** waste newspaper and used paper stationeries
7. **Consumption :** (assuming 12 egg trays)
   Waste paper used per hour: 40kg
   Water per day: 100 litres
8. **Workplace:** open ground
9. **Number of operators:** 1 person

Following the successful completion of fabrication of the machine, it can be said to comprise mainly of parts as stated above. The fabricated egg tray machine is as shown in Figures 6 and 7 while the drawing is shown in Figure 5.

Observations

The following observations and inferences were drawn:

- An egg tray machine was produced.
- the shape of the egg tray corresponds to that of the mould and the counter mould, the size being an average of the sizes of both the mould and the counter mould.
- the consistency of the pulp slurry used in the assessment was 5%. It was however observed that on further dilution, i.e, reducing the consistency of the slurry, the moulding process went at a faster rate although more water was also drawn toward the mould.
- The foam coating inside the counter mould aids the reception of the moulded product from the mould without fracture, it also compacts the moulding.

Conclusions

A recycled egg tray machine has been designed and fabricated working on suction vaccum principle capable of producing 12 egg trays/hour as shown in Figure 8 of the regular 30 cavity size 10 trays. The power requirement is low and the maintenance is easy. The weight of the egg trays produced corresponds to the weight of the standard egg trays.

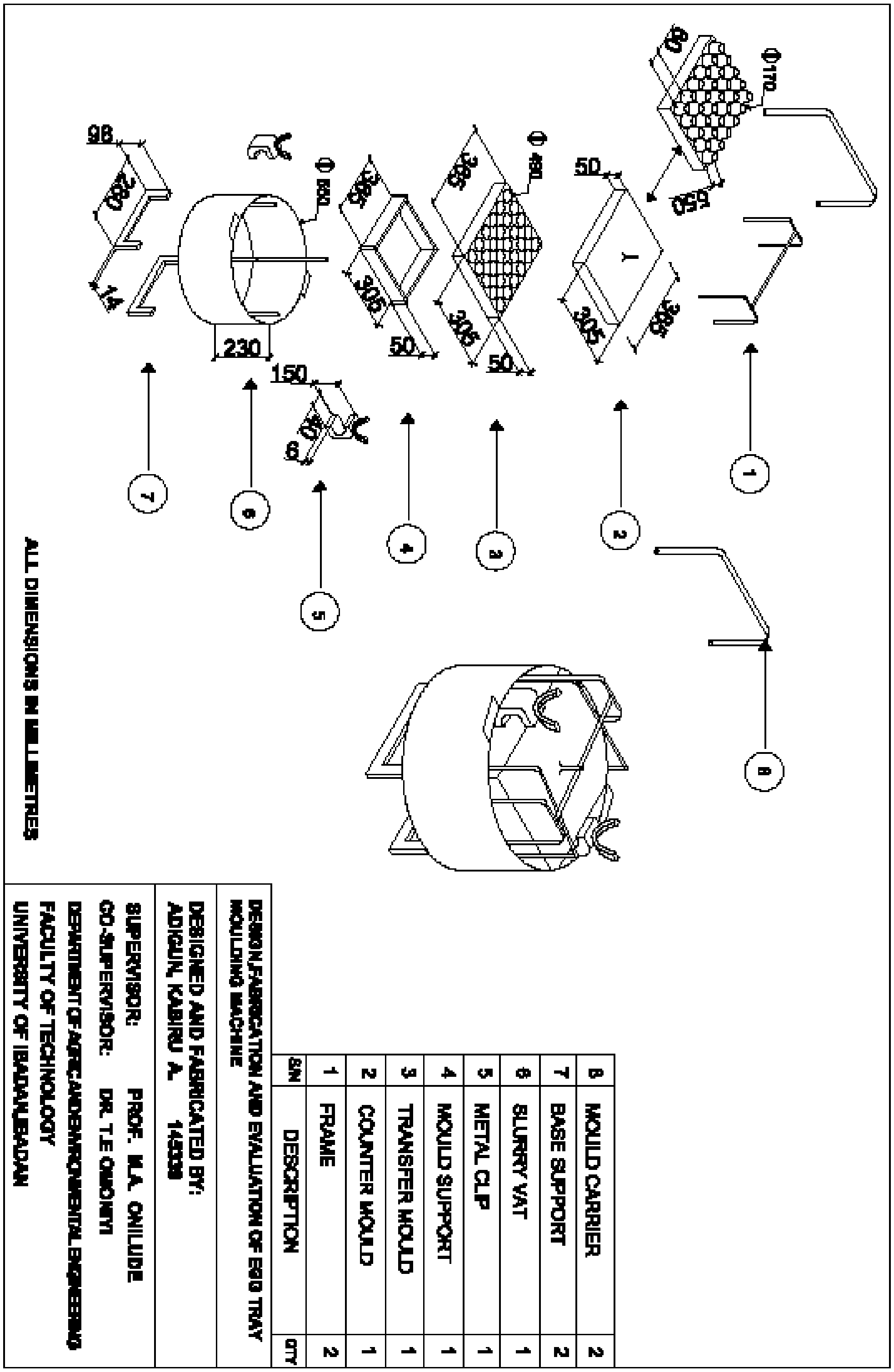

Figure 5: Engineering drawing of egg tray machine

Figure 6: Complete egg tray machine with vacuum pump and electric motor

Figure 7: Egg tray machine

Figure 8: An egg tray produced from the machine

References

Anonymous, 2007, Egg marketing, Pg 53. Accessed from (http://teca.fao.org/sites/default/files/technology_files/Egg%20Marketing%20Chapter%203%20Egg%20packaging%20transport%20storage.pdf).

Central Bank of Nigeria 1999, *Annual Report and Statement of Accounts*, CBN Publications.

Federal Ministry of Science and Technology, (2003): Pulp, Paper, Paper Products, Printing and Publishing Sector (4th Update). A Multidisciplinary Committee report. Raw Materials Development Research Council. www.rmrdc.gov.ng.

Ojo, S.O. 2003, *Productivity and Technical Efficiency of Poultry Egg Production in Nigeria*, Int. Journal of poultry Science. 2(6): 459 – 464.

Onilude M.A. and Owofadeju F.K. (2008): TWE 522 Lecture Note (Pulp and Paper Technology). Department of Agricultural and Environmental Engineering. University of Ibadan.

Ovwigho Bishop O, F.U.C. Mmereole, I. Udeh and P.O. Akporhuarho, *Comparison of Constraints to Poultry Producers in Delta State Nigeria,* International Journal of Poultry Science 8 (5): 480-484, 2009).