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ERGONOMICS OF TRACTOR OPERATION CONTROL FOR COMFORT IN NIGERIA

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ABSTRACT

In this work, anthropometric data were obtained from tractor operators with a view to determining favourable workplace environment according to their requirements and comfort. Tractor operation control distances were optimized to fit the physical needs of the operators so as to reduce the stresses from tractor operation. To achieve this, measurements of force application by the operators on brake and clutch pedals in operation, body of randomly selected operators including comfort rating, were taken. These parameters were analyzed and their results showed seat depth values of 430.0mm and 514.5mm; arm reach values of 775.0mm and 905.0mm for 5th and 95th percentiles respectively. The horizontal distance operation control point for comfortable operation of brake pedals from seat reference point (SRP) were 430.0mm and 525.5mm for 5th and 95th percentiles respectively, and those for clutch pedals from the SRP were 420.0mm and 252.5mm for the 5th and 95th percentiles. A steering column at 60° to 70° angle to the horizontal from the SRP provided a comfortable workplace for Nigerian tractor operators. It is therefore recommended that these test data be used for the design of tractor control system for Nigerian operators.

KEYWORDS: Anthropometric data, arm reach values, ergonomic data, comfort, control, operation, operators, seat depth values, seat reference point, tractor.

1. INTRODUCTION

Tractor operations require high mental and physical alertness for safety, efficiency and comfort. The operator uses his brain and muscle in the control process of different parts of the tractor. Machines and equipment in operation impose physiological strains on their operators in different ways. Besides the human energy demanded in machine control, vibration, noise and operational discomfort expose the operator to physical and mental hazards. The operator together with the tractor forms a *man-machine* system which is subjected to environmental stresses *of* temperature, humidity, rain, dust, noise in the atmosphere, solar radiation, work place arrangement and placement of control, that affect the operator. In a similar way, the amount of physical effort required for control of the machine components may limit performance efficiency and operator comfort. Tewari et al., (2002) stated that if tractor controls are not properly adapted to the operator's anatomy, the performance demanded of him may quickly reach and even exceed the limit of tolerance.

Man acts as controller of elements in the operation of tractors. Tractor operation is a repetitive process. Nwuba and Kaul (1987) as cited by Woodson and Conover (1992) reported that the greatest advantage man has over other sources of power is his ability when skilled, to carry out repetitive actions almost involuntarily without much thoughts and efforts. Nwuba and Kaul (1987) reported that successful design of tractor and equipment require consideration of human sensory capacities, muscle strength, intellectual abilities, common skills and ability to develop new skill, body dimensions and in addition, the effects of working environment upon human performance. However, Mganilwa et al., (2003) as cited by Nkakini et al., (2006) stated that there are differences in the anthropometric data in different countries of the world. Thus, to design a good tractor control system for Nigerians and indeed any country, anthropometric data from that population is necessary. Anthropometry is the Science dealing with dimensions of the human body; it is basically the listing of data and information on human body size. Hansson (1991) reminded

that man-machine relationship must be studied using anthropometric and ergonomic principles, to improve efficiency of machine, reduce risks and enhance operator comfort. Sanders and McCormick (1993) submitted that poorly designed operating arm and leg rooms of machine contributes to muscle fatigue and discomfort in operation.

Matthews (1972) reported that in the design of mobile equipment, a balance driver's seat reduces the ill effect of vibration in the spinal column of the operators. He concluded that care must therefore be taken in designing tractors and particularly tractor seats, to reduce vibration and shock to a minimum as well as ensure comfortable posture. Compared to hand controls, foot controls often restrict the posture of the user, and an inappropriate pedal design may contribute to muscle fatigue and cause discomfort to the driver McCormick, (1976). Phessant and Harris (1983) reported that in general, a seated position becomes less satisfactory as the operator either elevates the thigh by hip or extend the knee, since either of these actions stretch the arm string muscles and place them under tension.

Regarding design of operator's workplace, Hansson et al., (1970) stated that safety, comfort and convenience should be considered in the design, location and construction of the operator's workplace. The workplace should be located on the machine so that visibility in the driving position is good without requiring the operator to work in awkward, tiring position. Levers, pedals and instruments should be conveniently and logically located and the workplace should fit both tall and short operators. In addition, the operator should be able to change his working position easily and the work area should be free of sharp edges and obstructions such as transmission cases.

Ahlschwede and Klotzbach (2000) as cited by Carroll et al., (2003) stated that safety in the overall design of tractor is a major consideration by industry. Furthermore, reported that design teams and individual designers employ the concept of 'safety through design', which is the integration of hazard analysis and risk assessment methods in the design and engineering stages, so that the risk of injury or damage are at an acceptable level. Thus, this concept is based on the principles of avoiding, reducing the probability of a hazard related incident occurring; minimizing damage should an incident occur which is most effectively performed when designing new equipment.

The objective of this study was to provide anthropometric and ergonomic data for the design of more efficient and safer tractors that may be operated by Nigerians.

2. MATERIALS AND METHODS

Anthropometric and ergonomic data were obtained from 50 randomly selected Nigerian tractor and equipment operators, mechanics, farm workers and students of the Department of Agricultural and Environmental Engineering of the Rivers State University of Science and Technology, Port Harcourt, Nigeria. The selected age group used was between 24 and 60 years among male and female.

Tractor control seat reference distance to control points, from a specially designed experimental tractor in the Departmental farm workshop of the Department of Agricultural and Environmental Engineering, Rivers State University of Science and Technology, Port Harcourt, Nigeria, were measured, using rules, electrical strain gauge (wheat stone Bridge) and cardiomin through decoder of the telemetry. The data obtained were analysed for percentile distribution from 0 to 100%. The experimental tractor (Figure 1) used had seat, footrest, steering wheel, brake and clutch pedal, hydraulic control lever and gear - shift lever. To measure the force applied by the operator on the brake or clutch pedal in operation, tensile spring was attached at free end of a vertical iron flat 127mm thick that acted as a cantilever beam. Two 127mm electrical strain gauges were placed on both fixed ends of the flat.



Fig 1(a) Experimental Tractor (1) Frame (2) Seat (3) Steering (4) Foot Pedal (7) Power Transmission Unit (9) Vertical Iron Fiat with Tensile Spring

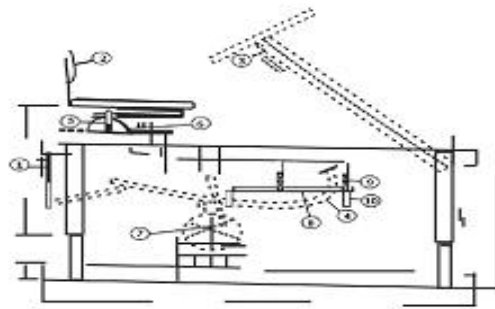


Fig 1(b) Tractor Operation Control Point (TOCP) Simulator (Side view). (1) Frame (2) Seat (3) Steering (4) Foot Pedal (5) Draft Control Lever (6) Amplitude Adjustment Mechanism (7) Power Transmission Unit (8) Horizontal Iron Fiat (9) Vertical Iron Fiat with Tensile Spring (10) Strain Gauge.

The following dimensions were also measured: weight, standing height (stature), arm reach, seat height, seat depth, seat breadth, elbow rest height, forearm hand length, foot length and inside grip diameter (Fig. 2).

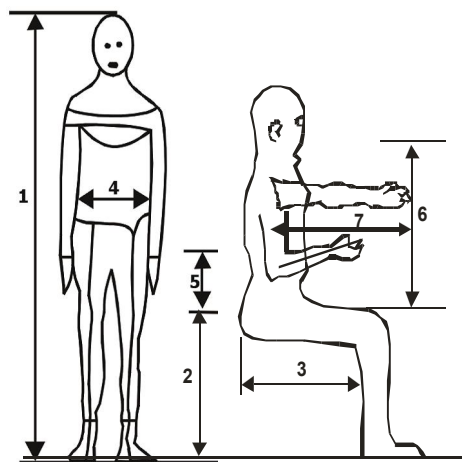


Figure 2: Anthropometric Measurement of operators (1) Standing height (2) Seat Height (3) Seat Depth (4) Seat Breadth (5) Elbow Rest Height (6) Shoulder Height (7) Arm Reach

Each of the participating operators was invited to sit driving the experimental tractor as to familiarize himself with the controls. The location of the control from seat reference point (SRP) was adjusted to fit the operator as the experiment was carried out. As the adjustment was completed for each control, the operator was asked to carry out a full brake pedal operation, which was followed by moving the right foot from the foot rest, engaging fully and disengaging the brake pedal and moving the foot back to the foot rest. The force applied to the brake was measured using the strain gauge.

At the end of the operation the operator was asked to give a comfort rating within the range of 0 to 10, (uncomfortable to very comfortable). The operator gave information concerning the comfort of pedal used, the arm reach, seat height, seat depth, seat breath, elbow rest height, foot length. The same method was used in all cases. In each case the optimization of the control points was done on the basis of maximum comfort rating in operation. Based on this comforting rating, the comfort scale ó 10 point scale was obtained from the answers given by the operators.

3. RESULTS AND DISCUSSION

3.1 Anthropometric Data for Farm Workers

The results obtained are shown in Tables 1 to 3. Table 1 shows summary of anthropometric data for 5th and 95th percentiles and difference between 95th and 5th percentile for Nigeria. The table shows seat height values of 400.0mm, 504.5mm vertical, seat depth values 430.0mm, 514.5mm horizontal, arm reach values of 775.0mm, 905.0mm all from seat reference point for 5th and 95th percentiles.

Table 1: Anthropometric data for farm workers in Nigeria

Dimensional Elements	Value of 5 th Percentile	Value of 50 th Percentile	Value of 95 th Percentile	Total Difference B / T 5 th and 95 th Percentile	Standard Deviation
Standing Height, mm	1,540.0	1,650.0	1,800.0	260.0	77.2
Body Weight, kg	598.0	651.0	774.5	181.7	60.5
Seat Height, mm	400.0	450.0	504.5	104.5	82.1
Seat Depth, mm	430.0	450.0	514.5	84.5	28.3
Seat Breadth, mm	300.0	320.0	360.0	60.0	19.4
Elbow Rest Height, mm	150.0	180.0	224.5	74.5	23.5
Shoulder Seat, mm	500.0	540.0	620.0	120.0	33.9
Arm Reach, mm	775.0	830.0	905.0	130.0	69.0

Source: Nkakini et al., (2006)

3.2 Comfort Rating for Tractor Operators

From Table 2, the average comfort rating suitable for the subjects, obtained were 8.4 and 8.7 from 10-point scales for 5th and 95th percentiles for comfortable operations.

Table 2: Comfort rating for tractor operation control points at 10 points scales

Dimensional elements	Value of 5 th Percentile	Value of 50 th Percentile	Value of 95 th Percentile	Difference between 5 th and 95 th Percentile
Break pedal	8.4	8.5	8.4	0.3
Clutch pedal	8.5	8.6	8.8	0.3
Steering wheel (Vertical)	8.4	8.5	8.7	0.3
Steering Wheel (Horizontal)	8.6	8.7	8.8	0.2
Average Comfort rating	8.4	8.6	8.7	0.3

3.3 Ergonomic Data for Operation Controls

Table 3 shows ergonomic data for operation controls. With respect to force applied to the brake pedal, perceived comfort rating and energy expenditure rate, average results obtained on horizontal distances from seat reference points were 436.4mm and 516.7mm for 5th and 95th percentiles respectively. Similarly, for clutch pedal, the average results on horizontal distance from seat reference point were 424.0mm and 527.0mm for 5th and 95th percentiles respectively. The average steering wheel were at 60° and 70° orientation angle columns with respect to vertical distances from seat reference point of 399.5mm, 432.5mm and horizontal distance from the same (SRP) were 502.0mm, 516.5mm for 5th and 95th percentiles respectively.

Table 3: Ergonomic data for tractor operation controls in Nigeria (All measurements are in mm)

Dimensional Element	Value of 5 th Percentile	Value of 50 th Percentile	Value of 95 th Percentile	Difference b/w 5 th and 95 th Percentile
Brake pedal ó horizontal distance from SRP on applied force	430.0	472.3	514.5	84.5
Brake pedal ó horizontal distance from SRP on perceived comfort rating	450.0	485.1	520.2	70.2
Brake pedal ó horizontal distance from SRP on energy expended rate	429.01	472.3	515.5	86.4
Average results on horizontal distance for brake pedals	436.4	476.1	516.7	80.2
Clutch pedal ó horizontal from SRP on the force applied	420.0	472.8	525.5	105.5

Clutch pedal 6 horizontal distance from SRP	428.0	477.3	526.5	98.5
perceived comfort rating				
Clutch pedal 6 horizontal distance from SRP on energy expended	423.0	475.78	528.5	103.5
Average results on horizontal distance for clutch pedal	424.0	475.1	527.0	103.0
Steering wheel at 70° orientation angle column. Vertical distance from SRP (seat height)	400.0 (Vertical Height) 504.5 (Horizontal Seat depth)	415.0 (Vertical) 509.5 (Horizontal)	430.0 (Vertical) 515.5 (Horizontal)	30.0 (Vertical) 10.0 (Horizontal)
Steering wheel at 60° orientation angle column. Horizontal distance from (SRP)	399.0 (Vertical Height) 504.5 (Horizontal Seat depth)	416.0 (Vertical) 512.0 (Horizontal)	433.0 (Vertical) 518.5 (Horizontal)	34.0 (Vertical) 13.0 (Horizontal)
Average steering wheel distance at 70° and 60° orientation angle column (Horizontal and Vertical) from SRP	399.5 (Vertical) 502.0 (Horizontal)	416.0 (Vertical) 509.3 (Horizontal)	432.5 (Vertical) 516.5 (Horizontal)	33.0 (Vertical) 14.5 (Horizontal)

SRP: Seat Reference Point

Table 4, shows the average anthropometric data for farm workers in Nigeria, Tanzania, US and India. The total data obtained are quite different from each of the countries. Based on results from these countries, it is clear that data from these regions are quite different from others. Therefore, the use of machine designed with the ergonomics and anthropometric data in other countries may not be directly applied in Nigerian and others (Gupta et al., 1983; the United Republic of Tanzania (URT) 1999; Mc Cormick, 1976 and Nkakini et al., 2006).

Table 4: Average anthropometric data for farm workers in Nigeria, Tanzania, US and India 6 all in mm

Countries	Average Value of 5 th Percentile	Average value of 50 th Percentile	Average value of 95 th Percentile	Differences between 5 th and 95 th Percentile	Total Average
Nigeria	559.7	606.9	685.6	312.2	540.8
Tanzania	566.4	639.3	732.8	152.1	522.7
U S	645.6	630.0	817.5	171.8	566.2
India	535.7	684.3	752.2	216.5	547.1

Source: Adapted from Mgnailwa et al., (2003); URT (1999), Mc Cormicr (1976).

4. CONCLUSION AND RECOMMENDATIONS

In a man-machine relationship, the human body is considered important. But, the ergonomic data available for other countries cannot be applied in Nigeria if comfort, safety, convenience and efficiency in operation by operators ought to be realized.

The ergonomics data as shown in Table 3 could enhance the comfort of Nigerian tractor operation. The average horizontal distance operation controls of brake and clutch pedals from SRP for 5th and 95th percentiles would add to high level of efficiency in mechanization as well as some levels of comfort to most operations.

The average steering wheel distance at 70° and 60° with the vertical and horizontal distance from SRP for 5th and 95th percentiles provides the desired comfortable operation controls for the Nigerian tractor operators.

The use of machines designed with the ergonomics data from other countries may have contributed to low level of efficiency in the operation of tractor and discomfort of most Nigerian operators.

It is therefore recommended that those test data obtained be used for the design of tractor control points for brake, clutch pedals and steering angles for Nigerian tractors operators. This may reduce physical and mental stresses, improving comfort in operation.

REFERENCES

- Ahlschwede, B and Klotzbach, K. 2000. Integrating safety into the design of agricultural equipment. ASAE 2000 Agricultural Equipment Technology conference, Kansas City, MO, 23 ó 25 February.
- Carroll, E. Georing., Marvin L. Stone., David W. Smith and Paul K. Turnquist 2003. Human Factors and safety. Published in off-Road Vehicle Engineering Principles, Chapter 15, Pp.421-462 American society of Agricultural Engineers.
- Gupta P. K., Gupta M. L. and Sharma A. P. 1983. Anthropometric survey of India Farm workers. Agriculture Mechanization in Asia, Africa and Latin America Vol. 14 No.1 Pp 27 ó 30.
- Hansson, T. 1991. Ergonomic checklist for Tractors and Agricultural Machinery. The National Swedish Institute of Occupational Health, NIOH, 1991.
- Hansson, J. E., Sjöflot, L. and Suggs C. W. 1970. Matching the farm machine to the operator's capabilities and Limitations. Implement and Tractor (21 August).
- Mganilwa, T. M., Mpanduyi, S. M., Makungu, P. T. and Dehenga, H. O. 2003. Promoting local production of small multipurpose tractor in Tanzania. International conference on Industrial Design Engineering UDSM, Dar es Salaam, July, 17-18, pp 136 ó 137.
- Mc Cormick, E. J. 1976. Human Factors in Engineering and Design, 4th ed. Tata McGraw Hill Book company, New Delhi.
- Matthews, J. 1972. The ergonomics of tractor design and operation. Proceeding of the XVI CIOSTA Congress, Wageningen. Wageningen University press, The Netherlands.
- Nwuba, E. I. U. and Kaul, R. N. 1987. Energy requirements of hand tools for wood cutting. J. Agric. Engineering Res. 36: 207 ó 215.
- Nkakini, S. O., Akor, A. J. and Zibokere, D. S. 2006. Development of Anthropometric data base for local production of simple agricultural machinery. Nigerian J. Engineering Res. Dev. 5 (2): 2.
- Phessant, S. T. and Harris C. M. 1982. Human strength in the operation of Tractor pedal. Ergonomics, 25 (1): 53 ó 63.
- Sanders, M. S. and Mc Cormick, J. 1993. Human Factor in Engineering Design. 7th ed, Mc Graw-Hill, New York.

- Tewari, V. K., Bhoi, P. K. and Dhav, R. 2002. Healthy and comfortable environment to the tractor operator during farm work. ASAE Annual international meeting / CIGR 15th World Congress, Hyatt Regency Chicago Illinois, U. S. A., July 28 ó 31, 2002, pp. 2
- The United Republic of Tanzania (URT) 1999. The Tanzania development vision 2025. Planning Commission Dare Salem.
- Woodson, W. E. and Conover, D. W. 1992. Human factor design hand book. 2nd ed. Mc Graw-Hill Book Co., New York.

DEVELOPMENT AND TESTING OF A SWIRL CHAMBER NOZZLE

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ABSTRACT

A swirl chamber nozzle [SCN] was designed and constructed with the aim of establishing the relations between the swirl/element forces, swirl element movement and geometric dimensions of the key components. A swirl element with helical groove served as the device responsible for the turbulent movement of fluid in the swirl chamber before a rotating spray is created at the exit orifice. The swirling spray exited at axial and rotational velocities due to the rotary motion of the swirl element created by the pressure of the incoming fluid stream. As expected, the flow rate of the developed nozzle prototype was sensitive to change in the exit orifice diameter.

The effects of two other factors namely system pressure and nozzle exit orifice diameter were tested on the flow rate and penetration range of the developed nozzle prototype at four levels each. The prototype was tested at four levels of exit orifice diameters (1.0mm, 2.0mm, 3.0mm, and 4.0mm) for each of the four levels of system pressures of 19Kpa, 350Kpa, 525Kpa and 700Kpa on a fabricated test rig. Independent control of liquid flow rate and droplet penetration range was achieved by varying the system pressure through combined manipulation of the two control valves installed on the test rig. The effect of the change in pressure and exit orifice dimensions on the droplet size spectrum was not investigated.

KEYWORDS: Swirl chamber nozzles; swirl element; penetration range; pest; pathogens; metering parameters.

1. INTRODUCTION

The effective control of any pest or pathogen depends to a large extent on the machines, tools and equipment utilized for the purpose. If the operation of the machines or tools is not satisfactory, the pests or pathogens may either remain unaffected or result in permanent damage of the principal crops that we are making attempt to protect. Sometimes the pathogen or pest attack could even be worse than those on fields in which no crop protection attempt of any form has been made.

However, it is possible to achieve high quality performance of the machine and equipment once strict adherence to some requisite basic, economic and management principles are met. Although there are several methods of effecting crop protection practices, the focus of the method in this research paper is one in which the mechanical equipment is utilized.

Mechanical application of agrochemical is the commonest method of pest control in modern crop protection practices. This is a method in which the controlling chemical agents either in the form of droplets or dusts are carried to their target plant(s) or soil surface(s) by kinetic energy due to the considerably high velocity with which they have been ejected from their application apparatus.

Even distribution of agrochemical may improve crop production efficiency and environmental protection (Boving and Winterfield, 1980). Nozzle discharge with high penetration range of tank-mixed chemicals achieves crop protection in tall areas of the tree crown that are often difficult to reach by conventional

knapsack spraying apparatus if not impossible (Bouse, 1994). Increasing the turndown ratio of nozzle flow rate may also go a long way in increasing the range of application spray rates (Womac and Bui, 2002).

According to Klenin *et al* (1985), pressure atomizers are the type mostly used to apply most liquid crop protection chemicals. Liquid discharge from an ordinary cone atomizer without a swirl chamber consists of minute droplets, which constitute the highest proportion by weight; this proportion limits the practical range of droplet penetration. Nozzle specific relations between pressure, droplet size spectra, spray pattern and initial discharge velocity limit the penetration range from solid cone hydraulic (or ordinary pressure) nozzles (Panneton, 2002).

A method of counting droplets from atomizing devices have been developed and tested by some researchers (Nawady, 1976). Theoretical assumptions about drop size distribution from pressure sprays were found to be inadequate and experimental verification of spray performance was, therefore, found to be always necessary. El-Awady (1978) proposed an atomization theory for swirl nozzles, which established the relationship between droplet size, pressure, and discharge rate and kinematic viscosity. Sidahmed (1996) noted that the theory had, at least, three limitations: (i) they are empirical in nature; (2) they are defined to predict only an average droplet size in a spray; and (3) in some cases, the nature of the average droplet size is ambiguous. He, however, explained that these limitations were inherited from the methods used in arriving at the equations developed; which is mainly by balancing an inertia force term with a surface tension or viscous force term. The exact formula describing the inertia force action on a droplet separating from a liquid sheet is still unknown.

Generalized theoretical and semi theoretical atomization equations were however presented in (Sidahmed, 1996) in addition to their validity which were examined using published data. The proposed equations are basically drop size/velocity correlation, which describe the behaviour of droplets just after (or near) their formation and which could be interpreted in many useful ways,

Boving and Winterfel (1980) tested some selected nozzles for deposit efficiency in aerial application of spray. Krishan and Williams (1988) developed a technique for measuring spray pattern displacement in agricultural nozzles. Koo and Kuhlman (1993) developed a theoretical method of measuring the spray performance of swirl-type nozzles. Wang and Zhang (1995) carried out an experimental analysis of spray distribution pattern uniformity for Agricultural spray nozzles.

Womac and Bui (2002) designed and tested a variable-flow fan nozzle. The design was used to develop a new concept whose aim it is to effect chemical application at variable rate. A split-end meter plunger incorporated in a tapered sleeve served as a variable orifice which varied both the flow rate and droplet size while creating fan spray by way of impinging streams of liquid together. The vector force analyses of this design indicated that longitudinal plunger position depended on line pressure, diaphragm area, plungers end area, spring constant of spring plunger end, maximum slit opening and taper angle. Results indicated that the Variable Flow Fan Nozzle (VFFN) spray angle equaled the taper angle of the nozzle sleeve at a pressure of 276 kPa. Observed turndown ratio (maximum to minimum flow rate) for the 90° prototype was 13 to 1 based on spray angles, flow rates, and pattern widths (at 45 cm nozzle height) which ranged from 65° to 100°, 0.227 to 3.028 Lmin⁻¹, and 70 to 110 cm, respectively. By adjusting the control pressure from 414 to 138kPa, the droplet spectrum $\Delta_{v0.1}$, $\Delta_{v0.5}$ and $\Delta_{v0.9}$ values were varied from 58 to 190µm, 141 to 522µm, and 300 to 850µm, respectively.

The geometry and performance of a rotary cup atomizer was also investigated by Panneton (2002). The effect of geometry on controlled droplet atomization using rotary cups was investigated. This was by way of performing experiments over a range of flow rates comparable to the one obtained with a commercial unit. A cup made of smooth surfaces was designed and tested in the study. A model for predicting the droplet size as a function of cup geometry, fluid physical properties, and rotational speed was developed.

One of the design parameters (the radius of the edge where fluid detaches from the cup) was identified as a key parameter in preserving droplet size uniformity under non-ideal conditions of operation.

Numerous experiments carried out by investigators reviewed in literature seem to confirm that above 203 kPa the effect of pressure is negligibly small in swirl nozzles. The length of the swirl chamber is suspected to be of vital importance, and all their considerations seem to have applied to only low chambers with heights not more than half of their diameters. In other words, their influences have been more or less left out of consideration. In addition, no equation has so far been developed for the average value of the cone's apex angle.

The goal of this research was to test the performance of a developed prototype Swirl Chamber Nozzle (SCN). The specific objectives were to: determine the engineering relations between swirl element forces, swirl element movement, and dimensions, swirl chamber inlet and outlet (orifice outlet) dimensions; observe droplet penetration range associated with the length-diameter ratio used for the swirl chamber for various exit velocities; determine the orifice discharge coefficient(s) for the prototype (SCN), and test the device for ranges in flow rate and droplet penetration.

2. MATERIALS AND METHODS

2.1 Overall Description of Swirl Chamber Nozzle (SCN)

The SCN consists of a nozzle body sleeve, a swirl element- that is, a plug with helical liquid-conveying grooves, the orifice disk with nozzle exit orifice, the hexagonal nut socket as securing cap, swirl chambers, a pair of tapered roller bearings, lip seal, rubber gasket and end cap (Fig.1). A pair of tapered roller bearing was used to accurately position the swirl element in the upper nozzle body sleeve. The tapered roller bearings are positioned in the lower nozzle body sleeve by means of the end cap and the bolted flanges welded to each of the nozzle body sleeves. The upper nozzle body sleeve has an inlet port through which pressurized fluid from the pump is taken into the nozzle to activate the swirl element. The differential pressure across the swirl element between the intake port and the nozzle exit orifice keeps the swirl element and the fluid in the swirl chamber rotating. Simultaneously, the rotating fluid moves in a direction parallel to the nozzle -, swirl element -, swirl chamber and nozzle exit orifice axes (all of which are collinear).

The exit orifice is uniquely countersunk at 45° in order to aid in the formation of the liquid sheet cone angle at the nozzle exit point (figure 1). The rotary motion of the swirl element as the liquid stream is conveyed through the helical groove generates a swirl in the swirl chamber; it is this swirling liquid that, in turn, generates a liquid spray with hollow cone shape when the liquid stream exits from the nozzle orifice.

The rotary motion of the swirl element as the liquid stream is moved through its helical groove generates a swirl in the swirl chamber which in turn generates a liquid spray with hollow cone shape.

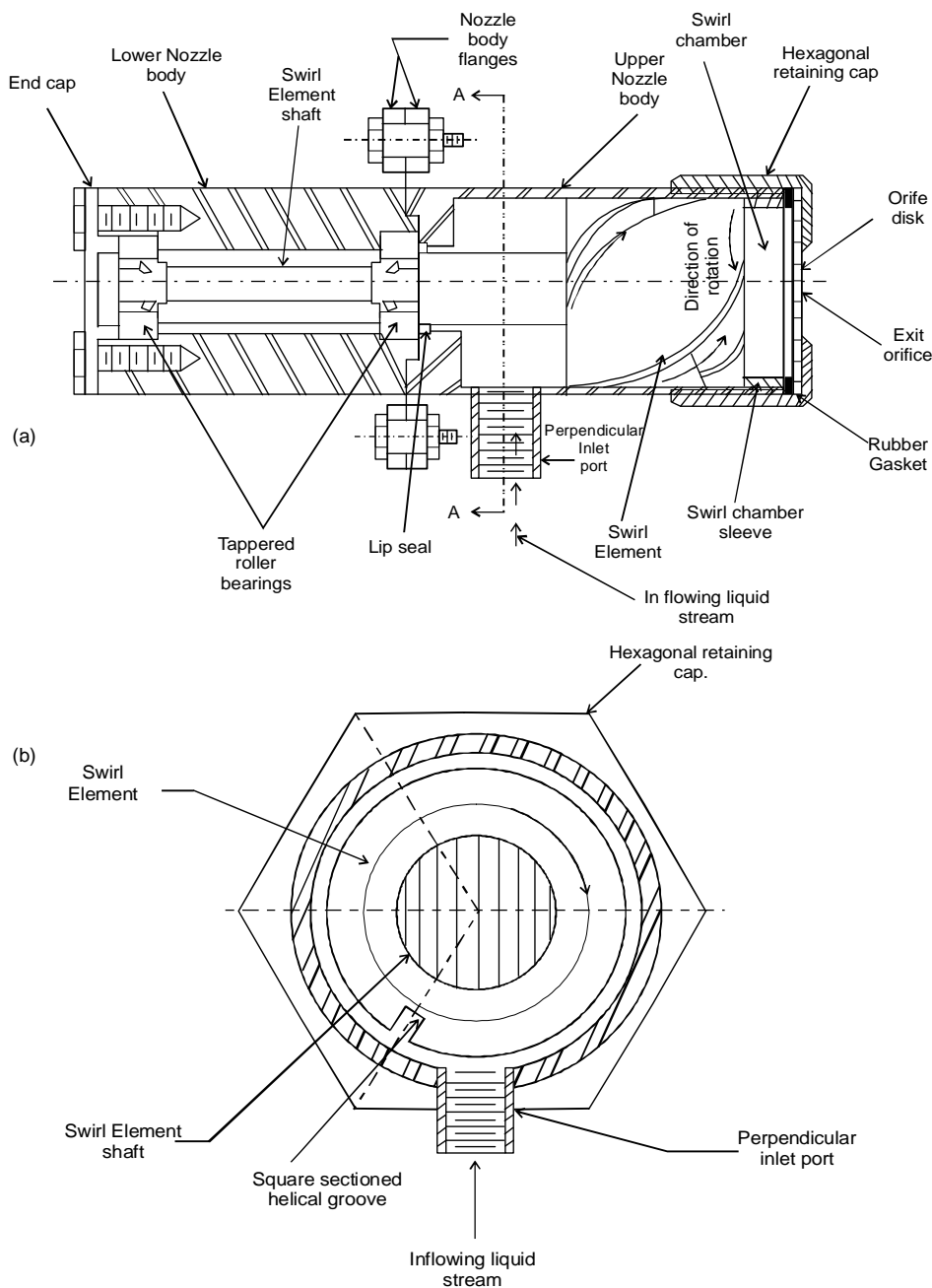


Figure 1. Swirl chamber nozzle: (a) longitudinal section (b) section A - A

2.2 Analysis of Forces Acting on the Swirl Element and Their System Pressure and Nozzle Discharge Relationships

With a system pressure (P), the radial, axial and tangential force components of the flowing fluid stream in the helical groove with helix angle (Ψ) was related to the system pressure through force vector analysis. The system pressure (P) acting on the cross-sectional area, A_G , of the groove transmitted force

(F) to the swirl element. The transmitted force (F) has an axial component (F_a) transmitted parallel to the axis of the swirl element, a tangential component (F_t) transmitted perpendicular to the axis of the swirl element and a radial component F_r transmitted in a direction perpendicular to the plane containing F_a and F_t (Fig. 2).

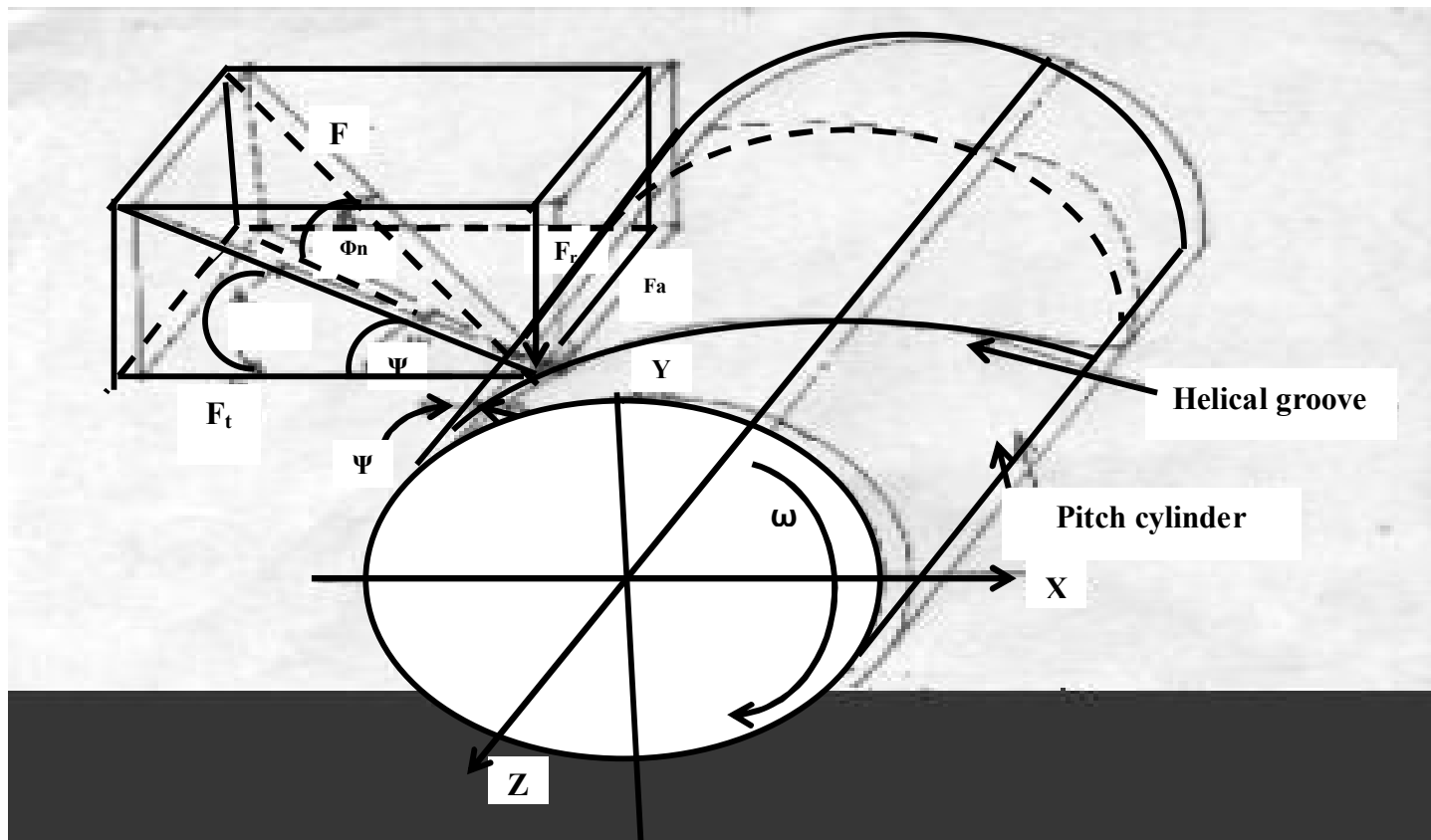


Figure 2. Forces acting on swirl element for geometric dimension determination.

The tapered roller bearings (figure 1) acted on the swirl element with an axial reactive component F_a' and a tangential component F_t' equal and opposite to F_a and F_t . Mathematically, these forces are expressed as follows:

$$F = P A_G \dots (1)$$

$$F_t = F \cos \phi_n \cos \psi \dots (2)$$

$$T = (d/2) F_t \dots (3)$$

$$F_a = F \cos \phi_n \sin \psi \dots (4)$$

$$F_r = F \sin \phi_n \dots (5)$$

$$PWSE = \frac{PQ \sin \phi_n}{1000} \quad \text{..(6)}$$

$$R = \frac{L_{sb}}{D_{sb}} \quad \text{..(7)}$$

where: F = Resultant force on the pitch cylinder; P = System pressure; A_G = Projected groove area; F_t = Tangential component of the resultant force (F) transmitted ϕ_n = Angle between the transmitted resultant force (F) and the XZ plane; = Helix angle of the helical groove which is also equal to the angle the projection of the resultant transmitted force (F) on the XZ plane and the tangential component (F_t) of the force (F); T = Torque developed by the tangential force (F_t) on the swirl element; d = Median diameter of the swirl element; F_a = Axial component of force (F) on the swirl element; F_r = Radial component of the force (F) on the swirl element; $PWSE$ = Power available to the swirl element; Q = Nozzle discharge; R = Length-Diameter ratio of the nozzle swirl chamber; L_{sb} = Length of swirl chamber; D_{sb} = Diameter of swirl chamber

2.3 Analysis of Swirl Element Velocities with Flow and System Pressure

The swirl element velocity depends on the fluid flow through the groove, the system pressure and the geometry of the groove and swirl element. The kinematic analysis is as follows:

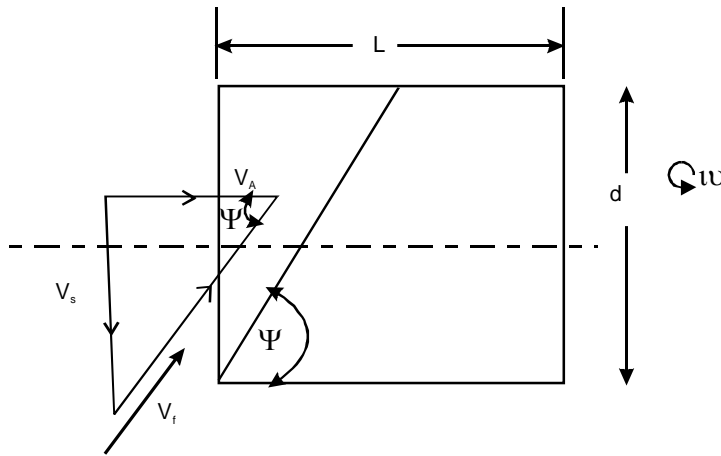


Fig. 3 Velocity diagram of the swirl element.

$$Q = A_G V_F \quad \text{..(8)}$$

$$V_A = Q / A_Z \quad \text{..(9)}$$

$$V_A = V_F \cos \psi \quad \text{..(10)}$$

$$V_F = Q / A_G \quad \text{..(11)}$$

$$\sqrt{\frac{Q}{V_F}} = W \quad \text{..(12)}$$

$$d = D_{sb} \phi W \quad \text{..(13)}$$

$$V_s = V_F \sin \psi \quad (14)$$

$$\omega = 2V_s/d \quad (15)$$

$$AG = W^2 \quad (16)$$

$$NE = 30\omega/\pi \quad (17)$$

$$\lambda = 90 - \psi \quad (18)$$

$$L = \pi d \tan \lambda \quad (19)$$

$$L = d/\tan \psi \quad (20)$$

$$Q = \pi r_z^2 K \sqrt{2gH} \quad (21)$$

$$PSB = \frac{\gamma H d}{1000} \quad (22)$$

where: V_F = Sliding velocity of flow through the helical groove; V_A = Axial component of fluid velocity through the groove; A_z = Area of Nozzle exit orifice; W = Length of sides of the square-sectioned helical groove; D_{sb} = diameter of swirl chamber; d = median diameter of the swirl element; V_s = Pitch line velocity of the swirl element; ω = Angular velocity of the swirl element; NE = Rotational speed of the swirl element; λ = Lead angle of the helical groove of the swirl element; L = Length of swirl element; K = Performance coefficient of the nozzle; H = Total pressure head H in the swirl chamber; γ = Specific weight of liquid.

Equations 1 to 22 were used to compute appropriate geometric sizes for the swirl chamber nozzle.

2.4 Test Rig and Tests

The test rig (Figure. 4) basically consists of the two parts namely the tank/pump bench and the nozzle bench. A pipe connection runs from the tank outlet to the centrifugal pump suction end.

The centrifugal pump is mounted on the same bench as the water tank. The discharge end of the pump is connected to a line control valve en-route to a Tee which directs flow to the tank and the nozzle. The line that connects flow to the nozzle is connected to a pressure gauge which in turn is connected to another valve from which the flow is directed to the nozzle inlet port. This is the valve used to control the system pressure. The line pressure which relieves possible excessive pressure in the upstream part of the system which could overload the pump whenever the pressure of liquid flow into the nozzle is high is controlled by the other valve which plays the role of a throttling valve. With this arrangement, excess fluid flow is then returned into the tank or reservoir. This is the means of actuating the swirl element in the swirl chamber nozzle.

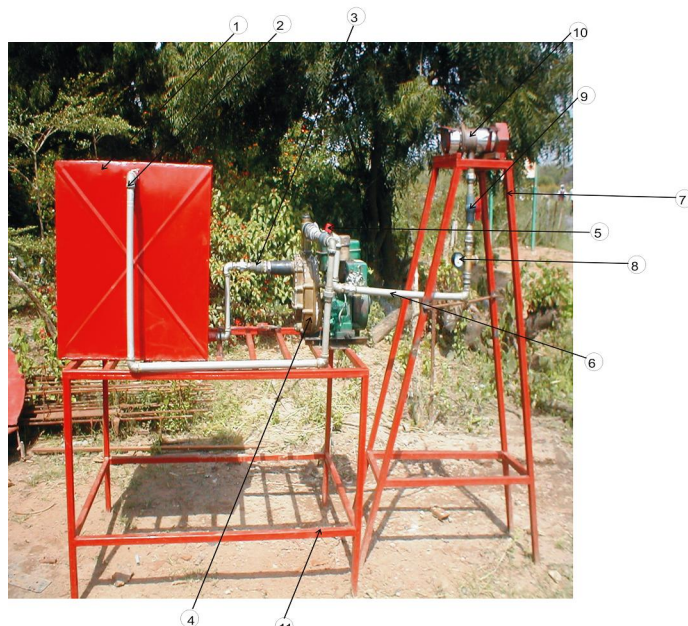


Figure 4: The nozzle test rig. 1-Return Pipe; 2-Tank; 3-Pump Inlet; 4-Pump; 5-Line Pressure Control Valve; 6-Nozzle supply Line; 7-Nozzle Bench; 8-Pressure Gauge; 9-System Pressure Control valve; 10-Nozzle Clamp; 11-Tank/Pump Bench.

The differential pressure across the swirl element between the inlet port and the swirl chamber controlled the speed of rotation of the swirl element and the turbulence of the liquid in the swirl chamber. Uniquely, the nozzle bench was fabricated separate from the tank for bench instead of welding the two together in order to make it possible to accommodate a wide range of pumps on the test rig. The nozzle is mounted horizontally on the nozzle bench so that the nozzle penetration range is measured in the horizontal direction.

2.4.1 Flow Test

Independent control of flow rates were obtained by a combination of varying system pressure and flow direction through simultaneous adjustments of the two valves (Fig. 4). The system pressure was adjusted in increments of 175kPa.

The minimum flow rate was measured by:

- (1) Setting the system pressure equal to 175kPa. This produced a radial force great enough to start the swirl element rotating.
- (2) Setting a 15-litre capacity calibrated plastic bucket at an angle of about 45° before the nozzle exit orifice to collect the discharge for a measured period of time.
- (3) Increasing the system pressure from 175kPa to 350kPa and repeating the same process of collecting nozzle discharge from the nozzle as was used in (2). Maximum flow rate was found at a system pressure of 700kPa when increased system pressure no longer increases flow rate.

Flow rate (Q) was calculated from the water collected in the calibrated bucket by dividing the volume of water collected by the time taken. This was repeated twice for each of the four orifice plates installed on the nozzle for each of the pressure levels.

2.4.2 Droplet Penetration Range Test

Independent control of droplet penetration range was effected by varying the system pressure. Droplet penetration ranges were measured for four exit orifice plates installed on the prototype nozzle. Each plate had an exit orifice of prototype nozzle. Each plate had an exit orifice of diameter ranging from 1mm to 4mm as in the discharge test. System pressures were varied from 175 kPa to 700 kPa. A steel tape was used to measure the droplet penetration range by measuring the throw of the droplet from the projection of the nozzle exit orifice on the ground and the furthest point traveled by the flowing stream on the ground. Two measurements were taken for each exit orifice diameter at each pressure level.

2.4.3 Data Analysis

All the data collected in the tests were based on a 2^2 fractional experiment because they involve a study of the effects of, at least, two factors simultaneously.

The nozzle discharge of the prototype swirl chamber nozzle is suspected to be influenced by the system pressure used in the nozzle and the exit orifice diameter. Two replicates of the factorial experiment were run for four system pressure levels and four exit orifice diameters and the results were tabulated as shown in Table 1.

3. RESULTS AND DISCUSSIONS

3.1 Flow Test

The analysis of variance of the data collected is as shown in Table 1. Since $F_{0.05, 9, 16} = 2.54$ and $F_{0.01, 9, 16} = 3.78$, that were both greater than calculated F , we conclude that there is no significant interaction between the system pressures and the exit orifice diameters of the prototype nozzle is not significant. Further more, $F_{0.05, 3, 16} = 3.24$ and $F_{0.01, 3, 16} = 5.29$, so the main effects of system pressure and exit orifice diameter were significant at both 5% and 1% level.

Table 1: Analysis of variance of nozzle discharge data

Source of Variation	Sum of squares	Degrees of Freedom	Mean Square	F Value		
				Calculated	Tabulated	
					5%	1%
System Pressure	122.8	3	40.93	11.43	3.24	5.29
Exit Orifice Diameter	1,434.74	3	478.25	133.59	3.24	5.29
Interaction	92.9	9	10.32	1.15	2.54	3.78
Error	57.2	16	3.58			
Total	1,707.64	31				

In general, higher nozzle discharge was attained at higher exit orifice diameter, regardless of the system pressure. Similarly, higher nozzle discharge was attained at higher system pressure for all exit orifice diameter tested. The flow rate range (0.8 to 27.1 Lmin^{-1}) resulted in a turn down ratio of 34:1 as the system pressure varied from 175 to 700 kPa.

In order to know exactly how the flow rate is related to the exit orifice diameter, the flow rate versus exit orifice diameter was fit with a linear relationship at each of the four system pressures tested (figure5). Regression lines of the form: $Q = (\text{slope}) \cdot d + \text{intercept}$ were used to describe the flow.

Slopes ($\text{Lmin}^{-1} \text{ mm}^{-1}$), intercepts (Lmm^{-1}), and coefficients of determination (r^2) for four system pressures p values (175 to 700kPa) were;

175KPa : 3.76, - 3.55, 0.9846; 350kPa : 5.388, - 5.125, 0.9831; 525kPa : 7.123, - 7.48, 0.9676
700kPa : 7.38, - 7.63, 0.9648



Fig. 5. Nozzle flow rate vs. exit orifice diameter

Overall sensitivity of the flow rate with exit orifice diameter was $\sim 7.25 \text{ Lmin}^{-1} \text{ mm}^{-1}$. This sensitivity could be altered with different swirl element geometrical parameters, length of swirl diameter and diameter of swirl diameter. The flow rate trend (Fig. 5) was similar to the prediction of equation 21. The prediction indicated flow rate depended mainly on a factor containing three parameters namely: system pressure head (H), the gravitational acceleration both raised to power 0.5, the nozzle exit orifice radius

raised to power 2. The contribution of each parameter to the sum total depended on different values of coefficient of discharge.

3.2 Droplet Penetration Range Test

The results data of the droplet penetration range test are shown in Figure 6. Different droplet penetration range values are shown for a given exit orifice diameter at different system pressures. Droplet penetration and nozzle exit orifice diameter are for system pressures from 175kPa to 700kPa.

Examination of the droplet penetration range versus the nozzle exit orifice diameter indicated a linear relationship (Regression lines) of the form:

$S = (\text{slope}). d + \text{intercept}$ described droplet penetration range. Slopes (m/mm), intercepts (m), and coefficients determination (r^2) for five system pressure (P) values (175 to 700kPa) were:

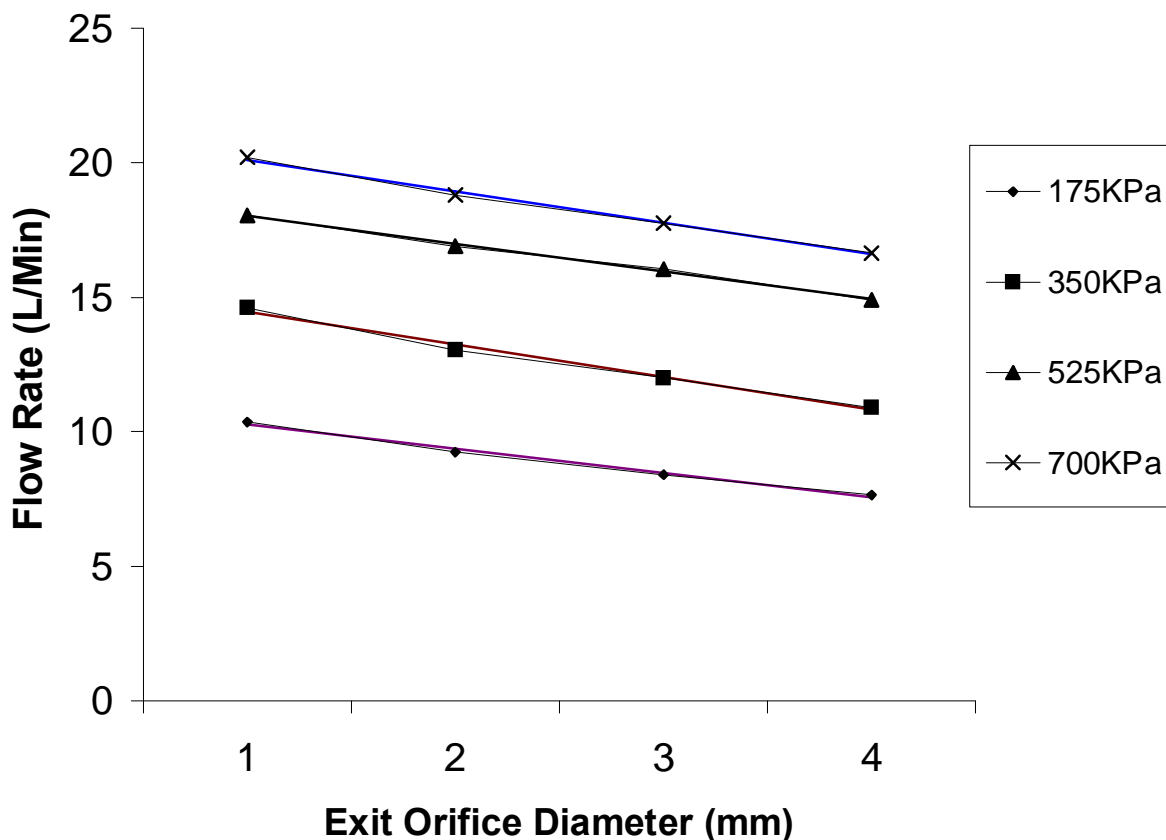


Fig. 6: Droplet penetration range vs. exit orifice diameter

175kPa :-0.898, 11.16, 0.9917; 350Kpa : -1.221, 15.70, 0.9905; 525kPa : -1.023, 19.03, -0.9984;
700kPa : -1.17, 21.28, 0.9956

Measured data of the nozzle penetration range are plotted in figure 6

The analysis of variance of the data is shown in Table 2. Since $F_{0.01, 9, 16} = 3.78$, we conclude that the interaction between the system pressure and the orifice diameters of the prototype nozzle is not significant. Furthermore the fact that $F_{0.05, 3, 16}$ and $F_{0.01, 3, 16} = 5.29$ implies that the main effects of the system pressure and the exit orifice diameter are significant on the droplet penetration range.

An increase in exit orifice diameter at a given system pressure resulted in an overall decrease in droplet penetration range.

Table 2: Analysis of variance of droplet penetration range data.

Source of Variation	Sum of squares	Degrees of Freedom	Mean Square	F Value		
				Calculated	Tabulated	
System Pressure	421.48	3	140.49	125.44	5%	1%
Exit Orifice Diameter	46.66	3	15.55	14.43	3.24	5.29
Interaction	-7.49	9	-0.83	-0.29	2.54	3.78
Error	17.95	16	1.12			
Total	478.61	31				

4. CONCLUSIONS

A prototype swirl chamber nozzle was evaluated for the purpose of determining the relationship between its geometrical dimensions and some selected metering parameters. The nozzle was positioned on a developed test rig and tested for nozzle discharge and droplet penetration range. Specific conclusions were arrived at as follows:

- The nozzle discharge of the prototype (SCN) is significantly affected by both the system pressure and the exit orifice diameter.
- The sensitivity of the flow rate with exit orifice diameter is highest for the 700Kpa system pressure and lowest for the 175Kpa pressure. The different in sensitivity reduces as the system pressure increases.
- The sensitivity of the flow rate with exit orifice diameter reduces with decrease in system pressure.
- The droplet penetration range is significantly affected by both the system pressure and the nozzle exit orifice diameter. The droplet penetration range decreases with increase in exit orifice diameter.
- The droplet penetration range increases with increase in system pressure.
- The limitations of the SCN include insensitivity of the swirl element to system bellows a minimum level of 175Kpa and the inability of the pump utilized to develop pressure above the 700Kpa level future investigations should consider an increased system pressure and the effect of the geometry of the swirl diameter on the metering parameters.
- The turn down ratio of the prototype (SCN) is 34:1.

REFERENCES

- ASAE Standards, 2002. S 327.2. Terminology and definition for agricultural chemical application. 49th Edition. St. Joseph. MI: ASAE.
- EL-Awardy, M.N. 1978. An atomization theory for swirl nozzles. Transactions of the ASAE. 21(1): 70-74.
- Bouse, L.F. 1994. Effect of nozzle type and operation on spray droplet size. Transactions of the ASAE. 37 (5): 1389-1400.
- Boving, P.A. and Winterfeld, R.G. 1980. Testing selected nozzles for deposit efficiency in aerial application of spray. Transactions of the ASAE 23 (1): 36 ó 42.
- Johnson, R. A. (ed) 1999. Probability and statistics for engineers. Fifth edition prentice Hall of India. New Delhi.
- Klenin, N. I., Popov, I. F., and Sakun, V. A. 1985. Agricultural machines. Amerind Publishing Co. Pvt. Ltd.. New Delhi.
- Koo, Y.M. and Kuhlman, D.K. 1993. Theoretical spray performance of swirl ó type nozzles. transactions of the ASAE. 36 (3): 671 ó 678.
- Krishan, P. and Willians, T.H. 1988. Technical note. Spray pattern displacement measurement technique for agricultural nozzles. Transaction of the ASAE. 31(2): 386 ó 389.
- Nawady, A.S. 1976. A method of counting droplets. Journal of Agricultural Engineering Research. 21:211 ó 212.
- Panneton, B. 2002. Geometry and performance of a rotary cup atomizer. Applied Engineering in Agriculture. 18(4) : 435-441.
- Salyani, M. and Fox, R.D. 1999. Evaluation of spray quality by oil ó and water ó sensitive papers. Transactions of ASAE. 42(1): 37 ó 43.
- Shigley, J.E and Mischke, C.R. 1989. Mechanical engineering design Fifth edition McGraw ó Hill Book Company New York.
- Sidahmed, M. M. 1996. A theory for predicting the size and velocity of droplets from pressure Nozzles. Transactions of the ASAE. 39(2):385 ó 391.
- Womac, A. R., Bui, Q. D. 2002. Design and test of a variable ó flow fan nozzle. Transactions of the ASAE. 45(2): 287 ó 295.
- Wang, L., Zhang, N., Slocombe, J. W., Thierstein, G. E., and Kuhlman, D. K. 1995. Experimental analysis of spray distribution pattern uniformity for agricultural nozzles. Applied Engineering in Agriculture. 11(1):51 ó 55.

DETERMINATION OF THE YOUNG'S MODULUS OF ELASTICITY OF MELON SEEDS BY APPLYING THE THEORY OF THIN PLATES UNDER COMPRESSION

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ABSTRACT

The theory of thin plates under compression with large deflections was developed and a formula proposed to determine the Young's modulus of elasticity of melon seeds. Whole melon seeds and the cotyledons were compressed between two flat parallel plates at breadthwise and lengthwise positions until they broke. The compressive forces and the deflections of the seeds and cotyledons were measured. Modulus of elasticity of melon seed and cotyledon were calculated using the formula proposed.

The mean values of the Young's modulus of elasticity from the breadthwise loading tests were 7.2×10^6 and $5.93 \times 10^6 \text{ Nm}^{-2}$ for whole melon seeds and cotyledons, respectively. At the lengthwise loading position with the tip up, the mean values of the modulus of elasticity were 4.0×10^7 and $3.6 \times 10^7 \text{ Nm}^{-2}$ for whole melon seeds and cotyledons, respectively. With the tip of the seeds and cotyledons placed downwards, the mean values of the modulus of elasticity were 4.05×10^7 and $2.7 \times 10^7 \text{ Nm}^{-2}$, respectively.

The modulus of elasticity of melon seeds is higher than that of the cotyledons. The modulus of elasticity of whole melon seed is in the range of 5.5×10^6 to $1.7 \times 10^7 \text{ Nm}^{-2}$ when loaded breadthwise, and 1.1 to $7.1 \times 10^7 \text{ Nm}^{-2}$ when loaded lengthwise. Modulus of elasticity of the cotyledon has a range of 4.2 to $7.7 \times 10^6 \text{ Nm}^{-2}$ when loaded breadthwise and 1.3 to $5.9 \times 10^7 \text{ Nm}^{-2}$ when loaded lengthwise.

KEY WORDS: Modulus of elasticity, melon seeds, cotyledons, thin plates

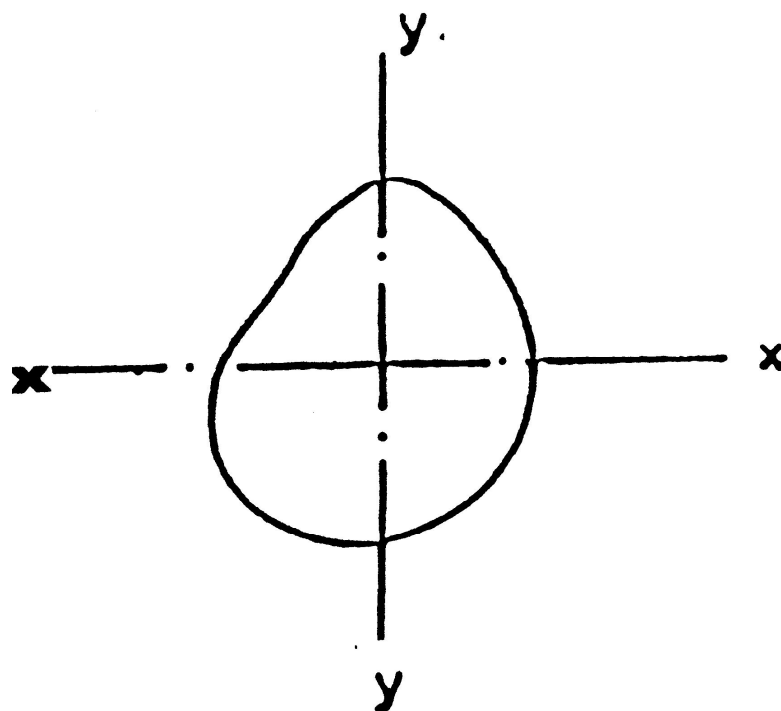
1. INTRODUCTION

The melon seed (*Citrullus vulgaris*) is small, flat and oval containing a white cotyledon in a thin walled shell with a thick ring around the edges (Adinisan and Wilson, 1981). The physical shape (Fig 1) of the melon seed is similar to a thin plate, which is bounded by two surfaces of some curvature, the distance between these surfaces called the thickness. Makanjuola (1972) studied the bending properties of melon seeds placed between two parallel plates under static loading. During loading, the seeds deflected and the shell broke due to bending. On further application of loading, the cotyledon broke. In that study, the height between the plates and the deflections of the seeds when the shell and cotyledon broke were measured. It was found that the amount of subsequent bending which the cotyledon could withstand after the shell had broken was very small.

From experimental evidence, (Lewis, 1987) agricultural products are linear or non-linear visco-elastic in behaviour, that is, exhibiting both elastic and viscous effects under stress. Since no general theory of non-linear visco-elasticity is available to model the rheological behaviour of agricultural products, we are forced to make simplifying assumptions and apply the theories of linear visco-elasticity. The assumptions of linear visco-elasticity can be valid if the stress is kept sufficiently small. The determination of the mechanical properties of grains and fruits by the so called parallel plates method, smooth spherical indenters and cylindrical indenters have been investigated. These studies reported that apparent modulus of elasticity obtained for Seneca wheat grain at 10% MC ranged from 1.1 - $5.7 \times 10^8 \text{ Nm}^{-2}$. Grains glued to

the bottom plate and assuming negligible deformation at the bottom end produced a mean value of modulus of elasticity equal to $1.4 (10^{-2}) \times 10^8 \text{ Nm}^{-2}$ with a standard deviation of 23%, where ν is the Poisson's ratio. Grains left loose on the bottom plate and allowing for deformation at top and bottom of the specimen produced the value $1.6 (10^{-2}) \times 10^8 \text{ Nm}^{-2}$ with a standard deviation of 37%.

The melon seeds were compressed breadthwise and lengthwise (Fig.1) by static loading between two parallel flat plates until the seeds bend and break. The deflection of each seed and the associated forces were measured. It was concluded from earlier studies by Mohsenin (1986) that tests between parallel plates were preferable to other types of tests for fruits because the test procedure is less critical and the results compare more favourably with those predicted by theory. In this study a theory of static loading of thin plates with large deflections has been developed. The formula obtained was then used to determine the Young's modulus of elasticity (E) of melon seeds.



Compression along x-x is breadthwise
Compression along y-y is lengthwise

Figure 1: Bending axes on melon seed flat side

2. THEORY OF THIN PLATES WITH LARGE DEFLECTIONS.

The theory of thin plates with large deflections (Von Karman, 1910; Von Karman et al, 1932; Timoshenko and Goodier, 1951) has the following assumptions (Fig 2):

- (i) The plate is thin and the thickness h is much smaller than the typical plate dimension a , i.e. $h \ll a$.
- (ii) The magnitude of the deflection of the middle surface of the plate w is of the same order as the thickness of the plate, h , but small compared with the typical dimension a , i.e. $w \ll a$.
- (iii) The tangential displacements u, v are infinitesimal. In the strain-displacement relation, only those non-linear terms which depend on $\frac{\partial w}{\partial x}, \frac{\partial w}{\partial y}$ are to be retained. All other non - linear terms are to be neglected.
- (iv) All strain components are small so that Hooke's law holds.
- (v) Traction on surfaces parallel to the middle surface are negligible, and strains vary linearly within the plate thickness.
- (vi) The slope is small everywhere, less than 1, i.e. $\left| \frac{\partial w}{\partial x} \right| \ll 1, \left| \frac{\partial w}{\partial y} \right| \ll 1$

Now consider a flat plate (Dally and Riley, 1978; Doebelin, 1976; Fung, 1965; Roark and Young, 1975; Timoshenko and Goodier, 1951) in a fixed right-handed rectangular Cartesian frame with x, y plane coinciding with the middle surface of the plate in its initial unloaded state and the z axis normal to it. (Fig. 2). The Green's strain tensor of a deformed body in the same rectangular Cartesian co-ordinate system may be written as:

$$E_{ij} = \frac{1}{2} \left[\delta_{\alpha\beta} \frac{\partial x_\alpha}{\partial a_i} \frac{\partial x_\beta}{\partial a_j} - \delta_{ij} \right] \text{-----(1)}$$

$$= \frac{1}{2} \left[\delta_{\alpha\beta} \left(\frac{\partial u_\alpha}{\partial a_i} + \delta_{ij} \right) \left(\frac{\partial x_\beta}{\partial a_j} + \delta_{\beta j} \right) - \delta_{ij} \right]$$

$$= \frac{1}{2} \left[\frac{\partial u_i}{\partial a_j} + \frac{\partial u_j}{\partial a_i} + \frac{\partial u_\alpha}{\partial a_i} \frac{\partial u_\alpha}{\partial a_j} \right] \text{-----(2)}$$

where $\delta_{\alpha\beta}, \delta_{ij}$ are the kronecker data and a point of a body at a certain instant of time is described by the co-ordinates $a_i (i = 1, 2, 3)$. Identifying a_1, a_2, a_3 , with x, y, z in equation (2) leads to:

$$E_{xx} = \frac{\partial u_x}{\partial x} + \frac{1}{2} \left[\left(\frac{\partial x_x}{\partial x} \right)^2 + \left(\frac{\partial u_y}{\partial x} \right)^2 + \left(\frac{\partial u_z}{\partial x} \right)^2 \right] \text{----- (3)}$$

$$E_{yy} = \frac{\partial u_y}{\partial y} + \frac{1}{2} \left[\left(\frac{\partial x_x}{\partial y} \right)^2 + \left(\frac{\partial u_y}{\partial y} \right)^2 + \left(\frac{\partial u_z}{\partial y} \right)^2 \right] \text{----- (4)}$$

$$E_{xy} = \frac{1}{2} \left[\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x} + \frac{\partial u_x}{\partial x} \frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x} \frac{\partial u_y}{\partial y} + \frac{\partial x_z}{\partial x} \frac{\partial u_z}{\partial y} \right] \text{----- (5)}$$

Let the components of the displacement of a particle located initially at (x,y,z) be denoted by u_x, u, u_z . Considering assumption (v),

$$u_x = u(x, y) - z \frac{\partial w}{\partial x} \text{-----} (6)$$

$$u_y = v(x, y) - z \frac{\partial w}{\partial y} \text{-----} (7)$$

$$u_z = w(x, y) \text{-----} (8)$$

where $u(x, y)$, $v(x, y)$ are the tangential displacements of points lying on the middle surface and $w(x, y)$ the vertical deflection of the middle surface of the plate. According to assumption (iii), the higher powers of the derivatives of u and v are negligible in comparison with their first powers, and since $|z| \leq h \leq a$, the only non δ linear terms to be retained in the strain δ displacement relations (3) δ (5) are the squares and products of $\frac{\partial w}{\partial x}, \frac{\partial w}{\partial y}$.

Hence,

$$E_{xx} = \frac{\partial u}{\partial x} - z \frac{\partial^2 w}{\partial x^2} + \frac{1}{2} \left(\frac{\partial w}{\partial x} \right)^2 \text{-----} (9)$$

$$E_{yy} = \frac{\partial v}{\partial y} - z \frac{\partial^2 w}{\partial y^2} + \frac{1}{2} \left(\frac{\partial w}{\partial y} \right)^2 \text{-----} (10)$$

$$E_{xy} = \frac{1}{2} \left[\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} - 2z \frac{\partial^2 w}{\partial x \partial y} + \frac{\partial w}{\partial x} \frac{\partial w}{\partial y} \right] \text{-----} (11)$$

Introducing the Kirchhoff's stress tensor S_{ij} and assume that S_{ij} is related to the Green's strain tensor E_{ij} through Hooke's law (assumption (iv)), hence

$$S_{ij} = \lambda E_{kk} \delta_{ij} + 2GE_{ij} \text{-----} (12)$$

The constant λ and G are Lamé's constants, where

$$\lambda = \frac{ev}{(1+\nu)(1-2\nu)}; \quad G = \frac{E}{2(1+\nu)}$$

E is the Young's modulus of elasticity. The constant ν is the Poisson's ratio. Identifying individual components from (9), (10), (11) and (12) leads to the following:

$$\begin{aligned} S_{xx} &= \frac{E}{1-\nu^2} \left[E_{xx} + \nu E_{yy} \right] \\ &= \frac{E}{(1-\nu^2)} \left[\frac{\partial u}{\partial x} + \nu \frac{\partial v}{\partial y} - z \left(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2} \right) + \frac{1}{2} \left(\frac{\partial w}{\partial x} \right)^2 + \frac{\nu}{2} \left(\frac{\partial w}{\partial y} \right)^2 \right] \text{-----} (13) \end{aligned}$$

$$S_{yy} = \frac{E}{(1-\nu^2)} \left[\frac{\partial v}{\partial y} + \nu \frac{\partial u}{\partial x} - z \left(\frac{\partial^2 w}{\partial y^2} + \nu \frac{\partial^2 w}{\partial x^2} \right) + \frac{1}{2} \left(\frac{\partial w}{\partial y} \right)^2 + \frac{\nu}{2} \left(\frac{\partial w}{\partial x} \right)^2 \right] \text{-----(14)}$$

$$S_{xy} = G \left[\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} - 2z \frac{\partial^2 w}{\partial x \partial y} + \frac{\partial w}{\partial x} \frac{\partial w}{\partial y} \right] \text{-----(15)}$$

Defining F_x , F_y , F_{xy} as stress resultants (forces per unit length) acting over the thickness and integrating lead to:

$$F_x = \int_{-h/2}^{h/2} S_{xx} dz = \frac{Eh}{(1-\nu^2)} \left[\frac{\partial u}{\partial x} + \nu \frac{\partial v}{\partial y} + \frac{1}{2} \left(\frac{\partial w}{\partial x} \right)^2 + \frac{\nu}{2} \left(\frac{\partial w}{\partial y} \right)^2 \right] \text{-----(16)}$$

$$F_y = \int_{-h/2}^{h/2} S_{yy} dz = \frac{Eh}{(1-\nu^2)} \left[\frac{\partial v}{\partial y} + \nu \frac{\partial u}{\partial x} + \frac{1}{2} \left(\frac{\partial w}{\partial y} \right)^2 + \frac{\nu}{2} \left(\frac{\partial w}{\partial x} \right)^2 \right] \text{-----(17)}$$

$$F_{xy} = \int_{-h/2}^{h/2} S_{xy} dz = \left(\frac{1-\nu}{2} \right) \left(\frac{Eh}{1-\nu^2} \right) \left[\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} + \frac{\partial w}{\partial x} \frac{\partial w}{\partial y} \right] \text{-----(18)}$$

Also defining M_x , M_y , M_{xy} , as stress moments (moment per unit length) in the plate and integrating lead to:

$$M_x = \int_{-h/2}^{h/2} S_{xx} z dz = -D \left(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2} \right) \text{-----(19)}$$

$$M_y = \int_{-h/2}^{h/2} S_{yy} z dz = -D \left(\frac{\partial^2 w}{\partial y^2} + \nu \frac{\partial^2 w}{\partial x^2} \right) \text{-----(20)}$$

$$M_{xy} = \int_{-h/2}^{h/2} S_{xy} z dz = -(1-\nu) D \frac{\partial^2 w}{\partial x \partial y} \text{-----(21)}$$

where the quantity

$$D = \frac{Eh}{12(1-\nu^2)} \text{----- (22)}$$

is called the bending (flexural) rigidity of the plate.

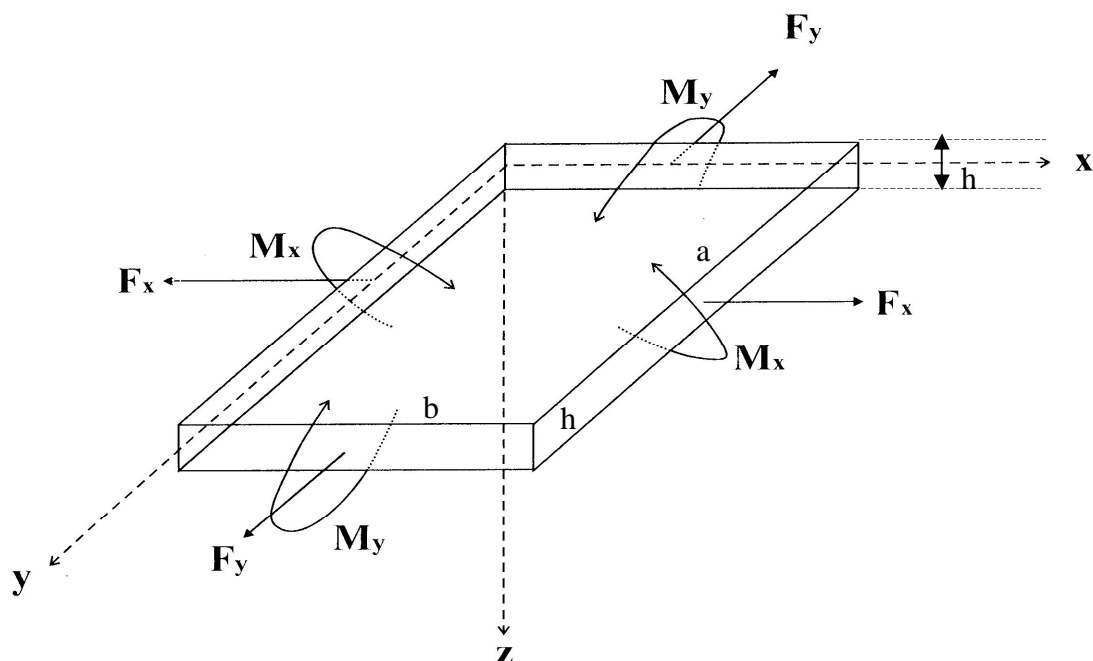


Figure 2: A flat plate in a fixed right-handed rectangular cartesian frame under load

3. MATERIALS AND METHODS

3.1 Sample Preparation:

Melon seeds from a local market in Uyo were sorted out to obtain whole and mature seeds. The moisture content of the seeds were then determined using the hot air convection oven method in accordance with ASAE Standard⁵. Four samples were chosen for the compressive tests: whole seeds, whole cotyledons, seeds with tips cut and cotyledons with tips cut. The length, width and thickness of the samples were measured.

3.2 Compression Test:

The loading was accomplished with a rig (Fig. 3) having two movable parallel horizontal plates. The lower movable plate was advanced by means of a screw and the seed placed in position between the plates. The upper movable plate is hooked to a spring gauge which was hung from a fixed upper plate. To apply the compressive load on the seed, the upper movable plate was advanced down by a screw and the force measured with the spring gauge.

3.3 Procedure:

Thirty seeds and cotyledons picked at random were each placed breadthwise (Fig. 1) between the two movable plates of the rig. The upper fixed plate set initially at zero spring extension was then slowly advanced downwards until the shell broke. The plate was further lowered until the seed broke. The compressive force and the deflections of the seeds when the seeds broke were measured. The tests were

carried out with the seeds and cotyledons placed lengthwise (Fig. 1) with the tips up and down. From the data obtained above, the Young's modulus of elasticity (E) of melon seeds was determined.

3.4 Calculation of the Young's Modulus of Elasticity (E) of Samples under Static Loading:

From longitudinal loading, the bending moment $M = \text{Force} \times \text{deflection} = Fw$ ----- (23)

For breadthwise loading, the stress moment per unit length on the edges parallel to the y axis is, (equ. 19).

$$M_x = -D \left(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2} \right)$$

Assuming $\frac{\partial^2 w}{\partial y^2} = 0$ and simplifying

$$\frac{\partial^2 w}{\partial x^2} = -\frac{M}{ID}$$

where l is the length of the sample in mm between the plates.

Integrating and substituting $\frac{\partial w}{\partial x} = 0$, $x = 0$, leads to

$$\frac{\partial w}{\partial x} = -\frac{Mx}{ID} \text{-----(24)}$$

where x is the height of the sample in mm between the plates. Substituting eq. (24) into eq. (16), the stress resultant, force per unit length (F_x) parallel to the x axis is

$$\begin{aligned} F_x &= \frac{F}{l} \left(\frac{Eh}{1-\nu^2} \right) \left[\frac{\partial u}{\partial x} + \nu \frac{\partial v}{\partial y} + \frac{1}{2} \left(\frac{\partial w}{\partial x} \right)^2 + \frac{\nu}{2} \left(\frac{\partial w}{\partial y} \right)^2 \right] \\ &= \frac{Eh}{(1-\nu^2)} \left[\frac{1}{2} \frac{M^2 x^2}{D^2 l^2} \right] \text{ where } \frac{\partial u}{\partial x}, \frac{\partial v}{\partial y}, \frac{\partial w}{\partial y} = 0 \end{aligned}$$

Substituting for M from eq. (23) and D from eq. (22) lead to

$$\frac{F}{l} = \frac{Eh}{(1-\nu^2)} \left[\frac{1}{2}, \frac{F^2 w^2 x^2}{E^2 h^6 l^2} 12^2 (1-\nu^2)^2 \right]$$

Simplifying and obtaining E, Young's modulus of elasticity Nm^{-2}

$$E = \frac{72 F w^2 x^2}{h^5 l} (1-\nu^2) \times 10^3 \text{----- (25)}$$

Where: F is the static compressive force in Newton; w is the deflection of the middle surface of the sample in mm; h is the thickness of the sample in mm and ν is the Poisson's ratio (0.3).

4. RESULTS AND DISCUSSION

The moisture content of the seeds during the experiment was 6.3 (percent, w. b). The computed values of the Young's modulus of elasticity (E) of melon seeds are shown in Table 1. In the breadthwise loading, the mean value is $7.2 \times 10^6 \text{ Nm}^{-2}$ and ranged from 5.5 to $9.6 \times 10^6 \text{ Nm}^{-2}$. At the lengthwise loading positions, the mean values were 4.0 and $4.05 \times 10^7 \text{ Nm}^{-2}$ with the tips up and down respectively. The values ranged from 2.0 to $7.1 \times 10^7 \text{ Nm}^{-2}$ and 2.4 to $6.0 \times 10^7 \text{ Nm}^{-2}$ respectively. The values obtained at lengthwise loading positions were about six times greater than at breadthwise loading.

Table 1. The values of the modulus of elasticity of melon seeds.

Method of Loading		Seed dimensions			Force F, N x 10^{-3}	Modulus of elasticity, E x 10^6 Nm^{-2}
		Length a, mm	Width b, mm	Thickness h, mm		
Breadthwise	Range:.	12.35- 15.45	7.19 \pm 9.9	1.3 \pm 1.9	11.25 \pm 16.25	5.5 \pm 9.6
	Mean	13.75	8.69	1.73	13.8	7.2
	std. dev	0.92	0.71	0.18	1.17	1.61
Lengthwise (tip up)	Range:.	12.25- 16.15	7.2 - 9.4	1.3 \pm 1.9	12.5 \pm 25.0	20 \pm 71
	Mean	13.7	8.32	1.7	19.8	40
	std. dev	0.79	0.67	0.21	3.59	12.9
Lengthwise (tip down)	Range:.	12.75- 15.2	7.25 -9.65	1.3 \pm 1.9	13.5 \pm 22.5	24 \pm 60
	Mean	13.94	8.5	1.75	19.55	40.5
	std. dev	0.79	0.58	0.18	2.87	10.8

Table 2. shows the values for seeds with the tips cut. The mean value is $1.1 \times 10^7 \text{ Nm}^{-2}$ for seeds loaded breadthwise. The values ranged from 0.6 to $1.7 \times 10^7 \text{ Nm}^{-2}$. At the lengthwise loading positions, the mean values were 3.5 and $2.13 \times 10^7 \text{ Nm}^{-2}$ with the cut end placed up and down respectively.

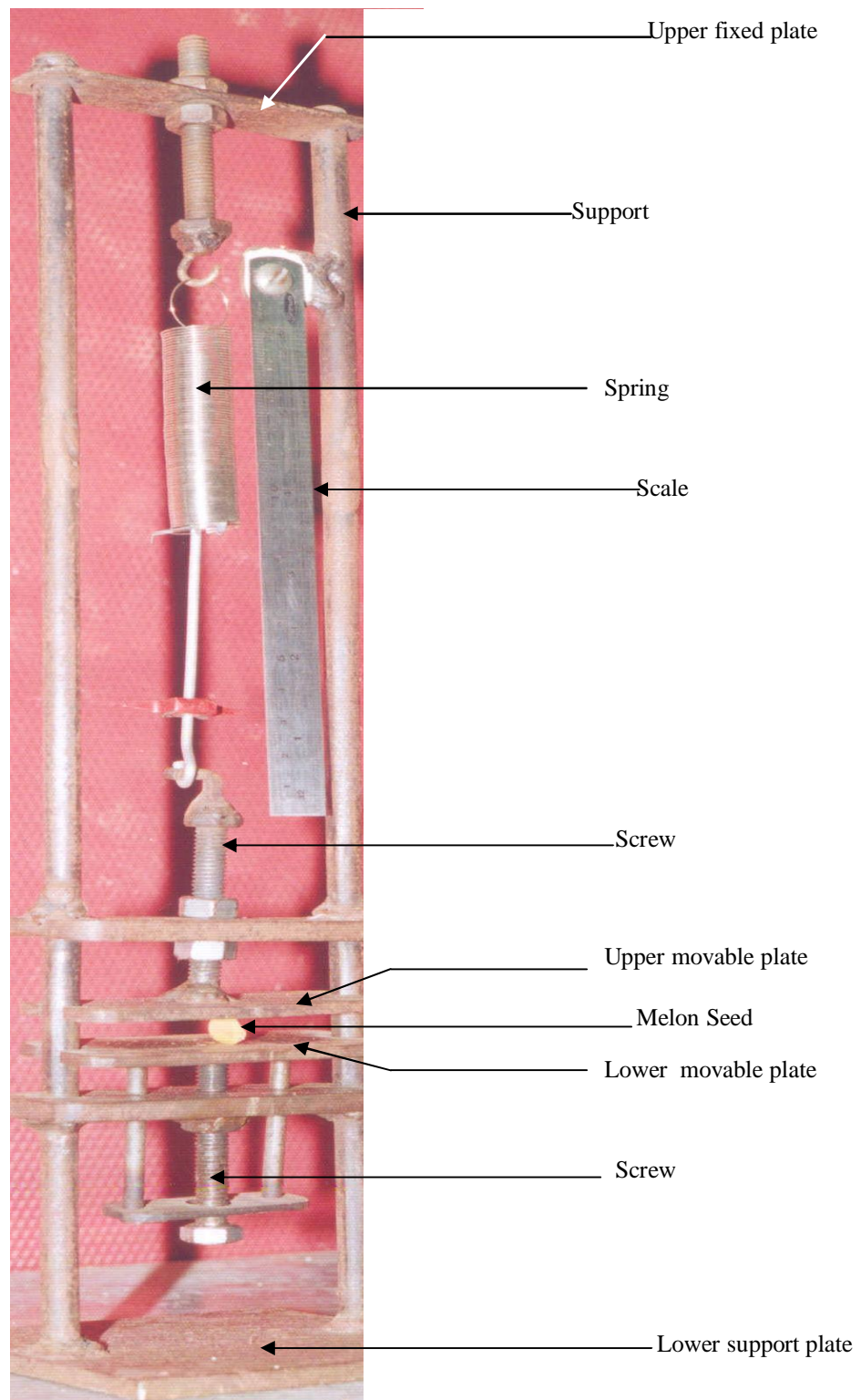


Figure 3: The Compression rig

Table 2: The values of the modulus of elasticity of melon seeds with the tips cut

Method of Loading		Seed dimensions			Force F, N x 10 ⁻³	Modulus of elasticity, E Nm ⁻²
		Length a, mm	Width b, mm	Thickness h, mm		
Breadthwise	Range:..	10.3 6 13.36	8.77-11.91	1.3 6 1.9	11.25 6 15.0	0.6 6 1.7 x 10 ⁷
	Mean	11.78	10.06	1.62	13.37	1.1 x 10 ⁷
	std. dev	0.77	0.87	0.14	1.0	0.37 x 10 ⁷
Lengthwise (tip up)	Range:..	11.04 -13.75	8.59 6	1.5 -1.75	13.75 6 18.8	2.3 - 4.8 x 10 ⁷
	Mean	12.49	10.89	1.57	16.6	3.5 x 10 ⁷
	std. dev	0.84	9.72	0.08	1.2	0.84 x 10 ⁷
Lengthwise (tip down)	Range:..	9.69 6 12.55	8.77-11.95	1.5-1.78	10.0 6 16.0	1.1 6 3.0 x 10 ⁷
	Mean	11.33	9.95	1.61	13.6	2.13 x 10 ⁷
	std. dev	0.75	0.91	0.09	1.56	0.62 x 10 ⁷

A summary of the values for cotyledons are shown in Table 3. For breadthwise loading, the mean value is $5.93 \times 10^6 \text{ Nm}^{-2}$ and ranged from 4.2 to $7.4 \times 10^6 \text{ Nm}^{-2}$. At the lengthwise loading positions, the mean values are 3.6 and $2.7 \times 10^7 \text{ Nm}^{-2}$ for the tip up and down respectively. The values ranged from 2.4 to 5.9×10^7 and 1.3 to $5.5 \times 10^7 \text{ Nm}^{-2}$.

Table 3: The values of the modulus of elasticity of cotyledons.

Method of Loading		Cotyledons dimensions			Force F, N x 10 ⁻³	Modulus of elasticity, E Nm ⁻²
		Length a, mm	Width b, mm	Thickness h, mm		
Breadthwise	Range:..	10.65 6 13.77	7.05-8.45	1.3 6 1.9	6.25 6 11.25	4.2 6 7.4 x 10 ⁶
	Mean	12.60	8.11	1.65	8.56	5.93 x 10 ⁶
	std. dev	0.50	0.43	0.20	1.64	1.34 x 10 ⁶
Lengthwise (tip up)	Range:..	10.65 6 13.85	7.1 6 8.5	1.3 6 1.9	11.25 6 15.0	2.4 6 5.9x 10 ⁷
	Mean	12.93	7.9	1.55	13.25	3.6 x 10 ⁷
	std. dev	0.49	0.41	0.28	1.24	1.33x 10 ⁷
Lengthwise (tip down)	Range:..	11.25 6 13.9	6.5 6 8.9	1.3 6 1.9	6.25 6 12.5	1.36 5.5 x 10 ⁷
	Mean	12.9	7.8	1.6	10.5	2.7 x 10 ⁷
	std. dev	0.58	0.58	0.23	1.73	1.1 x 10 ⁷

In Table 4, the summary for cotyledons with cut tips are shown. The mean value is $6.11 \times 10^6 \text{ Nm}^{-2}$ for breadthwise loading, ranging from 4.4 to $7.7 \times 10^6 \text{ Nm}^{-2}$. At the lengthwise loading positions, the mean values are 2.1 and $2.09 \times 10^7 \text{ Nm}^{-2}$ for the cut ends up and down respectively. The values range from 1.7 to 3.8×10^7 and 1.5 to $2.8 \times 10^7 \text{ Nm}^{-2}$.

Table 4: The values of the modulus of elasticity of cotyledons with tips cut

Method of Loading		Cotyledons dimensions			Force F, N x 10 ⁻³	Modulus of elasticity, E Nm ⁻²
		Length a, mm	Width b, mm	Thickness h, mm		
Breadthwise	Range:..	10.3- 12.50	7.30 6 8.50	1.2 6 1.9	6.25 6 10.0	4.4 6 7.7x 10 ⁶
	Mean	11.1	7.90	1.48	8.0	6.11 x 10 ⁶
	std. dev	0.58	0.36	0.16	1.24	0.99x 10 ⁶

Lengthwise (tip up)	Range:.	10.1 ó 12.9	7.6 ó 8.9	1.35 ó 1.9	7.5 ó 12.25.	1.7 ó 3.8x 10 ⁷
	Mean	11.7	8.0	1.46	9.5	2.1 x 10 ⁷
	std. dev	0.78	0.26	0.14	1.72	0.4x 10 ⁷
Lengthwise (tip down)	Range:.	10.2 ó 12.33	7.30 ó 8.53	1.33 ó 1.88	6.25 ó 12.5	1.5 ó 2.8 x 10 ⁷
	Mean	11.00	7.85	1.52	9.3	2.09 x 10 ⁷
	std. dev	0.5	0.36	0.14	1.7	0.45 x 10 ⁷

The results show in all cases that the Young's modulus of elasticity of whole melon seeds (Tables 1 & 2) is higher than that of the cotyledons (Tables 3 & 4). The cotyledons are without their shell and the shell provides stiffness to the melon seeds. This explains the higher values of the modulus of whole melon seed. This agrees with other findings (Makanjuola, 1972) that under static loading between parallel plates, melon seeds bend along both directions and the amount of subsequent bending which the cotyledon can withstand after the shell had broken was very small.

The Young's modulus of elasticity of melon seeds and cotyledons in all breadthwise loading positions are significantly lower than when the seeds and cotyledons were placed in the lengthwise positions. This shows that the average stiffness of the seed bending laterally is higher than the stiffness of the seed bending longitudinally. The thick ring around the edges of the seed also increases the stiffness of the seeds. Under certain circumstances the maximum load a member will sustain is determined not by the strength of the material but by the stiffness of the member (Timoshenko and Goodier, 1951). This condition arises when the load produces a bending moment that is proportional to the corresponding deformation.

Melon seeds and cotyledons also show anisotropy, exhibiting different mechanical properties in two directions under load. This characteristic which conforms with findings on other agricultural materials have been shown to be, carrot 2 to 4 x 10⁷ Nm⁻², peas 1.2 to 3 x 10⁷ Nm⁻², potatoes 0.6 to 1.4 x 10⁷ Nm⁻², apples 0.6 to 1.4 x 10⁷ Nm⁻² and banana 0.08 to 0.3 x 10⁷ Nm⁻² (Lewis, 1987).

The cutting of the tips of seeds and cotyledons was found to affect the modulus of elasticity of melon seeds. The values increased slightly at breadthwise loading positions but decreased in value at lengthwise loading positions. It is assumed that without the tip, the samples exhibited less stiffness under lengthwise loading. Some of the seeds and cotyledons were found to deform or be crushed under load before bending takes place.

5. CONCLUSIONS

The following conclusions can be drawn from the determination of the Young's modulus of elasticity of melon seeds and cotyledons:

1. The modulus of elasticity E of whole melon seeds is higher than that of the cotyledons.
2. The modulus of elasticity of whole melon seeds is in the range of 5.5 x 10⁶ to 1.7 x 10⁷ Nm⁻² when loaded breadthwise and 1.1 to 7.1 x 10⁷ Nm⁻² when loaded lengthwise.
3. The modulus of elasticity of cotyledons is in the range of 4.2 to 7.7 x 10⁶ Nm⁻² when loaded breadthwise and 1.3 to 5.9 x 10⁷ Nm⁻² when loaded lengthwise.
4. Cutting the tips of the seeds and cotyledons affected the modulus of elasticity. The values increased slightly at breadthwise loading positions but decreased at lengthwise loading positions.

REFERENCES

- Adeniran, M. O. and G. F. Wilson. 1981. Seed type classification of egusi melon in Nigeria. Paper presented at the 6th African Horticultural Symposium, University of Ibadan, 9th ó 25th, July.
- Ajibola, O. O., S. E. Eniyemo, O. O. Fasina, and, K. A. Adeeko, 1990. Mechanical expression of oil from melon seed. *Journal of Agricultural Engineering Research* 45: 31 ó 45.
- Akpan, N. A. 2004. Determination of the force required to crack melon seed shell by static loading at different moisture content. B. Eng. Thesis, University of Uyo, Uyo, Nigeria.
- Akubuo, C. O. and E. U. Odigboh. 1999. Egusi fruit coring machine *Journal of Agricultural Engineering Research* 74:121-126.
- ASAE 1982. American Society of Agricultural Engineers, ASAE Standard S.352. *Agricultural Engineers Year Book* St. Joseph, Michigan pp.345.
- Baryeh, A. E. and B. K. Mangope. 2003. Some physical properties of QP ó 38 variety of pigeon pea. *Journal of Food Engineering* 56 (1): 59 ó 65.
- Baumeister, T., Avallone, E. A. and Baumeister III, T. 1978. *Shigley's Standard handbook for mechanical engineering*. 8th ed., McGraw-Hill Book Company, New York,.
- Dally, J. W. and Riley, W. F. 1978. *Experimental stress analysis*, 2nd ed., McGraw-Hill Book Company, New York.
- Deshpande, S. D. , S. Bal, and T. P. Ojha, 1993 Physical properties of soyabean. *Journal of Agricultural Engineering Research* 39: 259 ó 268.
- Doebelin, E. O. 1976. *Measurement Systems. Application and design*, rev. ed., McGraw-Hill Book Company, New York.
- Egbuta, U. and C. G. Uyah, 2003. Design, fabrication and testing of the melon impact sheller. B. Eng. Thesis, of the University of Uyo, Uyo, Nigeria.
- Fung, Y. C. 1965. *Foundations of solid mechanics*. New Jersey: Pentice-Hall, Inc, Englewood Cliffs.
- Gupta, R. K. and S. K. Das. 1997. Physical properties of sunflower seeds. *Journal of Agricultural Engineering Research* 66: 1 ó 8.
- Isiaka, M., A. M. I. Elokere and T. A. Oyedele, 2006. Determination of physical properties of melon seeds. In *Proc. NIAE Conference*, Zaria, Nigeria, 6th ó 10th November.
- Juvinall, R. C. 1967. *Stress, Strain and strength*. New York, McGraw-Hill Book Company.
- Lewis, M. J. 1987. *Physical properties of foods and food processing systems*. England: Ellis Horwood Ltd, Chichester.
- Makanjuola, G. A. 1972. A study of some of the physical properties of melon seeds. *Journal of Agricultural Engineering Research* 17 (1), 128 ó 137.
- McLean, W. G. and E. W. Nelson. 1997. *Schaum's outline of engineering mechanics ó static and dynamics*. 2nd edition. New York: McGraw Hill Book Company.
- Mohsenin, N. N. 1986. *Physical properties of plant and animal materials*, Vol. 1 New York: Gordon and Breach Science Publisher, New York.
- Montgomery, D. C. and G.C. Runger. 1994. *Applied statistics and probability for engineers*. New York: John Wiley and Sons, Inc.
- Nwosu, R. C. 1988. Engineering properties of egusi fruit and the design of egusi seeds extraction equipment. B. Eng Project Report, Department of Agricultural Engineering, University of Nigeria.
- Obot, V. W. 2005. Determination of the force required to break melon seed in static loading. B. Eng. Thesis, of the University of Uyo, Uyo, Nigeria.
- Odigboh, E. U. 1979. Impact egusi shelling machine. *Transactions of the ASAE* 22(5): 1264 ó 1269.
- Okokon, F. B., E. Ekpenyong, and A. U. Ukpoho, 2005. A study of the shelling characteristics of melon seeds in a factorial experimental design. *Journal of Food, Agriculture and Environment*, Finland. Vol. 3 (1): 110-114.
- Oloko, S. A., B. J. Agun and A. A. Jimoh. 2002. Design and Fabrication of melon washing machine. *World Journal of Biotechnology*. 3(2): 481-486.

- Roark, R. J. and Young, W. C. 1975. Formulas for stress and strain, 5th ed., McGraw-Hill Book Company, New York.
- Timoshenko, S. and Goodier, L. N. 1951. Theory of elasticity, McGraw-Hill Book Company, New York.
- von Kármán, T., 1910. Festigkeitsprobleme im maschinenbau, Encyklopadie der Mathematischen Wissenschaften, 4(4); 349.
- von Kármán, T., Sechler, E. E. and Donell, L. H. 1932. The strength of thin plates in compression, Trans ASME. 54 (2): 53.

EFFECTS OF MOISTURE CONTENT ON SOME FRICTIONAL PROPERTIES OF *LABLAB PURPUREUS* SEED

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ABSTRACT

The effect of moisture content on the frictional properties of two varieties of *Lablab* (Rongai and Highworth) seed was determined in the moisture range of 9.65 to 28.95% wet basis (wb) for Rongai and 10.2 to 22.56% wet basis (wb) for Highworth. The frictional properties investigated were angle of repose, coefficient and angle of internal friction and kinetic coefficient of friction. The angle of repose increased from 28.39° to 33.82° for Rongai variety and 24.93° to 35.57° for Highworth *lablab* seed. The coefficient of internal friction of Rongai variety increased from 0.61 to 0.83 while that of Highworth *lablab* seed increased from 0.55 to 0.86 within the above moisture range. The angle of internal friction of Rongai seed increased from 31.88° , 39.69° while that of Highworth seed 28.81° to 40.70° within the moisture range. The kinetic coefficient of friction (COF) ranged from 0.30 (plywood) to 0.57 (mild steel and plywood) for Highworth while Rongai *lablab* seed ranged from 0.37 (Aluminum, galvanized steel and plywood) within the moisture range considered. These properties are useful in the design of planting, harvesting, processing, handling and storage equipment.

KEYWORDS: Frictional properties, *Lablab*, moisture content, seed,

1. INTRODUCTION

The Hyacinth bean (*Dolichos lablab*, syn. *Lablab purpureus*), also called Indian bean and Egyptian bean, a plant of the family fabaceae is a specie of bean widespread as a food crop throughout the tropics, especially in Africa. It is also grown as forage and as an ornamental plant (Wikipedia, 2001).

Lablab purpureus is a dual-purpose legume crop that is rapidly gaining acceptance by agro pastoral farmers in Northern Nigeria. It is drought resistance and is usually sown after the normal cropping season, thereby acting as a buffer crop for ruminant feeding during the dry season (Adu, *et al.*, 1992). In addition to the Research Centers where the crops are grown, *lablab* is produced on a small scale level by agro-pastoralist farmers in Jigawa, Kano, Zamfara and Kaduna States (Bawa, 2003). It is easy to cultivate and it remains green far into the dry season. It is fairly high yielding (seed yield of 870 to 1170 kg/ha) and the seeds have crude protein content ranging from 22 to 29 per cent (Kay, 1979). *Lablab* seeds have low human preference for food and unlike soybean and groundnut cake, their value in livestock feeding has not been fully investigated (Bawa, 2003).

Frictional properties are important in predicting the lateral pressure on a retaining wall in storage bins or design of bins and hoppers for gravity flow. The coefficient and angle of internal friction have applications in problems of flow of bulk granular materials encountered in the design of gravity and forced flow equipment (Irtwange and Igbeka, 2002). The friction of fruits and vegetables against machine parts is one of the main causes of mechanical injuries during handling (Singh, *et. al.*, 2004). Knowledge

of the coefficient of friction (COF) is therefore important in the design of production and handling equipment and storage structures.

The frictional properties are useful for design purposes for most seeds and grains (Potter and Doyle, 1992). The theoretical performance of machines and mechanisms cannot be adequately designed without knowledge of the frictional properties of the material (Irtwange and Igbeka, 2002). Therefore the need to explore the frictional properties of *lablab* seed cannot be overemphasized. The objective of this study is to determine the effect of moisture content on the frictional properties of *lablab* seed.

2. MATERIALS AND METHODS

2.1 Samples

Samples of 3.5 kg each of two varieties of *lablab* seeds, Rongai (White, w) and Highworth (Black, b) were obtained from the National Animal Production Research Institute, (NAPRI), Shika ó Zaria, Nigeria. The seeds were manually cleaned by winnowing in the wind and hand sorted to eliminate dirt, stones, immature seeds and other foreign materials. Different moisture levels were obtained by soaking different bulk samples of *lablab* seeds in calculated quantity of clean water, followed by spreading out in thin layer to dry in natural air in the room for about eight hours. The amount of cleaned water added was calculated using the relationship given by Sacilik, *et al.*, (2003) quoted by Isik (2007):

$$Q = \frac{W_i(M_f - M_i)}{100 - M_f} \quad \text{í í í í í í í í í í í í í í .. 1}$$

Where Q is the amount of cleaned water added, g; W_i is the initial mass of sample, g; M_i is the initial moisture content of sample, % wb; and M_f is the final moisture content of sample, % wb. The samples were sealed in separate polyethylene bags and kept in a Thermo cool (T200) refrigerator at 5°C until were needed to allow the moisture to equilibrate. The moisture contents in the range of 10.20 % wb to 22.56% wb for Highworth *lablab* seeds and 9.65 to 28.95 % wb for Rongai *lablab* seeds respectively were used for the experiments. All measurements were made at room temperatures between 27-30°C.

2.2 Moisture Content

The moisture content of whole seeds was determined using the procedure detailed by Henderson, *et al.*, (1997). Five grams of seed samples from each variety were oven dried at 130 °C for 24 hours (ASAE 2003). The weight loss of the samples was recorded and the moisture in percentage determined. This was replicated three times. The average moisture content was calculated using the relationship:

$$MC_{wb} \% = \frac{W_i - W_d}{W_i} \cdot 100 \quad \text{í í í í í í í í í í í í í í 2}$$

Where MC_{wb} is moisture content, wet basis, %; W_i is initial mass of sample, kg; W_d is dried mass of sample, kg.

2.3 Angle of Repose

The angle of repose was determined by constructing an open box 15.6 x 5.8 x 13 cm³ made of plastic glass which is divided into two compartments 4.4 x 13 x 5.8 cm³ and 10.7 x 13 x 5.8 cm³ by a slidable wedge. The small compartment was filled up to the top and then the slidable wedge was slowly lifted, thus resulting in

a triangular shape of the sample material. By measuring the base and height of the triangle, angle of repose was calculated as:

$$\phi_r = \tan^{-1} \left(\frac{H_g}{B} \right) \quad \dots 3$$

Where ϕ_r is angle of repose, degrees; H_g is height of grain in the plastic glass, cm and B is base of grain forming the angle, cm.

The above procedure was repeated three times and average angle of repose calculated at each moisture content level.

2.4 Coefficient and Angle of Internal Friction

The coefficient of internal friction is the friction of grain against grain and was measured with the set up shown in Fig. 1. In this experiment, a guide plastic frame of size (11 x 9.2 x 2.5) cm³ was placed under a cell of size (6.4 x 8.2 x 2.5) cm³. The method explained by Stepanoff (1969) as published by Irtwange and Igbeka (2002) was used. The guide plastic frame and the cell were filled with the sample material. The cell was tied with the cord passing over a pulley attached to the weight. The weights (W_2) were placed on a wire attached to the cord to cause the cell to just slide. Next, the cell was emptied and weights (W_1) to initiate sliding over the guide frame were noted. The coefficient of internal friction was calculated as:

$$\mu_i = \frac{W_2 - W_1}{W} \quad \dots 4$$

Where μ_i is coefficient of internal friction, W_1 is weight to cause sliding of the cell when empty, g; W_2 is weight to cause sliding of the cell filled with sample material, g and W is weight due to sample material in the cell, g.

While angle of internal friction (for free flowing solids) was calculated as:

$$\phi_i = \tan^{-1} \mu_i \quad \dots 5$$

Three replications were taken for each sample.

2.5 Kinetic Coefficient of Friction on Material Surfaces

The kinetic coefficient of friction on material surfaces (plywood, P, mild steel, M, galvanized sheet metal, G and aluminum, A) was measured using a set up similar to Fig. 1, except that changeable surface was provided instead of a grain bed (Fig. 2). The method as explained by Stepanoff (1969) as published by Irtwange and Igbeka (2002) was used. The coefficient of friction on material surfaces was calculated as the ratio of limiting force to the corresponding normal pressure:

$$\mu_e = \frac{W_2 - W_1}{W} \quad \dots 6$$

Where μ_e is coefficient of kinetic friction, W_1 is weight to cause sliding of the cell when empty, g; W_2 is weight to cause sliding of the cell filled with sample material, g and W is weight due to the sample material in the cell, g.

Three replications were taken for each sample.

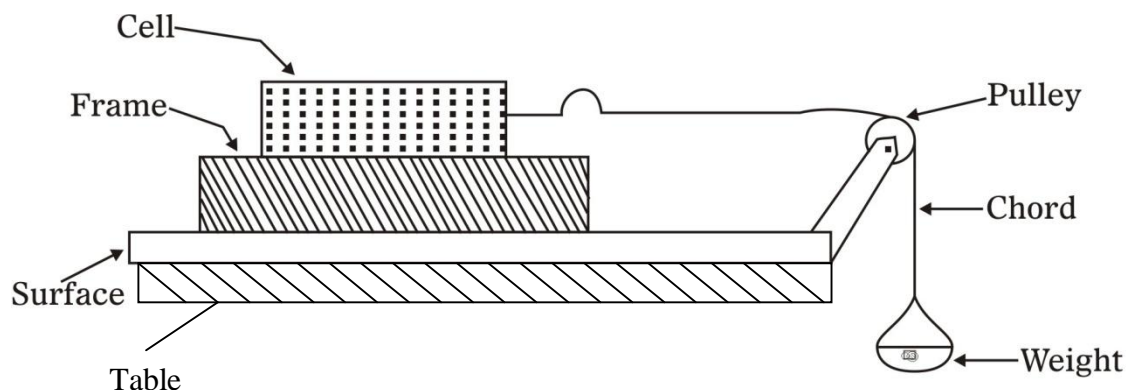


Fig. 1. Set-up used for determination of coefficient of internal friction

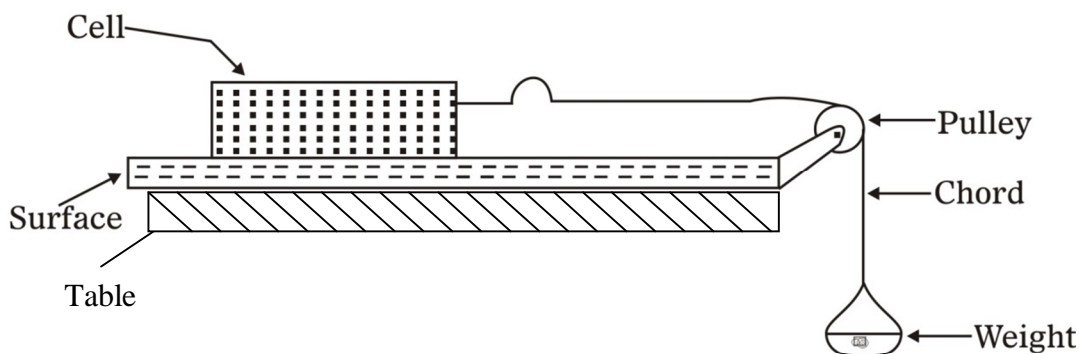


Fig. 2. Set-up used for determination of kinetic coefficient of (external) friction

2.6 Statistical Analysis

Data collected were analyzed using General Linear Model (GLM) procedure of Statistical Analysis System (SAS, 1989) was used to analyze the data.

3. RESULTS AND DISCUSSION

3.1 Angle of Repose

The angle of repose increased with increase in moisture content for the Rongai and Highworth varieties of *lablab* seeds (Table 1). The angle of repose increased from 28.39° to 33.82° for Rongai and 24.93° to 35.57° for Highworth respectively. At higher moisture contents, the *lablab* seeds were sticky thereby increasing its adhesiveness. The adhesive force played an important role in increasing the values of the angle of repose with moisture content. The effect of moisture content was highly significant ($P \leq 0.01$) on the angle of repose.

3.2 Coefficient and Angle of Internal Friction

Coefficient of internal friction and angles of internal friction data for the Rongai and Highworth varieties of *lablab* seeds is given in Table 1. The coefficient of internal friction of Rongai increased from 0.61 to 0.83 while that of Highworth *lablab* increased from 0.55 to 0.86 within the above moisture range. The angle of internal friction of Rongai increased from 31.88°, 39.69° while that of Highworth 28.81° to 40.70° within the moisture range.

The regression equations in the moisture content range of 9.65 to 28.95% are presented in Table 2. These properties were positively correlated with high R^2 values (in the moisture content range of 9.65 to 28.95%) as shown by the regression analysis in Table 2. From this study, it is clearly seen that coefficient of internal friction which is the friction of ðgrain against grainö and the corresponding angle increase with increase in moisture content probably due to the fact that adhesive interactions and surface tension effects of the particles increase with increase in moisture content. The angle of internal friction is crucial in calculating hopper side wall slope angle (Irtwange and Igbeke, 2002).

3.3 Coefficient of Kinetic Friction on Material Surfaces

Table 1 also gives the kinetic coefficient of friction on plywood mild steel, galvanized steel metal and aluminum for Rongai and Highworth varieties of *lablab* seeds and the regression equations are presented in Table 2. From the results, it can be observed that kinetic coefficient of friction on material surface increases with increase in moisture content in all the material surfaces used (plywood, mild steel, galvanized sheet metal and aluminum).

Regression analyses (Figs. 3 - 8) showed a linear relationship between coefficient of friction and moisture content for all surfaces as shown by their high R^2 values for the varieties under study. These agree with the earlier work of Irvine, *et al.*, (1992), which published that for most seed types (wheat, linseed, fababeans, and Eston lentils) increasing moisture content resulted in increased coefficient of friction.

The kinetic coefficient of friction (COF) ranged from 0.30(plywood) to 0.57(mild steel and plywood) for Highworth while Rongai *lablab* seed ranged from 0.37 (Aluminum, galvanized steel and plywood) within the moisture range considered. It has to do probably with the degree of surface roughness of these materials. Dutta, *et al.*, (1988) found that coefficient of friction varies from surface to surface and from grain seeds that he tested, the coefficient for all material surfaces used (corrugated steel not inclusive) was maximum with respect to plywood. Irvine, *et al.*, (1992) published that corrugated steel has higher values than plywood for flaxseed, lentils and fababeans that he tested.

Table 1. Coefficient and angle of internal friction and kinetic coefficient of friction on material surfaces of *lablab* seeds

S/N	Lablab seed varieties	Moisture Content (% wb)	Angle of repose*	Coefficient of internal friction*	Angle of internal friction (degrees)*	Kinetic Coefficient of friction*			
						Plywood	Mild steel	Galv. sheet metal	Aluminum
1.	Rongai (white)	9.65	28.39	0.61	31.88	0.37	0.42	0.37	0.37
		21.07	29.09	0.78	37.95	0.38	0.45	0.42	0.37
		23.85	29.15	0.78	37.95	0.47	0.55	0.42	0.42
		28.95	33.82	0.83	39.69	0.55	0.60	0.50	0.50
2.	Highworth (Black)	10.20	24.93	0.55	28.81	0.30	0.38	0.30	0.30
		13.43	24.95	0.59	30.54	0.32	0.41	0.41	0.32

15.73	29.06	0.61	31.38	0.42	0.51	0.42	0.42
22.56	35.57	0.86	40.70	0.57	0.57	0.52	0.52

*Mean of 3 replicates.

Table 2. Regression equations for frictional properties for lablab seed in the moisture range of 9 to 30%

Property	Lablab seed varieties		Highworth	
	Rongai Linear regression Equation.	R ²	Linear regression Equation.	R ²
Coeff. of internal friction	0.012x + 0.51	0.96	0.026x + 0.25	0.93
Angle of internal friction	0.411x + 28.29	0.96	0.988x + 17.56	0.94
Coeff. of external friction				
Plywood	0.009x + 0.26	0.72	0.023x + 0.05	0.96
Mild steel	0.009x + 0.31	0.80	0.016x + 0.22	0.91
Galvanized sheet metal	0.006x + 0.30	0.84	0.017x + 0.16	0.93
Aluminum	0.006x + 0.29	0.64	0.019x + 0.10	0.94

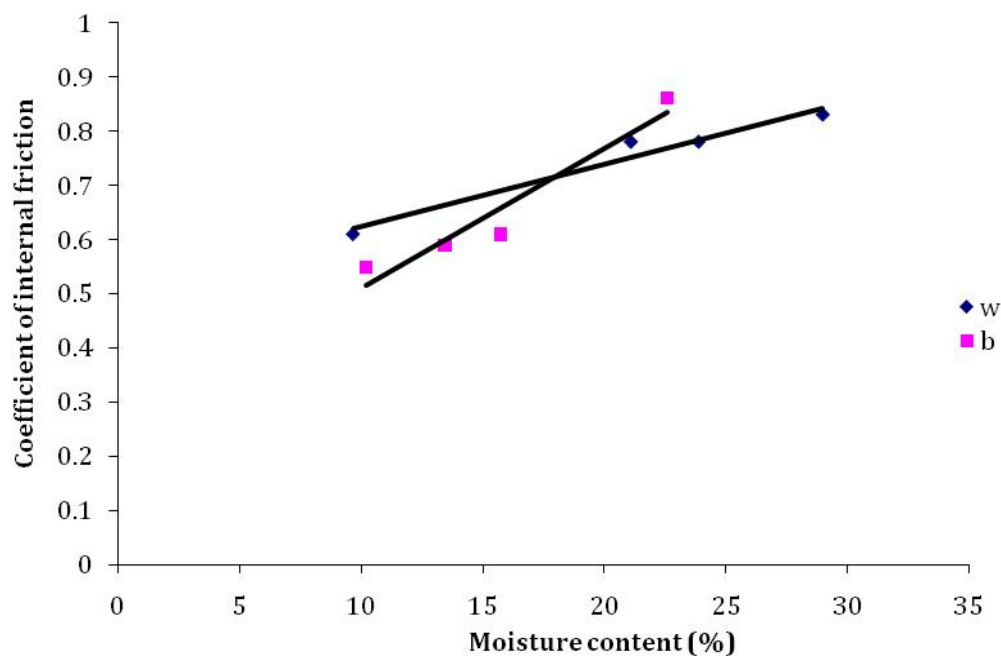


Fig. 3: Effect of moisture content on the coefficient of internal friction.

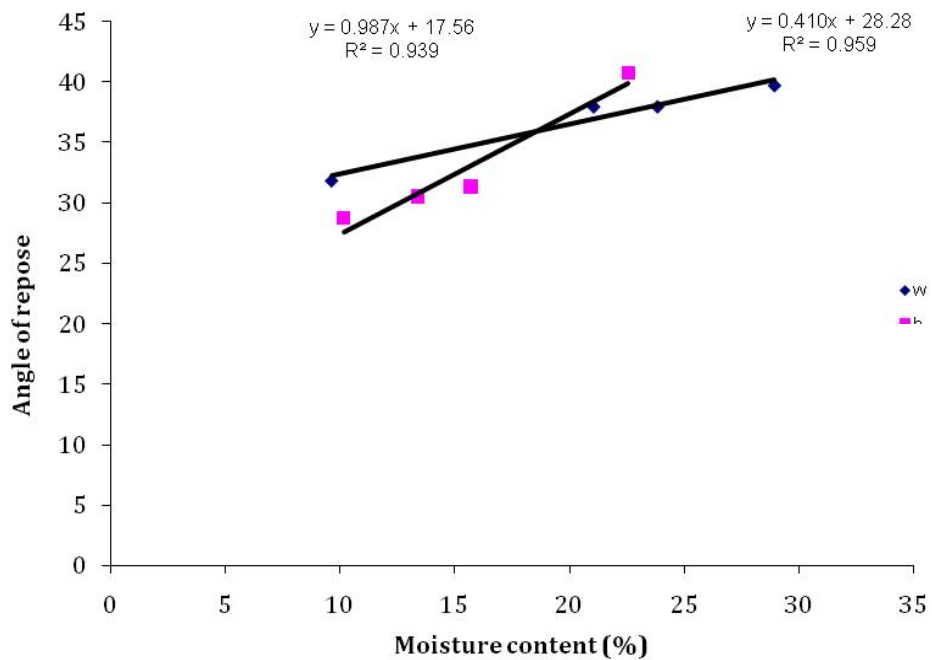


Figure 4: Effect of moisture content on the angle of repose

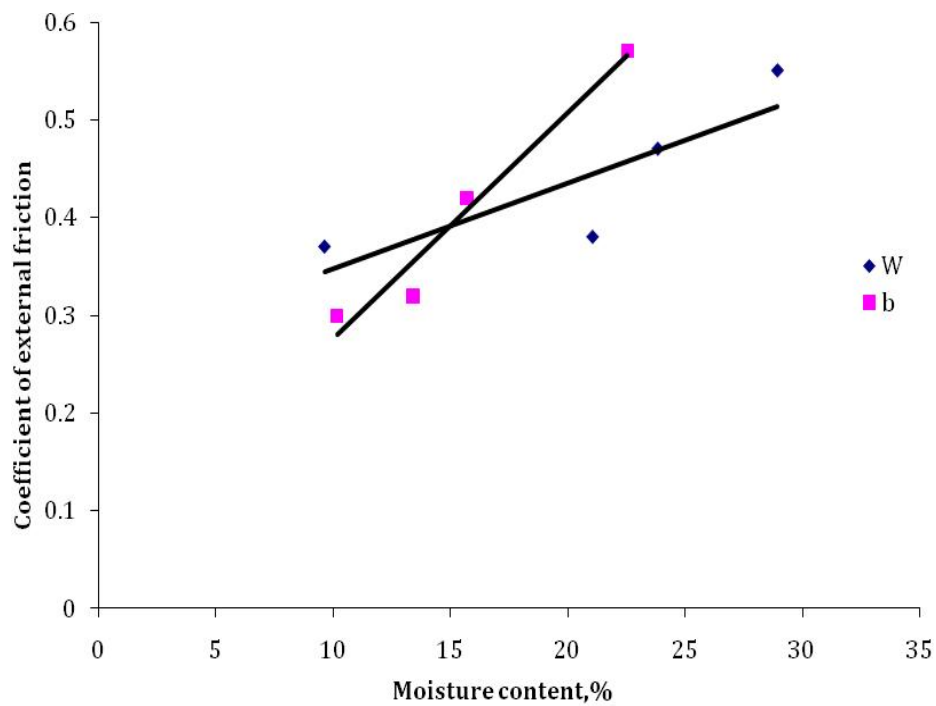


Figure 5: Effect of moisture content on the coefficient of external friction - plywood

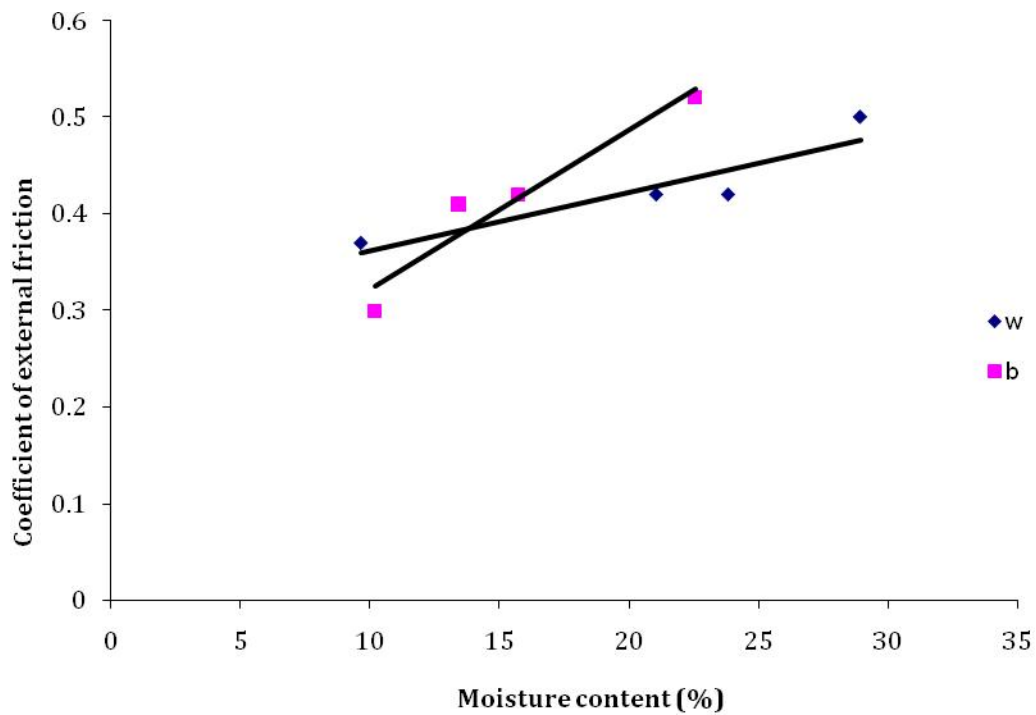


Figure 6: Effect of moisture content on the coefficient of external friction-metal sheet

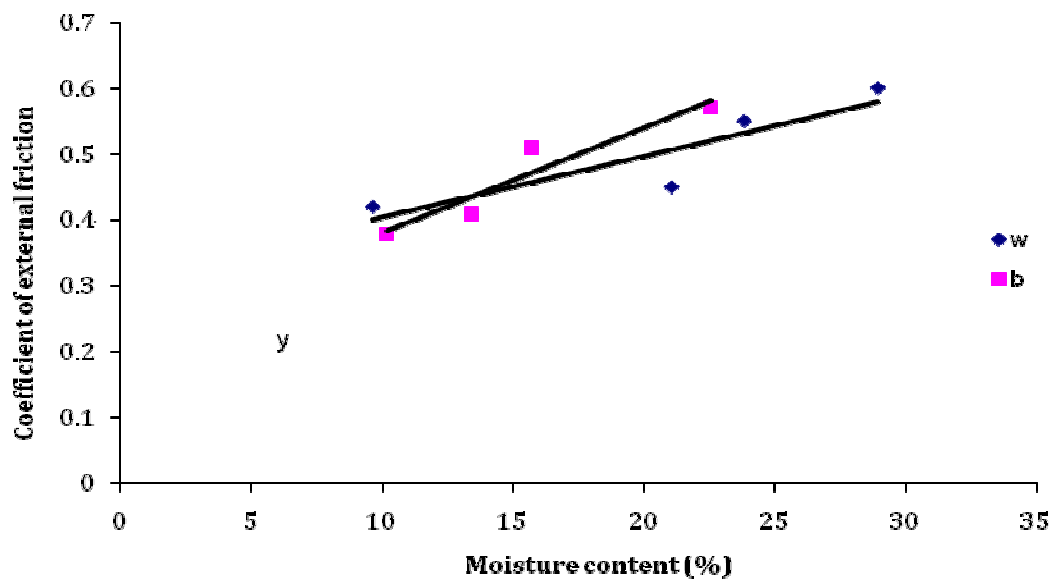


Figure 7: Effect of moisture content on the coefficient of external friction-mild steel

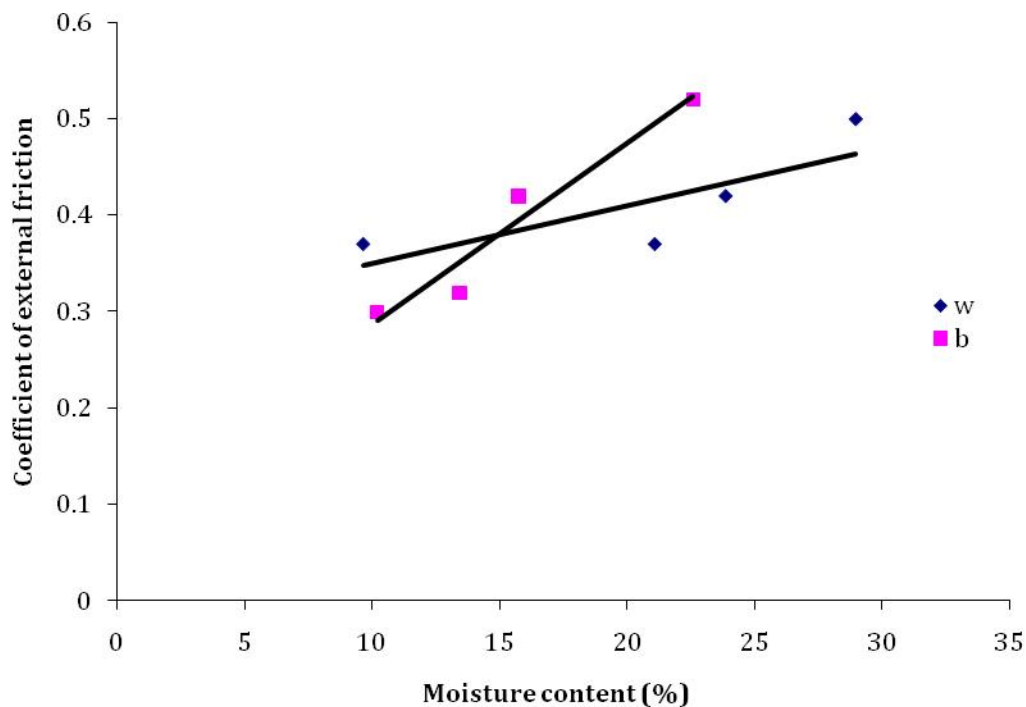


Figure 8: Effect of moisture content on the coefficient of external friction-aluminium

4. CONCLUSIONS

The effect of moisture content on the frictional properties of Rongai and Highworth varieties of *Lablab* seed was determined in the moisture range of 9.65 to 28.95% wet basis (wb) for Rongai and 10.2 to 22.56% wet basis (wb) for Highworth.

The angle of repose increased from 28.387° to 33.817° for Rongai and 24.933° to 35.567° for Highworth. The coefficient of internal friction of Rongai increased from 0.61 to 0.83 while that of Highworth *lablab* increased from 0.55 to 0.86 within the above moisture range. The angle of internal friction of Rongai increased from 31.88° , 39.69° while that of Highworth 28.81° to 40.70° within the moisture range. The kinetic coefficient of friction (COF) ranged from 0.30 (plywood) to 0.57 (mild steel and plywood) for Highworth while Rongai *lablab* seed ranged from 0.37 (Aluminum, galvanized steel and plywood) within the moisture range considered.

REFERENCES

- Adu, I.F., Fajemisin, B.A and Adamu, A.M. 1992. The Utilization of sorghum stover fed to sheep as influenced by urea or graded levels of *lablab* supplementation: In: B. Rey, S.H.B Lebbie and L. Reynolds (Eds) Small Ruminant Research and development in Africa. Proceedings of the 1st Biennial Conference on African Small Ruminant Research network KRAD, International Livestock Centre for Africa, Nairobi Kenya; 10-14 December, pp 367-373.
- ASAE Standards. 2003. S352.2FEB03. Moisture measurement- unground grain and seeds. St Joseph, Mich. ASABE. USA.

- Bawa G. S. 2003. Effects of cooking time on the levels of anti nutritional factors and the nutritive value of *Dolichos Lablab* (*Lablab Purpureus cv Rongai*) seed for pigs. Unpublished PhD .168 pp. Dissertation. Department of Animal Science, Ahmadu Bello University, Zaria.
- Dutta S. K. , Nema V. K. and Bhardwaj R .K.1988. Physical properties of gram. Journal of Agricultural Engineering Research 39(2), 59-68.
- Henderson S. M., Perry R. L and Young J. H .1997. Principles of Process Engineering.4thEdition ASAE Michigan USA. Pp 280-283.
- Irtwange S. V. and Igbeka J. C. 2002. Some physical properties of two African yam bean (*Sphenostylis stenocarpa*) accessions and their interrelations with moisture content. Applied Engineering in Agriculture 18(5), 567-576.
- Irvine D. A., Jayas D. S., White N. D. G. and Britton M. G. 1992. Physical properties of flaxseed, lentils and fababeans. Canadian Agricultural Engineering 34(1), 75-81.
- Isik E. 2007. Some physical and mechanical properties of round red lentils grains. Applied Engineering in Agriculture 23(4), 503-508.
- Kay, D.E. 1979. Crop and product digest No. 3 Food Legume, London: Tropical Product Inst. No. 3: 184-196.
- SAS ,1989. *SAS Users guide*: Statistics. SAS Institute Inc. Box 8000 Cary North Carolina 27511.
- Potter D. and Doyle J. J. 1992. Origins of the African yam bean (*stenostylis steno carpa*, leguminosae) evidence from morphology, isozymes, chloroplast DNA and linguistics. Economy Botany 46(3), 276-292.
- Sacilik K., Ozturk R. and Keskin R. 2003. Some physical properties of hemp seed. Biosystems Engineering. 86(2), 191-198.
- Singh K. K., Reddy B.S., Varshney A .C. and Mangraj S. 2004. Physical and frictional properties of orange and sweet lemon. Applied Engineering in Agriculture 20(6), 821-825.
- Stepanoff A. J. 1969. Gravity flow of bulk solids and transportation of solids in suspension. New York. John Wiley and Sons, Inc.
- Wikipedia.2001. The free Encyclopedia. [http://en.wikipedia.org/wiki/ Hyacinth bean](http://en.wikipedia.org/wiki/Hyacinth_bean). Accessed on 6th October 2007.

DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF A MANUALLY OPERATED VEGETABLE SLICER

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ABSTRACT

A manually operated equipment for slicing vegetables (Tomatoes, Okro and Carrot) with claw cutter (scissors) was designed, fabricated and tested at the National Centre for Agricultural mechanization (NCAM), Ilorin. The equipment consists of cutting blades with sharp serrated edges to pierce and slice the material effectively, and press bar to push the materials against the stationary cutting blades during slicing and at the same time push the individual slices into the collecting tray.

Test results on the slicer gave the thickness produced as 4.88, 5.40 and 4.90mm for Tomatoes, Okro and Carrot respectively. Maximum throughput capacity obtained was 37.4, 19.9 and 15.13kg/h with slicing efficiencies of 79.30, 90.08, and 95.30% for Tomatoes, Okra and Carrot respectively.

KEYWORDS: Slicer, tomatoes, okro, carrot, vegetable.

1. INTRODUCTION

Tomatoes, Okro and Carrot, like other horticultural crops have tissue and high moisture content, ranging from 70-93% (wet basis) and a high rate of physiological activities such as respiration and transpiration. These characteristics make them liable to rapid deterioration, resulting in heavy losses during handling, transportation and storage after harvesting (Oyeniran, 1989; Aworh et al, 1988).

The storage potential of tomatoes, okro and carrot are low. They do not store well in their fresh form and transportation is costly due to their bulkiness. Therefore, processing into non perishable and easily transportable produce offers an alternative to storage in their fresh form. Due to the high moisture content of these fruits and vegetables, they do not dry easily unless the moisture is reduced by exposing the internal surfaces to drying. This can be aided by slicing the materials.

Slicing operation is achieved by cutting, which involves moving, pushing or forcing thin sharp blades or knives to penetrate the materials resulting in minimum rupture and deformation of the materials (Raji et.al 1994). Various types of slicing and chipping equipment have been designed and constructed. In Nigeria a number of researchers have worked on slicing machine for various crops. Raji et al (1994) designed; fabricated and tested a pedal operated chipping and slicing machines for cassava, yam and potato. The equipment has a throughput of 377 kg/h at efficiency of 94.40 % for 5 mm slices while 23.90 kg/h at efficiency of 83.40 % was obtained for 2 mm chips.

With technological advancement, there is the increasing awareness on the importance of using mechanical devices to slice tomatoes, okro and carrot. The peculiar mucilaginous properties of okro and carrot and the demand for dried tomatoes, okro and carrot are factors that must be considered in designing a mechanical device to slice these fruits and vegetables.

It has been stated that tomatoes are the world's most widely grown vegetables other than white potatoes. Commercially, 45 million tonnes of tomatoes are produced each year from 2.2 million hectares

excluding the large amount grown in gardens (Villarreal, 1980). In Nigeria, figures like 6 million tonnes of tomatoes have been quoted as annual production figures (Oyeniran, 1980), Slicing tomatoes, okro and carrot for drying is very important but has not received any form of mechanization except tomatoes canning, ketchup, paste, puree and tomatoes powder, okro and carrot canning.

Most of the slicing machines in Nigeria are imported, expensive and sophisticated which may not be easily operated and maintained by the farmers. Also some of these machines were designed for a particular type of crop and cannot be used for tomatoes (skin), okro (mucilaginous) and carrot because of the peculiar nature of the skin.

Considering the present need for increased fruit and vegetable preservation in the country most farmers dry some of their produce in order to prolong storage period. Therefore, to boost the preservation of fruits and vegetables in large quantity- and retain their quality, the need to design and construct equipment that will enhance this operation cannot be over emphasized.

The designed equipment is aimed at solving the problem of small-scale farmers in the aspect of slicing and drying for commercial purposes.

2. MATERIALS AND METHODS

2.1 Design Consideration

A number of factors were considered in the design of the vegetables slicer these include the rheological properties of the material such as the physical and mechanical properties of the fruits and vegetables and the properties of the materials for construction. Tomatoes have tough thin skin, soft mesocarp and contains a lot of water (high moisture content 93% (Oyeniran, 1988). Okro is a draw or mucilaginous vegetable while carrot is a turgid fruit. Due to these inherent natural phenomena, a device for slicing these vegetables requires to be thin and sharp. It must require little force for the blade to penetrate the materials thus, the materials needed for construction must not be capable of contaminating the vegetables that is the materials must not be corrosive when in contact with water. Therefore stainless steel materials were strictly used as action materials because of the following reasons.

2.2 Design Features

The Blade Support: It was constructed using an angle stainless steel of 3mm thickness, length of 180mm and width of 25mm. It is tilted at an angle of 45^0 to the horizontal and bolted to the frame.

The Blade: This was constructed using 2mm thickness flat bars of hardened heat-treated stainless steel. The length and width are 160 and 20mm respectively. It has sharp serrated edges. They are coupled together as a unit with 13mm diameter threaded stainless steel rod with spacers of 1.6mm thick. The blade unit is attached to the supports with nuts.

The Handle: It was constructed with stainless steel of 10mm diameter and length of 250mm and bent at an angle of 180^0 at the two ends with length 200mm at both sides and bolted to the main frame.

The Mainframe: This was constructed with 3mm thick aluminum square pipe with length of 45 mm. width 250mm and height of 25mm it is rectangular in shape and provide support to the other units

The Tray: This is constructed using 3mm thickness galvanized iron sheet with length, width and height of 147, 270 and 25mm respectively.

The Slicing Unit: This consists of the following parts: the blades, the press frame and press bars.

The Press Frame: This consists of 3mm thick flat stainless bars. The length and width is 50 and 16mm respectively. The bars are twelve (12) in number. They are welded together at a distance of 5mm apart and welded to the handle at the center to form the press frame.

2.3 Design Concept

Fig. 1 shows the forces acting on the blades during slicing. During slicing, the crop material would be located at distance X from pivot. This is the point of contact of the vegetables in actual slicing. The shear force provided by the pointed edges of the blades is considered sufficient to accomplish the slicing. This force is the resultant force required by the blades to accomplish the slicing and it is equal to the resistance force given by the materials.

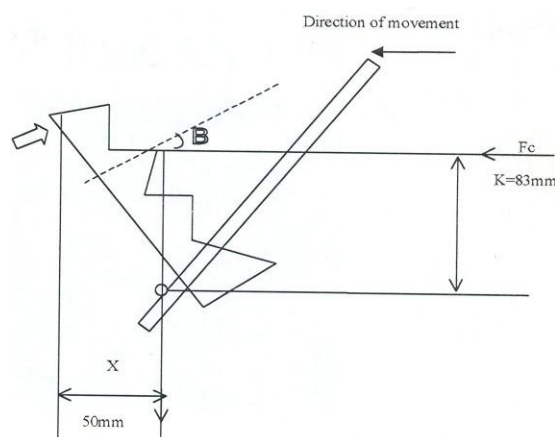


Fig.1. Forces acting on the blade edges during the slicing.

$$F_{cmax} = F(x) \text{ (Dasa et al 2000) } K$$

Where: F_{cmax} = Maximum slicing force (N); F = Force applied by the blades (N); K = Perpendicular distance from pivot to the line of F_c (mm); X = Horizontal distance from the pivot to the linkage (mm)

2.4 Operational Principle of the Machine

The NCAM fruit and vegetable slicer consists of eighteen (18) sharp serrated edges blade hinged together, spaced at a distance of 5mm and bolted to a support which in turn is bolted to a frame. Fig. 2 shows the isometric view of the slicer. The slicer has press bars coupled together as a unit with space of 3mm in between the bars and connected to the frame with bolts and nuts.

The handle is connected to the press bars. As the handle is pushed it pushes the press bars and this presses the fruits or vegetables against the sharp serrated blades and thus slices the fruits and vegetable. The press bars at the same time pushes the individual slices into the tray below the frame.

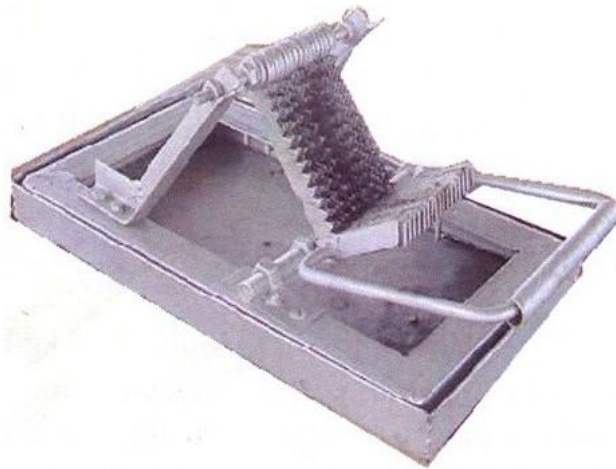


Fig. 2. Isometric view of the Slicer

The materials to be sliced (Tomatoes, Okro and carrot) are dropped into the cutting unit, the number of materials to be sliced depends on the size and length of the material. It should be arranged horizontally along the direction of cut for okro and carrot. When the press frame is pushed, it pushes the press bars, which in turn pushes the material against the sharp serrated blades to slice the materials. The press bars at the same time pushes out the vegetable into the tray by acting on individual sliced to slice vegetable.

2.5 Performance Test of the Vegetables Slicer

The performance test was conducted at the Centre with five (5) persons (men and woman). A sample of 1kg each of the vegetables was given to each person to slice using the machine. The tomatoes and carrot were fed singly while okro was fed in twos. The time of slicing and slice thickness of each crop were noted. These were compare with knives by the same people and the time and slice thickness also noted.

3. RESULTS AND DISCUSSION

The results of the performance tests are shown in Table 1.

Table 1: Comparism of fruits and vegetable slicer with the manual knife slicing

Crops parameters	Vegetables slicer	Manual Knife slicing
Tomatoes		
Weight of sample kg	1	1.00
Moisture content	90.60	90.60
Time of slicing	1.62	11.06
Thickness of slicer (min)	4.88	8.00
Output capacity (kg/hr)	37.49	5.60
Slicing efficiency (%)	79.30	71.52
Okro		
Weight of sample (kg)	1.00	1.00
Moisture content (% wb)	84.20	84.20
Time of slicing (min)	3.28	17.07

Thickness of slicer (mm)	5.94	8.38
Output capacity (kg/hr)	19.94	3.54
Slicing efficiency (%)	96.08	89.20

Carrot

Weight of sample (kg)	1.00	1.00
Moisture content (% wb)	86.74	86.74
Time of slicing (min)	3.99	11.69
Thickness of slicer (mm)	4.89	8.18
Output capacity (kg/hr)	15.13	5.27
Slicing efficiency (%)	95.30	96.38

The NCAM fruit and vegetable slicer slices more effectively than the traditional method (knife slicing). The maximum throughput of the slicer are 37.49, 19.94, and 15.13 kg/h for tomatoes, okro and carrot respectively as against a throughput of 5.60, 3.54 and 5.27 kg/h obtained for tomatoes, okro and carrot respectively using the traditional knife slicing method. It takes a period of about 1.62, 3.28, and 3.99 min to slice 1 kg tomatoes, okro and carrot respectively using the NCAM slicer while a period of 11.06, 17.07 and 11.69 min is required to slice 1 kg tomatoes, okro and carrot respectively using manual knife slicing. The efficiency of the traditional method of slicing is less compared to the machine slicer. Efficiency values of 79.30, 96.08 and 95.30% were obtained for tomatoes, okro and carrot respectively using the slicer while values of 1.52, 89.20, and 90.30, were obtained respectively using the traditional (knife) method.

The values of the throughput, time of slicing, thickness of slices and efficiencies indicate that the machine performs better than the traditional method of slicing.

4. CONCLUSIONS

The fruit and vegetable slicer was found to perform satisfactorily with production of slices of average thickness of 4.88 mm, 5.40 mm and 4.90 mm for tomatoes, okro and carrot respectively. These slice thickness were found acceptable and suitable for drying by local processors. The machine sliced satisfactorily the Roma-type of Tomatoes and all varieties of okro and carrot. Maximum throughput of the machine was 37.49 kg/h, 19.94 kg/h and 15.13 kg/hr for tomatoes, okro and carrot respectively. The efficiencies were 79.30 %, 96.08 % and 95.30% respectively.

The equipment is easy to maintain and found to be a better substitute to manual slicing with knives. The machine is therefore recommended for the small-scale entrepreneur.

REFERENCES

- Aworh, O. C and Olorunda, A. O. 1988. Packaging and storage technology for fresh fruits and vegetables, specific references to tropical conditions. Proceedings of national workshop on improved packaging and storage systems for fruits and vegetables, Nigeria ó Ilorin.
- Oyeniran, J. O. 1988. Report of Activities of National Coordinated Research on Fruits and Vegetables Storage in Nigeria. Proceedings of the National Workshop on Storage of Fruits and Vegetables, Nigeria -Ilorin.
- Raji, O. A. and Igbeka, J. C. 1994. Pedal operated chipping and slicing machine for tubers. Journal of Agricultural Engineering Tech. 2: 90-99.
- Villareal, R. I. 1980. Tomatoes in the Tropics. I. A. D. S. Development oriented literature series. West view Press/boulder, Colorado, and U. S. A.

DEVELOPMENT AND PERFORMANCE EVALUATION OF A MOTORIZED RASPING MACHINE FOR *TACCA INVOLUCRATA*

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ABSTRACT

Tacca involucrata grows wildly in the tropical regions and every part of the plant is of economic importance to man. Its starch, currently extracted manually, from its subterranean tubers is the most widely used for food and medicine. A motorized rasping machine was designed and fabricated with a view to evaluate the grating and rasping efficiencies necessary in starch production in *Tacca involucrata* tubers. Results obtained from preliminary investigations on some engineering properties of the tuber were used in the design of the motorized rasping grating machine. The machine was tested and evaluated with freshly harvested tubers at a moisture content of 73.9% w.b. using clearances of 1.2, 1.7 and 2.2 mm at three speeds of 1100, 1200 and 1300 rpm. The highest grating capacity of 580 kg/h and rasping efficiency of 99.2% were obtained at the combined clearance and speed of 1.2 mm and 1300 rpm respectively. In view of the high grating capacity and the rasping efficiency achieved, motorized rasping was therefore recommended.

KEYWORDS: Rasping, grating capacity, rasping efficiency.

1. INTRODUCTION

Tacca involucrata is a deciduous plant with a subterranean tuber and it belongs to the family Dioscoreaceae. The synonyms of *Tacca involucrata* include *Tacca leontopetaloides*, *Tacca hawaiiensis*, *Tacca oceanica* and *Tacca pinnatifida*. It is native to the tropical regions of Africa, Southeast Asia and Australia; though it was brought into tropical Pacific Islands with early human migration (NTGB, 2007). In Nigeria, the plant is native to both the rain forest and the savanna vegetative regions of the country where it is called gbache (Tiv), giginyar birii (Hausa) and aduro-susu (Yoruba).

The use of different parts of the *Tacca involucrata* plant for medical treatment has been reported amongst the Hawaiian communities (Krauss, 1998). In addition, the starch obtained from its tubers is utilized in preparing a variety of puddings and sauces in the Pacific islands and among the Tiv people of Nigeria (Anon, 2007; Ahemen, 2008). Spennemann (1998) reported that the fine crystal structure of the starch makes it easily digestible and therefore a favorite food for weak and sick as well as children. The use of *Tacca involucrata* starch in the food and pharmaceutical industries has been increasingly investigated (Ofoefule and Esimone, 1998; Attama, 2001; Kunle et al., 2003; Ofoefule et al., 2004; Manek et al., 2005; Ahemen et al., 2008).

Rasping is the process of grating to obtain a smooth grate. It involves tearing of the cell walls of tubers in order to release the starch therein. This, as stated by Sajeew and Balagopalan (2005), is the most important unit operation in the starch production process by wet extraction from tubers. Other unit operations include washing, peeling, screening, settling, purification, pulverization and drying. Spennemann (1998) and Ahemen (2008) reported the use of rough but soft coral among the Marshallese and a traditional manual grater amongst the Tiv people, for reducing *tacca* tubers into pulp for starch production. In cassava starch production, FAO (1998) stated that manual rasping leaves 3-5% of the cassava ungrated. In addition, it considered hand grating as the most tedious and painful operation in cassava processing as it usually causes injuries to palms and consumes about 10-15 mandays/tonne of fresh peeled cassava roots.

Figure 1 shows the traditional manual grating of tacca tubers among the Tiv people in north central Nigeria.



Figure 1: Manual rasping of *Tacca involucrata* tuber

Despite the increasing knowledge of the economic importance of *Tacca involucrata* starch, processing of the tuber into starch is still done manually with the associated risks of injury to palms and fingers, fatigue, low output, and wastage of time and raw materials during rasping, hence the need for a simple inexpensive motorized machine to overcome these problems. The objective of this work was to develop a motorized rasping machine for production of tacca pulp suitable for starch production in addition to overcoming the problems.

2. MATERIALS AND METHODS

2.1 Design Considerations

The machine was designed with the following variables considered: ability to grate *Tacca involucrata* tubers with high rasping efficiency or effect, more efficient use of power by reducing the time and drudgery as well as elimination of the risk of injury to fingers and palms associated with manual grating of tubers. Others are choice of materials that would not contaminate the product and at the same time keep the machine cost at levels affordable to the local farmers without compromising durability, simplicity of operation and maintenance.

2.2 Design Conception

The rasping machine was conceived to consist of the following components: a hopper, the rasping unit, pulp outlet and frame. The hopper was made of hard wood due to its availability, low cost and convenience. A wooden plate to adjust the rasping clearance was incorporated in the hopper. The rasping drum is similar to the cassava grater drum but the design was made to conform to the requirements for the tacca especially the perforation size and arrangement as well as the material. This is with a view to obtaining tacca pulp as against the relatively coarse mash in grating. The drum was made of solid hardwood wrapped with perforated galvanized steel sheet. The pulp discharge chute was also made of hard wood inclined at a suitable angle that would facilitate discharge by gravity. The frame on the other hand was made of angled mild steel of 50 x 50 x 5 mm and mounted on two wheels. This was to facilitate the mobility of the machine from one farm settlement to another. The assembled machine is shown in Figure 2.



Figure 2: The *Tacca involucrata* rasping machine.

2.3 Selection of Parameters

The design parameters listed below were designed for or selected based on the preliminary investigations on the engineering properties of *Tacca involucrata* tubers (Raji and Ahemen, 2008) as well as information obtained from literatures; rasping drum diameter and length of 100 mm and 300 mm respectively, plate thickness of 1 mm, rasping surface of 3 mm, desired rasping effect $\times 60\%$, capacity of 500 \pm 1000 kg pulp per hour, operating speed of 1200 rpm and rasping clearance of 1 - 3 mm.

2.4 Design Calculations

2.4.1 The Hopper

The hopper dimensions were designed for by calculation and iteration to accommodate the maximum linear dimension of 110 mm for the tubers as well as their bulk density (539.57 kg/m^3) obtained from the preliminary investigations of the properties of *Tacca involucrata* (Raji and Ahemen, 2008; Ahemen, 2008) by using Equations 1 and 2. The inner volume of a hopper is

$$V = \frac{m}{\rho} \quad (1)$$

where, m is the mass and ρ is the bulk density. Since the hopper is an inverted frustum of a pyramid, volume is given by:

$$V = \frac{1}{3} (B + b + \sqrt{Bb}) H \quad (2)$$

where, B is the base area of complete pyramid, b is the base area of small pyramid cut out for frustum to form, H , the height of complete pyramid and h , the height of the small pyramid. Using the value obtained in Equation 1 and solving Equation 2 by iteration gives B as $0.45 \times 0.37 \text{ m}^2$ (upper part of hopper), H as 0.55 m , b as $0.26 \times 0.21 \text{ m}^2$ (lower part of hopper) and h as 0.15 m .

2.4.2 The Rasping Unit

The rasping unit comprises the grating drum made up of a cylindrical wooden drum wrapped with a galvanized steel rasping plate and the housing. Thickness of galvanized steel used as rasping plate wrapped round the wooden drum was calculated by assuming that the projections of the rasping plate perforations are cantilevers. If the shear stress at the bottom of the projection is τ , the horizontal force F (force at break of tuber) per unit length of projection l , is given by the following expression adopted from Stephens (1988):

$$F = \tau l \quad (3)$$

Where t is the thickness of steel sheet/plate required, l is 3 mm (measured), F is 728.52 N (Ahemen, 2008). Using the maximum shear stress theory on failure relationship stated by Krutz *et al.* (1984)

$$\tau = \frac{1}{2} \text{ tensile stress} \quad (4)$$

Also from the ASTM-A621 AISI-DQ, the tensile stress of low carbon steel is 430 MPa (430 N/mm²) which gives the shear stress at the foot of the projection as 215 N/mm². Substituting values into Equation 3 gives the rasping plate thickness of 1.1 mm. The total weight of the rasping drum assembly was obtained as 24 N.

The perforations on the grating drum plate were effected using a 3 mm concrete nail. The plate was punctured in a chess board pattern with inter row overlap of perforations as shown in Figure 3. The overlap was to ensure that no portion of the tuber escapes ungrated.

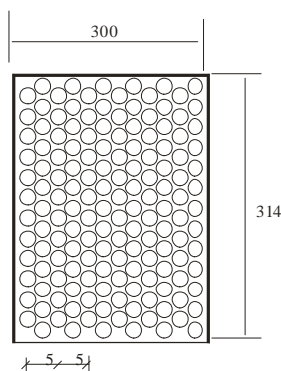


Fig. 3: Outline of the rasping -plate perforations.

2.4.3 The Rasping Drum Shaft

Assuming that the weight of the rasping drum assembly is uniformly distributed over the length of the shaft carrying it (300 mm) and leaving an allowance of 95 mm on both sides of shaft for the frame and the grating drum housing, with an additional 30 mm on one of the sides for the driven pulley, the shaft length was 520 mm. With the driven pulley weighing 11 N placed at one of the ends of the shaft as a point load, the shaft was designed for bending, deflection and shear failure to obtain the diameter from the relation given by Singh (2001):

$$d^3 = \frac{16}{\pi S_s} [(K_b M_b)^2 + (K_t M_t)^2]^{1/2} \quad (5)$$

where, d is the shaft diameter (m), S_s , the allowable shear stress for shaft ($= 40 \text{ MN/m}^2$), K_b is the combined shock and fatigue factors applied to bending moment ($= 1.5$), M_b is the bending moment (Nm), K_t is the combined shock and fatigue factors applied to torsional moment ($= 1.0$) and M_t is the torsional moment (Nm). Similarly, the torque required to run the rasping drum was obtained from:

$$T = M_c R \left(g + \frac{2v^2}{D} \right) \quad (6)$$

where, T is the Torque (Nm), M_c is the total mass of grating drum (2.4 kg), R , the radius of the driven pulley of the drum (m), D , the effective diameter of the drum (0.101 m), v , the peripheral velocity of the drum (7.07 m/s) and g , the acceleration due to gravity (10 m/s^2).

The peripheral velocity (v) of the rasping drum and the radius (R) of the rasping drum pulley (driven) were obtained from Equations 7 and 8 given respectively by Joshi (1981) and Sahay (2006):

$$v = \frac{\pi D N}{60} \quad (7)$$

Where v = Peripheral velocity, m/s; D = Drum diameter, m; N = Drum speed, rpm and

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} = \frac{R_2}{R_1} \quad (8)$$

where, N_1 is the number of revolutions of driving pulley, N_2 , the number of revolutions of driven (drum) pulley, R_1 , the radius of the driving pulley and R_2 , the radius of the driven (drum) pulley.

For a prime mover of 4 kW and 4000 rpm (selected for its availability, durability and relatively cheap cost), with driving pulley diameter of 32 mm and the designed drum speed of 1200 rpm, the radius of the drum pulley was obtained as 53.5 mm and the torque as 128.37 Nm giving a shaft diameter of 25 mm.

2.4.4 Bearing Selection

Krutz *et al.* (1984) stated that the radial load acting on a shaft can be determined from:

$$F = \frac{19.1PK \times 10^6}{D_p S} \quad (9)$$

where, F is the radial force on the shaft (N), P , the power transmitted (kW); D_p , the pitch diameter of sheave (mm); S , the speed of shaft (rpm) and K ($=1.5$) is the drive tension factor for V-belt drives. The radial force on the shaft from the V-belt ($F_{v\text{-belt}}$) was therefore obtained as 892.52 N.

The load from the v-belt pull on bearings A and B as shown in Figure 4 are given respectively as (Krutz *et al.*, 1984):

$$F_A = F_{v-belt} \frac{a}{c} \quad (10)$$

$$F_B = F_{v-belt} \frac{b}{c} \quad (11)$$

Where F_A is the load on bearing A, (N); F_B is the load on bearing B, (N); F_{v-belt} is the radial force of v-belt on shaft, (N); a is the distance between sheave and bearing A, (mm); b is the distance between sheave and bearing B, (mm) and c is the distance between bearings A and B, (mm). The loads on bearings A and B were obtained respectively as 947.16 N and 54.64 N. A single row ball bearing with 25 mm bore (shaft diameter = 25 mm), outside diameter 47 mm, width 12 mm, and capacity (7892.64 N) capable of withstanding the load of 947.16 N was therefore selected from the codes reported by Spotts (1988). The force and the moment diagram of the shaft as affected by the dead loads (vertical) and belt tension (horizontal load).

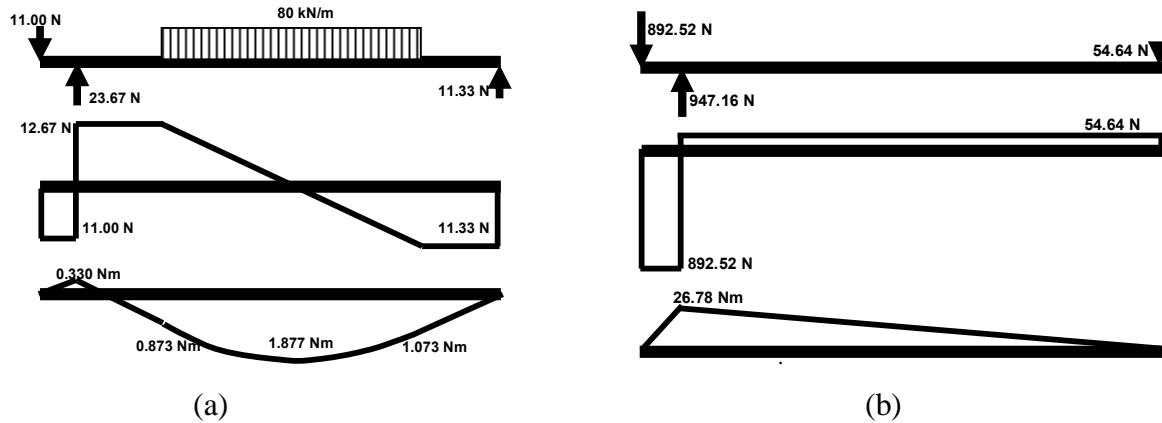


Fig. 4: Force and moment diagram for the shaft (a) Vertical load (b) Horizontal load

2.4.5 The Discharge Chute

The discharge chute was designed to align with the lower part of the hopper. The upper part of the discharge chute forms part of the grating drum casing. The lower part is inclined in such a way as to allow discharge by gravity.

2.4.6 The Frame

The dimensions of the frame are 930 mm x 470 mm x 650 mm for length x breadth x height respectively. There is a provision of a handle and two wheels on the frame for pushing of the machine from one farm settlement to another. An additional hopper height of 400 mm brings the overall height of the machine to 1650 mm, very suitable for an average person to stand on the ground and operate the machine.

2.5 Performance Evaluation

Moisture content of the freshly harvested *tacca* tubers was determined using the oven-dried method. Since the aim of this study is to evaluate the performance of the machine for its suitability to produce pulp useful in starch production, the following criteria by FAO (1977) and Sajeev and Balagopalan (2005)

were used to evaluate the performance of the rasping machine on the basis of the Grating Capacity (GC) and the Rasping Efficiency (RE) in pulp and mash production meant for starch processing.

$$GC(kg/hr) = \frac{Q}{t} \quad \text{and} \quad RE = 1 - \frac{s_w f_r}{s_r f_w} \quad (12)$$

where Q is the weight of pulp and t is the time taken to process the tuber to pulp, s_r is the starch content of the root, f_r , the fibre content of the root, s_w , the starch content of the waste pulp and f_w is the fibre content of the waste pulp.

The s_r and f_r of the tuber were obtained by adopting the method described by FAO (1977) where *tacca* tubers, thoroughly washed in water using an iron sponge, were weighed (W_t) and kept in polythene bags then stored in a deep freezer. Weighed frozen samples were sliced and blended with 500 ml of water for 5 minutes. The pulp was washed on a sieve with additional 500 ml of water, and the fibrous material retained on the sieve poured into aluminium pans and dried at 85°C until a constant weight (W_f) was attained. The washed material was poured into aluminium pans and dried under similar conditions described above until a constant weight (W_s) was attained. Then s_r and f_r were calculated using following relationships:

$$s_r(\%) = \frac{W_s}{W_t} \times 100 \quad \text{and} \quad f_r(\%) = \frac{W_f}{W_t} \times 100 \quad (13)$$

These were done in three replications and their means taken respectively.

The pulp obtained from processing the tubers in the rasping machine was sieved to retain the waste. A sample of the waste pulp was weighed (W_{wp}), dried in an oven and milled. The milled material was then analysed for the fibre content of the waste pulp (f_w) and the starch content of the waste pulp (s_w) from:

$$s_w(\%) = \frac{W_{ws}}{W_{wp}} \times 100 \quad \text{and} \quad f_w(\%) = \frac{W_{wf}}{W_{wp}} \times 100 \quad (14)$$

where W_{wf} = weight of fibre in waste pulp, W_{ws} = weight of starch in waste pulp.

The machine was operated empty for 5 minutes in order to stabilize speed before introducing the cleanly washed tubers into it. The time of operation was taken using a stopwatch. The output from the discharge chute collected after each operation was weighed using a digital balance. This was done using three rasping drum speeds of 1100 rpm, 1200 rpm and 1300 rpm, against three grating clearances of 1.20 mm, 1.70 mm and 2.20 mm. The speeds were varied by changing the engine (prime mover) speed until the desired speed was attained on the rasping drum shaft. The speed of the rasping drum was measured using a tachometer pressed against one of the ends of the rasping drum shaft, while the variation in grating clearance was achieved by using the clearance adjuster attached to the hopper. Each combination of speed and grating clearance was replicated three times and the mean taken as the representative value.

A split block design in Randomized Complete Block Design (RCBD) was used with a total of 27 observations (3 speeds x 3 grating clearances in three replicates), after which the data was subjected to the Analysis of Variance (ANOVA) to ascertain whether or not there are significant differences in the data. Plots were also made to determine the effect of speed and grating clearance on the grating capacity and the rasping efficiency of the machine. Multiple regression was done using Eregress, a Microsoft Excel add-in software to analyse for response surface used to predict the optimum operating conditions.

3. RESULTS AND DISCUSSION

The moisture content of the tubers was obtained as 73.91 % (wb). The grating and rasping efficiency obtained with the standard deviation are as presented in Figures 5 and 6.

3.1 Grating Capacity

The effect of the speed and the clearance on the grating capacity (GC) of the machine is presented in Figure 5. From the figure, the grating capacity of the machine generally increased with increase speed except for higher clearance of 2.2. The highest grating capacity of 580 kg/hr was recorded at the grating clearance and speed of 1.20 mm and 1300 rpm respectively. This is within the range of 300 kg/hr and 1000 kg/hr reported by Hung *et al.* (1995) and FAO (1998) for motorized grating of cassava tubers. The ANOVA however showed no significant difference ($p < 0.05$) in the grating capacity of the machine across the varying clearances.

In starch production, the performance of the machine is not solely based on its grating capacity and efficiency i.e. the quantity of pulp produced with time or relative to the input but also on its ability to produce pulps from which starch can be released from the cells effectively which is known as the rasping efficiency.

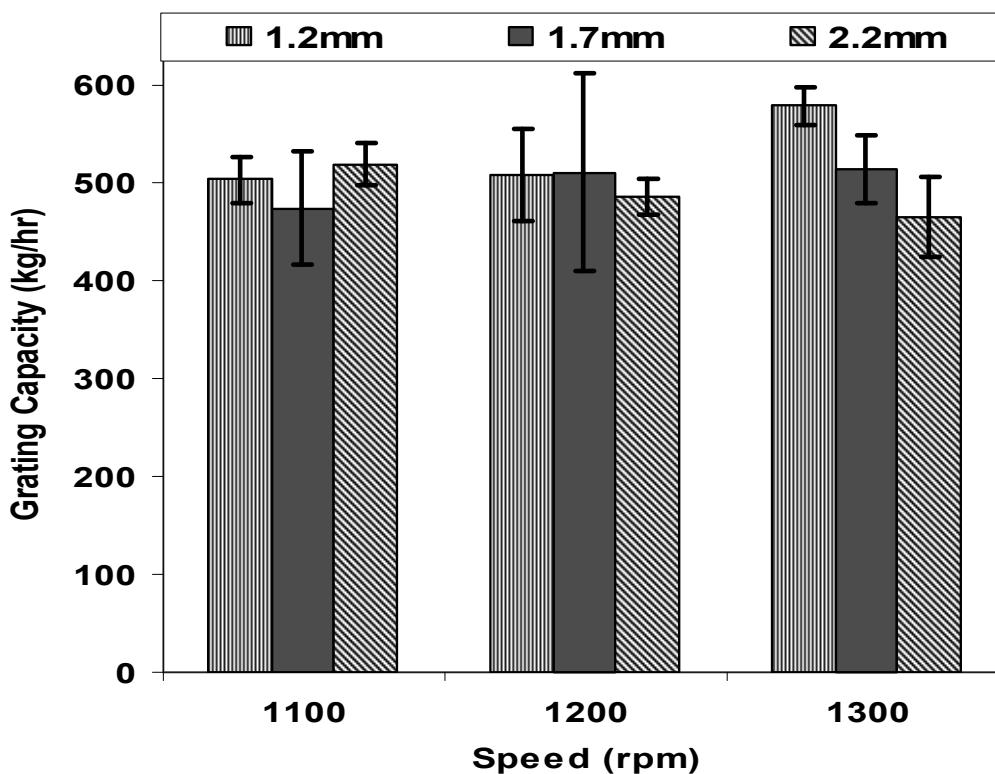


Figure 5: Effect of clearance and speed on the grating capacity

3.2 Rasping Efficiency

The starch content (s_r) and the fibre content (f_r) of the *tacca* tubers were determined to be 25.90% (SD = 0.728) and 0.014% (SD = 0.00085) respectively. This result is very close to the range of 10-25% starch

content of *tacca* tubers reported by Spennemann (1998). The effect of speed and clearance on the rasping efficiency of the machine is presented in Figure 6. The rasping efficiency generally decreased with increase in speed at varying clearances except for the smallest clearance of 1.20 mm. The highest rasping efficiency of 99.23% was also obtained at the same combined grating clearance of 1.20 mm and speed of 1300 rpm. This is higher than the rasping efficiency of 90% reported for a cassava rasping machine (FAO, 1998). Part of the reason for this very high efficiency may be due to the pattern of perforations on the rasping plate that ensured no portion of the tuber escaped ungrated. Again the ANOVA showed no significant difference ($p < 0.05$) in the effect of the clearance on the rasping efficiency at varying speeds.

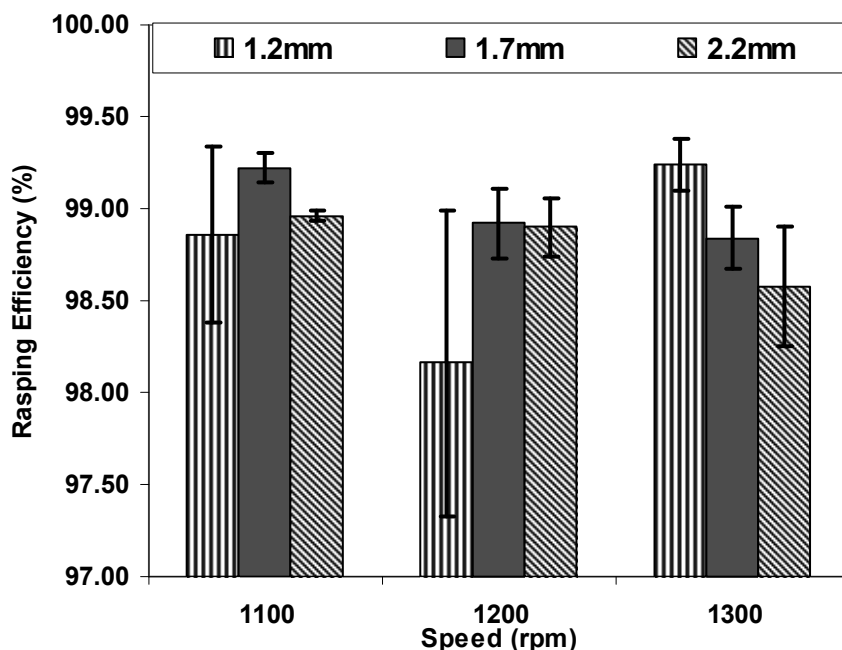


Fig. 6: Effect of clearance and speed on the rasping efficiency

The response surface predictions to obtain the optimized conditions using a full quadratic multiple regression analysis are presented in Figures 7 and 8. The surface shows that the predicted optimum grating capacity, 576 kg/hr, was obtainable at the highest speed of 1300 rpm and the least clearance of 1.2 mm. The trend from the figure shows that the GC is inversely proportional to the opening as the speed increases with direct proportion at low speed. The trend for the speed is the opposite of the clearance with the GC decreasing with speed at the highest clearance and increasing with speed at low clearance.

The surface in Figure 8 for the rasping efficiency (RE) shows that the predicted optimum RE of 99.26 % was obtainable at the lowest speed of 1100 rpm and clearance of 1.7 mm. The trend from the figure shows that the RE has an inflexion curve with respect to the opening, increasing to a peak and decreasing thereafter. The trend is the inverse for the speed which shows a deflection curve.

The conditions i.e. speed of 1100 rpm and clearance opening of 1.7 mm, which gives the best rasping necessary for starch is recommended for use on this machine when handling *tacca* tubers. This conditions i.e. speed of 1100 rpm and clearance opening of 1.7 mm gave a grating capacity of 500 kg/hr which is an acceptable level of grating.

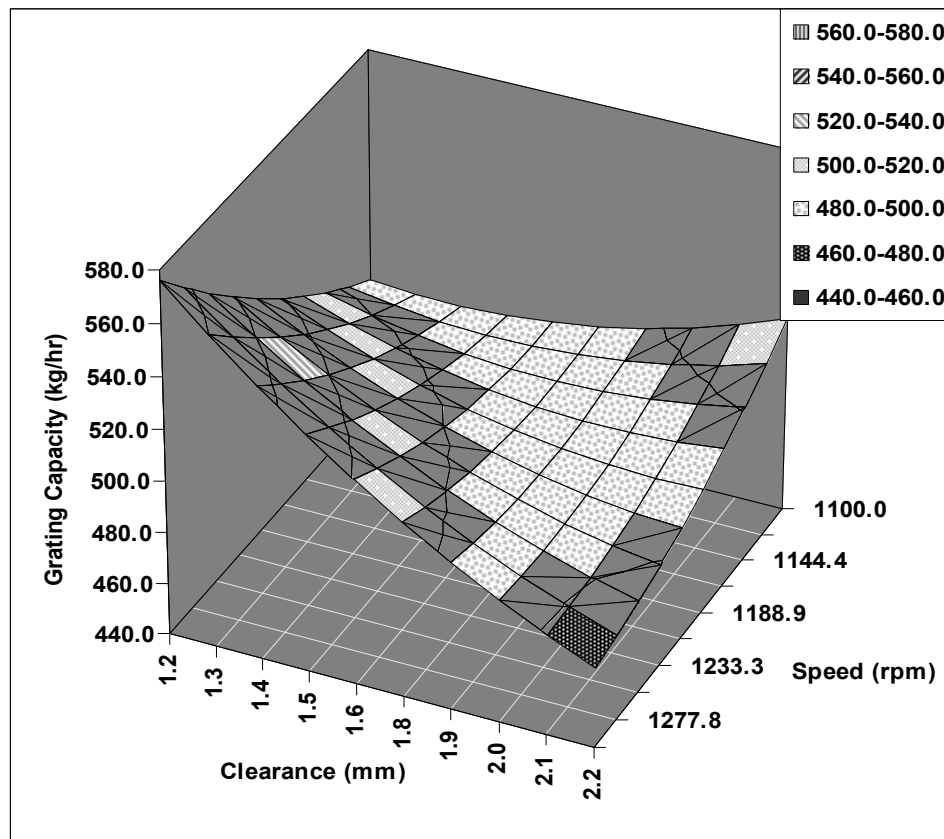


Fig. 7. Surface Response of the Grating Capacity

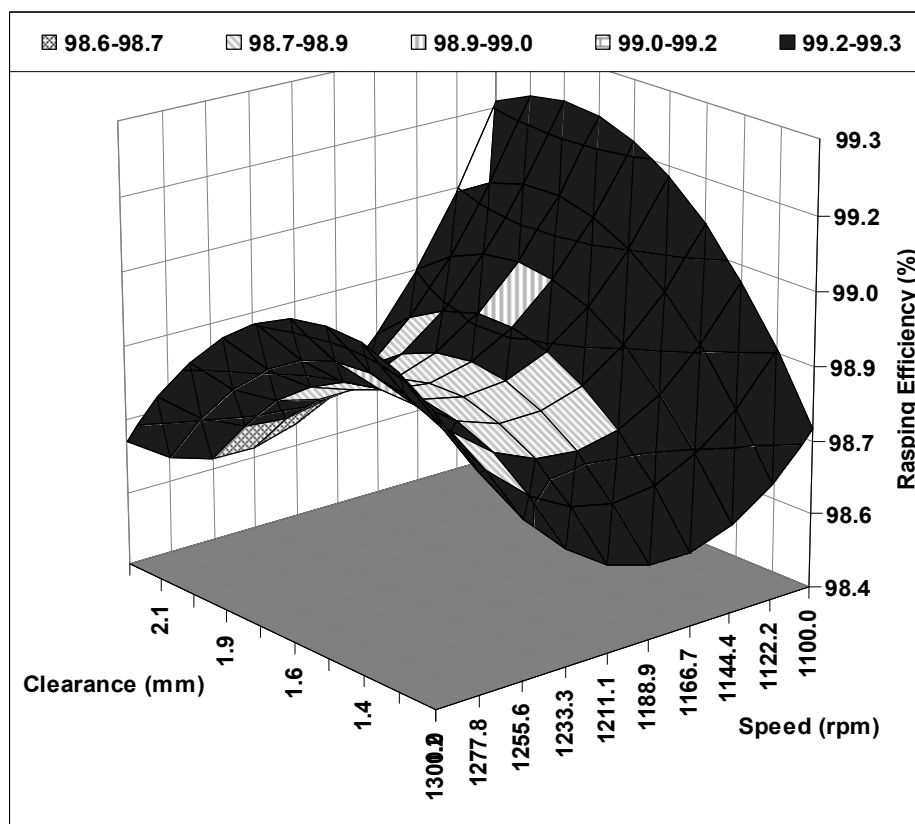


Fig. 8. Surface Response of the Rasing Efficiency

4. CONCLUSIONS

The motorized rasing machine designed, fabricated and evaluated, proved to be easy to operate and maintain, and very effective in the rasing of *Tacca involucrata* tubers for starch production. The high grating capacity of 580 kg/hr and rasing efficiency of 99.23% achieved by the machine shows that motorized rasing did not only eliminate drudgery and hazards associated with manual rasing of the tuber, but also saved time, ensured nearly complete extraction of starch from the tubers and consequently, reduced wastage. The ease of movement of the machine will ensure its acceptance in the community where the process of rasing is currently done manually. This is because *tacca* is still a wild plant harvested at low scale. Its commercial production is still under investigation.

REFERENCES

- Ahemen, S.A. 2008. Engineering properties of tacca tubers and performance evaluation of motorized rasing in *Tacca involucrata* starch production. An unpublished M.Sc. Thesis, University of Ibadan, Nigeria.
- Ahemen, S. A.; Nyon, A. and Akaaimo, D. I. 2008. Some engineering properties of *Tacca involucrata* starch necessary for its handling and storage. A paper presented at the First National Conference on Revitalising Agriculture for Sustainable National Growth and Stable Democracy by the Department of Agricultural Engineering Technology, Akperan Orshi College of Agriculture, Yandev. October 22- 23, 2008.
- Anon 2007. *Tacca leontopetaloides*. <http://florawww.eeb.uconn.edu/199700062.html> [Accessed 8/22/2007].

- Attama, A. A. 2001. Studies on plastoelasticity and drug migration in granules prepared from pyroextrins of two tropical starches. PhD Thesis. Department of Pharmaceutics, University of Nigeria, Nsukka, 368p.
- FAO 1977. Cassava processing. <http://www.fao.org/docrep/X5032E/X5032E02.htm>. A publication of the Food and Agriculture Organization. Plant Production and Protection series No 3. [Accessed 10/31/2007].
- FAO 1998. Storage and processing of roots and tubers in the tropics. Published by Food and Agriculture Organization, Agricultural support system division. <http://www.fao.org/docrep/X5415E/x5415e05.htm>. [11/7/2007].
- Hung, C. V., Vu, N. K. and Ian, D. T. 1995. Cassava processing in the northern and central parts of Vietnam. Proceedings of the international symposium held in China: pp 135-153.
- Joshi, H. C. 1981. Design and selection of thresher parameters and components. AMA 12(2): 61-68.
- Krauss, B. H 1998. Native plants used as medicine in Hawaii. <http://library.kcc.hawaii.edu/%E2%80%92Esoma/krauss/welcome.html> [8/22/2007].
- Krutz, G., Thompson, L. and T. Claar 1984. Design of agricultural machinery. John Wiley and Sons New York. Pp 77-116, 259-277.
- Kunle, O. O., Ibrahim, Y. E., Emeje, M. O. Shaba, S. and Y. Kunle 2003. Physicochemical properties of *tacca* starch (*Tacca leontopetaloides*). Starch-Starke 55 (7): 319-325.
- Manek, R.V., Kunle, O. O., Emeje, M. O., Builders, P., Rama, G., Rao, V., Lopez G. P. and Kolling, W. M. 2005. Physical, thermal and sorption profile of starch obtained from *Tacca leontopetaloides*. Starch-Starke 57(2): 55-61.
- NTBG 2007. *Tacca leontopetaloids*-meet the plants. National Tropical Botanical Garden Plant Data. http://www.ntbg.org/plants/plant_details.php?plantid=10965 [8/9/2007].
- Ofoefule, S. I. and Esimone, O. 1998. Studies on the properties of tableting *Tacca involucrata* starch 1: Evaluation as a binder. Bolletino chimico farmaceutico 137(66): 7-12.
- Ofoefule, S. I., Osuji, A. C. and Okorie, O. 2004. Effects of physical and chemical modifications on the disintegrant and dissolution properties of *Tacca involucrata* starch. Bio-Research 2(1): 97-102.
- Raji A. O. and Ahemen, S. A. 2008. Engineering properties of *Tacca involucrata* tubers. Journal of Food Process Engineering. (In press)
- Sahay Jagdishwar 2006. Elements of Agricultural Engineering. Standard Publishers Distributors, Delhi. Pp 211-223.
- Sajeev, M. S. and Balagopalan C. 2005. Performance evaluation of a multi-purpose mobile starch extraction plant for small scale processing of tuber crops. Journal of Root Crops 31(2): 105-110.
- Singh, S. 2001. Machine design. Khanna Publishers, Delhi, Pp 298-333.
- Spennemann, Dirk H. R 1998. Essays on the Marshallese past. <http://marshall.csu.edu.au/marshalls/html/essays/es-tf-1.html> [8/22/2007].
- Spotts, M. F. 1988. Design of machine elements. Prentice-Hall of India Private Limited, New Delhi. pp 148-210.
- Stephens, R. C. 1988. Strength of materials, theory and examples. Edward Arnold, London. pp 198-216.

THE PRESERVATIVE POTENCY OF LOCAL SPICES IN OIL FISH

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ABSTRACT

An experimental analysis was carried out on the effects of local spices (ginger, garlic, red pepper, turmeric and cloves) on the self-life of Mackerel fish (*Scomboromorus scombrus*) over a period of four weeks. The study revealed that 2% level of dry ground spices each on the fish sample enhanced the keeping quality and the nutritional value over the control which had a reduction in their keeping quality and nutritive value. The parameters on which these effects were based on are percentage moisture, crude protein, fat and ash content. Physico-chemical analysis, and total titrable acidity (TTA), showed that the treated samples were able to maintain their levels of pH throughout the period of study over the control sample where the pH increased with time. The percentage total titrable acidity on the other hand increased for the spiced samples over the control that decreased with time. The former was due to the formation of lactic acid. The spices were also able to exhibit antioxidant property on the samples because of their ability to bring a decrease in the peroxide value and slight increase in the free-fatty acid (FFA) of the lipids contained in the fish sample. There was a great reduction in the microbial load of the treated sample over the control samples. The microbial property of pepper is due to the contents of phenolic compounds that can bind the microbial enzymes thereby inhibiting their growth. Cloves on the other hand contain 95% eugenol that forms insoluble complexes with microbial proteins, garlic was also found to have bacteriostatic effects due to its active ingredients called allicin. Turmeric has a terpene derivative as an antimicrobial agent.

KEYWORDS: Spices, preservatives, oily foods, proximate physicochemical, fish.

1. INTRODUCTION

Spices are aromatic vegetable products of tropical origin that are used, in a pulverized state, primarily for seasoning or garnishing foods and beverages. They are characterized by pungency, strong odour, and sweet or bitter tastes. Included on this category are hard or hardened parts of plants such as pepper, cinnamon, cloves, ginger, turmeric, garlic, nutmeg, mace, vanilla, etc. In ancient times, they were valued as basic components of incense, embalming preservatives, ointments, antidotes against poison, etc. today, they are widely used by the sauce, canning, frozen food industries and food manufacturing industries generally. They are also used in the cosmetic, perfumery, soap, and toothpaste industries. Spices and essential oils are of liqueurs and cordials.

Spices, especially ginger, cloves, garlic, turmeric, pepper, rosemary, etc. are referred to as important food condiment. Also, the role they play as flavouring and seasoning agents have been known for ages. However, some of them can exert antimicrobial effects (Frazier and Westhoff, 1977) and antioxidant properties (Chipault, 1982). These have made it possible to use them as preservatives. The antimicrobial properties of some of the spices have been demonstrated. Lake and Waterworth (1980) observed that spices at concentrations that are customarily used in foods have little or no bacteriostatic effect but may aid other antimicrobial agents in the preservation of the growth of undesirable organisms in food. Extensive research done on rosemary and sage showed that they exhibited pronounced antioxidant effects (Chipault, 1982).

Further research on the antioxidant properties of rosemary has produced industrial products which are sold as natural antioxidants, which are primarily de flavoured rosemary extracts. These have been known, for some time, for their antioxidants effects in food. The antioxidant component have since been isolated and determined to be camosol and rosemanol. Two additional diterpene antioxidants have been isolated and characterized as rosemaridiphenol and rosemariguinine (Jacobs, 1958; Lee, 1986). They have been determined to be almost as effective as Butylated Hydroxytolune (BHT) and more effective than Butylated Hydroxyl Anisole (BHA). Therefore, natural antioxidants available commercially are extracted from rosemary. This research work was aimed at establishing the antioxidant and antimicrobial enhancing properties of such local spices as pepper, ginger, garlic, turmeric and cloves on the shelf life and keeping quality of mackerel fish. Mackerel fish (*Scromboromorus Scrombrus*), is an oily fish which contains between 10 to 18% fat. They contain vitamins A and are important sources of vitamin D. However, due to the high nutritive value of the Mackerel, they are highly perishable, if not properly preserved. Hence the use of the aforementioned five local spices for this purpose.

2. MATERIALS AND METHODS

2.1 Sample Collection

Spices used for this project include ginger, pepper (red), garlic, turmeric and cloves. They were bought from Eke Ukwu, one of the local markets in Owerri, Imo State. The Mackerel fish (*Scromonoromorus Scrombrus*), was bought from a cold store depot at Owerri. The fish samples were kept in a freezer before use.

2.2 Preparation of Spices

The spices were prepared by breaking each separately using a sterile mortar and pestle for the purpose of size-reduction. Thereafter, they were ground with a sterile grinding stone. This further size-reduction was necessary for the increase in surface area of the spices thereby giving way for high activity rates. The now powder-like spices were separately stored in sterile containers until they were used.

2.3 Preparation of the Fish Samples

The fish sample was prepared by the following steps:

- i. Inserting a knife into the fish, close to the dorsal fin and cutting through the head.
- ii. Cutting from close to dorsal fin to the tail
- iii. Opening the fish with the knife
- iv. Removing the gills (viscera), fins and blood and
- v. Thorough washing of the split fish.

The washed fish samples were further rinsed in 5% saline water and thereafter, allowed to drain for 20 minutes at ambient temperature. To each of the cut fish 2% of the prepared spices was added by smearing it on both the outside and inside the fish samples. This was done separately for each of the spices and a control (no spice added) was prepared. This was allowed to remain on them for a period of 20 minutes. The spiced fish samples were then placed in an oven (Mamet model) at 50°C for 4½ hours in order to impart smoking characteristics on the fish sample. The samples were then wrapped in a foil paper and placed in a clean tray at room temperature for a period of 4 weeks. At weekly intervals of storage, physicochemical, proximate, lipid oxidation and microbiological analysis of the samples were carried out.

2.4 Physiochemical and Proximate Analysis of the Spiced Sample

These involve analyzing the chemical compositions of the sample as to their moisture content, crude protein, fat content and total ash content.

2.4.1 Moisture Content Determination

This was carried out as described in AOAC (1990). A quantity of 5g of the spiced sample was accurately weighed into a pre-weighed aluminum drying dishes (18g) and spread as thinly as possible over the bottom of the dish to cover the greatest surface area of the base. The sample was then dried for 4 hours in an oven maintained at 105⁰C. After the first four hours, it was brought out from the oven, cooled in a desiccator and then weighed. The dish was then returned to the oven and dried for further 30 minutes after which it was removed, cooled and weighed again. The drying, cooling and weighing continues until a constant weight was contained. The moisture content was calculated from the weight loss of the sample:

$$\% \text{ of Moisture content} = \left[\frac{M_1 - M_2}{M_1 - M_0} \times 100 \right] \quad - \quad 1$$

2.4.2 Crude Protein Determination

The crude protein content was determined using the micro ó kjelahl method (Purseglove, 1981). One gram of dried moisture free spiced sample was put into the kjelahl digestion flask and half of a mercury tablet catalyst was added into the flask together with 25ml of concentrated tetraoxosulphate (VI) acid. The mixture was digested on the digestion unit in a fume chamber until the black specks initially produces after the addition of acid is cleared. The cleared digest was then washed into a 100ml volumetric flask and made up to the mark with distilled water, and then thoroughly shaken.

The distillation apparatus was then used for the ammonia distillation. The apparatus was flushed and rinsed with distilled water and then steamed for 15minties. The 5ml of the digest were introduced into the distillation flask. Next, 20ml of 4% boric acid was pipetted into a 100ml conical flask. Five drops of methyl red was added to each flask as indicator and the sample was diluted with 75ml distilled water. Then 5ml of sodium hydroxide was introduced into the distillation set up from the top after which the actual distillation was carried out for 7 minutes. The distillate was titrated against 0.1NHCl and the titre value was read from the burette when a change of colour of boric acid solution to green was observed. The percentage total nitrogen was calculated as follows:

$$\% \text{ Total Nitrogen} = \frac{(V_1 - V_2 \text{ Normality of HCl } \times)}{0.04 \text{ Sample weight}} \quad - \quad 2$$

$$\% \text{ crude protein} = \% \text{ Total Nitrogen} \times \text{Conversion factor (CF)} \quad - \quad 3$$

2.4.3 Determination of Fat Content

Fat determination was carried out using solvent extraction method with the aid of the soxhlet Extractor unit and petroleum ether as the solvent. The extractor flask was washed, dried and cooled and

subsequently weighed. Exactly 5g of the minced moisture free sample was introduced into the thimble, and some quantity of the solvent was placed in the flask, which the extraction kit was set up and extraction cycles were carried out for 6 hours. At the end of the period the solvent was recovered leaving the oil in the flask. The flask was next dried in the oven to drive off any remaining solvent, and the flask finally cooled in the desiccators and the weight taken. The fat content of the sample was then calculated as follows:

$$\% Fat = \frac{(w_2 - w_1)}{w_1} \times 100 \quad - \quad 4$$

2.4.4 Total Ash Content Determination

The analyses for the total ash content of the spiced samples were carried out using standard procedures (AOAC, 1990). The dry silica crucibles used for the test were first heated in the oven to eliminate moisture. Then they were cooled in the desiccator and weighed. Five gram of the moisture-free sample were accurately introduced into the crucible and then inserted into the muffle furnace. Heating started slowly until a temperature of 600°C was attained and was maintained for 6 hours, until there was a white ash residue left in the crucible. The crucible was then removed from the muffle furnace, cooled in the desiccator and finally weighed

$$\% Total Ash = \frac{(X_2 - X_1)}{X_1} \times 100 \quad - \quad 5$$

2.5 pH Determination of the Spiced Sample

This was monitored on a weekly basis as follows:

Ten grams of the spiced sample was homogenized in 10ml of distilled water. The sample was centrifuged at 3000 rpm for 15 minutes. The pH of the decanted resulting solution was determined by using a previously standardized pH meter.

2.6 Total Titrable Acidity

The titable acidity was determined by titrating 25ml of the decanted homogenate used for pH determination against 0.1N NaOH to pH 8.3 (Mbugua, 1981) using phenolphthalein indicator. The relative amount of lactic acid was calculated as percent lactic acid as follows:

$$\% \text{ Lactic acid} = \frac{T_v \times \text{Normality of NaOH} \times 9}{W_a} \quad - \quad 6$$

2.7 Rancidity Tests

The rancidity development during storage was evaluated through the determination of peroxide value (PV). A sample of 0.5g of the extracted oil was weighed into a clean dry crucible flask. To it was added 7.5ml of a mixture of glacial acetic acid (ethanol acid) and tetrachloromethane (CCl₄) of ratio 2:1. The mixture was swirled to dissolve the oil. A freshly saturated solution of 0.22g potassium iodide was dissolved in 1ml water and the mixture swirled. It was set aside for 5 minutes in a dark cupboard. After 5 minutes, the flask was brought out and 50ml of water was added and this was thoroughly mixed. Then few drops of starch indicator were added to obtain the blue colour change. This was then titrated with

0.01M sodium phosphate, gradually until the blue colour disappeared. A blank titration was also carried out,

The peroxide value, in milli-equivalent of peroxide kilogram of fat, was calculated thus.

$$\text{Peroxide value} = \frac{(T_1 - T_0) \times 1000}{W_0} \quad - \quad 7$$

2.8 Microbiological Analysis of the Sample

This was carried out by the method described by Toledo, (1981). One gram of the spiced fish sample was aseptically weighed and following serial dilution, the homogenized sample is turned into a test tube. The serial dilution was continued until it gets to 10^{-10} dilution from the appropriate dilution from the appropriate dilution of 10^{-3} . A volume of 1ml was taken and by pour-plate method using nutrient agar, used in calculating the total microbial colonies.

3. RESULTS AND DISCUSSION

The proximate composition of the treated spiced fish samples and that of the control samples for a period of four weeks are as shown on tables 1 to 6. The values obtained for the fresh sample at 0 week are in agreement with observations made by Bhandary, (1995), who although with slight variations reported higher moisture content (70.3%), a lower fat (9.2%) for the same closely related species of fish. The difference in the moisture content might be as a result of the fact that the samples used were oven dries to an extent. The difference in the fat content might be as a result of lipid contents variation of the fish, which is a function of the year and inhibition. The high ash content recorded was probably due to the non-removal of the bone before analysis.

It was also observed that there was increase in the moisture content of samples A and D during the period of storage as shown in Tables 1 and 4. However, in samples B, C and E, the moisture content showed only a slight increase (Tables 2, 3 and 5). The moisture content of the control sample was very high (Table 6). The samples with high moisture content within the storage period are an indication that the samples may attract some level of spoilage. The protein, fat and ash content when compared with the control as shown in Tables 1 to 6, reveal that all the treated samples retained the nutritive composition of the food sample. However, samples B, C, and E (Table 2, 3 and 5), showed a more nutritive keeping quality than samples A and D (Tables 1 and 4). The ability of the samples to retain the nutritive property of the sample is as a result of the presence of the spices, which has conferred some level of anti-microbial effects on the samples and hence preserved them.

Table 1. Sample A. (Fish Garlic) /Parameter (%)

Weeks of storage	Moisture	Protein	Fat	Ash
0	20.00	18.50	18.00	3.20
1	24.00	18.50	17.50	3.20
2	25.00	18.00	16.00	3.00
3	25.00	17.50	16.00	2.80
4	28.00	16.00	15.50	2.80

Table 2. Sample B. (Fish + Cloves)/Parameters (%)

Weeks of storage	Moisture	Protein	Fat	Ash
0	20.00	18.50	18.00	3.20
1	22.00	18.50	18.00	3.20

2	22.00	18.50	18.00	3.10
3	21.50	18.00	17.50	3.10
4	23.00	18.00	17.50	3.10

Table 3. Sample C (Fish + Ginger)/Parameter (%)

Weeks of storage	Moisture	Protein	Fat	Ash
0	20.00	18.50	18.00	3.20
1	22.00	18.50	17.00	3.20
2	25.00	18.00	17.00	2.70
3	23.00	17.50	16.50	2.60
4	24.00	17.50	16.00	2.40

Table 4. Sample D (Fish + Turmeric)/ Parameters (%)

Weeks of storage	Moisture	Protein	Fat	Ash
0	20.00	18.50	18.00	3.20
1	24.00	16.50	17.50	2.60
2	26.00	16.00	16.50	2.40
3	27.00	14.50	16.50	2.30
4	28.00	14.00	10.50	2.20

Table 5. Sample E (Fish + Pepper)/Parameters (%)

Weeks of storage	Moisture	Protein	Fat	Ash
0	20.00	18.50	18.00	3.20
1	22.00	18.00	17.00	3.10
2	22.50	18.00	16.50	2.60
3	23.00	17.00	16.50	2.40
4	23.00	17.00	16.00	2.20

Table 6. Sample F (Control)/Parameters (%)

Weeks of storage	Moisture	Protein	Fat	Ash
0	20.00	18.50	18.00	3.20
1	20.00	14.00	15.00	2.40
2	34.50	12.00	13.00	2.10
3	28.00	10.00	10.00	2.00
4	29.50	8.00	8.50	1.80

Changes in pH of spice treated mackerel fish are as shown in Table 7. The initial pH of all the samples was 6.40. There was only a slight change in all the treated samples. The control however, had pH values that increased with the storage period, and went above the neutral pH value. The total titrable acidity (TTA) of all the treated samples was as shown in Table 8. The values therein showed that all the treated samples had an increased in initial TTA value of 7.3. The enhanced TTA was due to chemical reaction occurring in the formation of lactic acid during oxidation process. The control however has a fall in its lactic acid content due to the absence of the various spices in the sample. Therefore, there was no formation of lactic acid.

The changes in the peroxide value of the spiced fish sample and control during 4 weeks of storage were as shown in Table 9. All the samples have an initial peroxide value thereby showing antioxidant property. This is however more in sample E (Fish + Pepper), followed by sample B (fish + Cloves). There was a

slight increase in the peroxide value of the control thus, revealing the antioxidant properties of all the spices used for this project.

The effect of the spices on the free fatty Acid (FFA) content during the storage of the samples is as shown in Table 10. Gradual increase was observed in all the treated samples, whereas, they increase more in the control. The increase was due to the hydrolytic rancidity in the samples. However, less of rancidity was observed in all the spiced samples. The microbiological analysis of the various spiced samples is shown in Table 11. The result showed that all treated sample had a microbial load that was within acceptable limits. The control however has a number that was outside the acceptable range of limits.

Table 7. Effects on pH of Samples during Storage

SAMPLE						
Weeks of storage	A	B	C	D	E	F
0	6.40	6.40	6.40	6.40	6.40	6.46
1	6.69	6.36	6.42	6.38	6.47	6.50
2	6.50	6.50	6.48	6.58	6.11	6.60
3	6.17	6.20	6.36	6.30	6.30	6.80
4	6.36	6.37	6.37	6.36	6.38	7.30

Table 8. Changes in the Total Titrable Acidity (TTA) During Storage of Spices Fish Sample

SAMPLE						
Weeks of storage	A	B	C	D	E	F
0	7.30	7.30	7.30	7.30	7.30	7.30
1	7.80	7.50	7.60	7.50	7.80	6.40
2	8.40	7.80	7.80	8.30	8.10	6.30
3	8.60	8.20	8.20	8.60	8.30	5.80
4	8.60	8.40	8.40	8.70	8.40	5.30

Table 9. Effect of the Spices on Peroxide Value (Milli/Equi. kg Fat) of the Spiced Mackerel during storage

SAMPLE						
Weeks of storage	A	B	C	D	E	F
0	3.50	3.50	3.50	3.50	3.50	3.50
1	3.20	2.84	3.40	3.30	1.88	3.91
2	3.00	2.72	3.00	3.10	0.88	4.01
3	2.70	2.72	2.80	2.70	0.82	4.40
4	2.60	2.60	2.62	2.40	0.62	4.70

Table 10. Effects of Spices on Free Fatty Acid of the Spiced Sample

SAMPLE						
Weeks of storage	A	B	C	D	E	F
0	8.36	8.36	8.36	8.36	8.36	8.36
1	8.60	4.30	6.10	6.30	5.30	6.68
2	8.40	4.60	7.00	6.90	6.20	9.50
3	8.20	4.80	7.80	7.10	6.90	9.70
4	8.50	5.00	7.90	7.40	7.80	12.01

Table 11. Total Aerobic Bacteria ($\times 10^3$) (cfu/ml) of Spiced Samples during storage
SAMPLES

Weeks of storage	A	B	C	D	E	F
0	1.20×10^1	1.30×10^1	1.40×10^1	1.50×10^1	1.20×10^1	1.30×10^1
1	1.60×10^1	1.50×10^1	1.50×10^1	1.30×10^1	1.40×10^1	1.80×10^1
2	1.80×10^1	1.30×10^1	1.20×10^1	1.20×10^1	1.30×10^1	2.20×10^1
3	2.00×10^1	1.20×10^1	1.20×10^1	1.30×10^1	1.20×10^1	2.50×10^1
4	1.80×10^1	1.0×10^1	1.20×10^1	1.20×10^1	1.30×10^1	3.80×10^3

4. CONCLUSIONS AND RECOMMENDATION

The local spices, namely, garlic, ginger, turmeric, red pepper and cloves not only improve significantly, the keeping quality, nutritive value and the overall shelf life of the Mackerel fish but also contained a potent antioxidant activity against lipid oxidation in fatty food substance. The antioxidant activity was shown by the lower values of peroxide values and free fatty Acids (FFA) as compared to the untreated samples. More so, the preventive and antiseptic properties of these spices are on the basis of their anti-microbial properties. This is confirmed by low moisture content, low increase TTA, reduction as a result of the formation of lactic acid, and the reduction of microbial load of the spiced mackerel samples over the control. Thus, they are able to bring about, unfavourable conditions for the growth of micro-organisms which can eventually cause spoilage.

The ability of these spices to cause a reduction or maintain the microbial load is due principally to anti-microbial properties contained in them. The anti microbial property of pepper is due to the contents of phenolic compounds that can bind the microbial enzymes, thereby inhibiting their growth. Ginger is bacteriostatic due to the terpen oil which prevents the growth of bacteria of the protein. Cloves on the other hand, contain 95% eugenol that forms insoluble complexes with microbial protein. Garlic was also found to be bacteriostatic due to its active ingredient called allicin. Finally, turmeric has similar effect owing to the presence of a terpene derivative called turmerone. In view of high cost of basic refrigerating storage facilities, coupled with sporadic power supply, in food preservation especially the fatty foods such as meat and fish product, it is recommended that these and other cheaper spices should be applied in the preservation of this class of food.

REFERENCES

- AOAC, 1990. Official methods of analyses of the Association of Official Analytical Chemist. 15th Edition Arlington, Virginia.
- Bhandary, C. S. and Idoko, J. O. 1995. The effect of spices on lipid oxidation of minced meat During Frozen Storages. Nigeria Food Journal 13: 40 ó 42.
- Chipault, J. E. 1982. The antioxidant properties of spices in Fiid. Food technology 10. Pp. 209 ó 211.
- Frazier, W. C. and Westhoff, D. C. 1977. Food microbiology. McGraw Hill Publishing Co. New Delhi. Pp. 261 ó 264.
- Jacobs, M. A. 1958. The chemical analysis of foods and food products, Van Nostrand Co. Inc. Toronto, Pp. 675 ó 677.
- Lake, B. and Waterworth, M. 1980. Food and nutrition. Chancer Press Ltd. Burigay, Suffolk, Pp. 348 ó 353.
- Lee, Y. B. 1986. Antioxidant property in ginger, rhizome and its application to meat product, J. Food Sci. 51(1), Pp 20, 21.

- Noah, N. 1990. Public health, good and industrial microbiology. Nigerian Journal of Microbiology 3(1). 46 ó 50.
- Purseglove, J. W. 1981. Spices, Vol.1, Longman Group Ltd. New York. Pp. 33 ó 259.
- Toledo, T. R. 1981. Fundamentals of food process engineering. AVI Pubs. Co. Inc. Westport Connecticut, Pp 347, 348.
- Vickery, B. 1979. Plant products of tropical Africa. Macmillan Press Ltd. London. Pp. 84 ó 89.

List of Symbols

PV	-	Peroxide Value
TTA	-	Total Titrable Acidity
FFA	-	Free Fatty Acid
M ₀	-	Weight of aluminium dish
M ₁	-	Weight of fresh sample + weight of the dish
M ₂	-	Weight of dried sample + the dish
V ₁	-	Blank titre value
V ₂	-	Samples titre value
C ₁	-	Conversion factor
W ₁		Weight of sample
W ₂	-	Weight of empty flask
W ₃	-	Weight of empty flask + extracted oil
X ₀	-	Sample weight
X ₁	-	Weight of empty Crucible
X ₂	-	Weight of empty crucible + ash residue
T _v	-	Titre Value
W _s	-	Weight of Sample
T _o	-	Titre Value of the Blank
M	-	Exact Molarity of the Thiosulphate
W _o	-	Weight of the oil
t	-	Weight of sample
g	-	grammes
cfu	-	Colony Forming Units
A	-	Fish + garlic
B	-	Fish + cloves
C	-	Fish + ginger
D	-	Fish + turmeric
E	-	Fish + pepper
F	-	Control Sample

EVALUATION OF FURROW IRRIGATION WATER ADVANCE MODELS

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ABSTRACT

The problems of on-farm water management and irrigation system design parameters which are often chosen with limited or no analysis of the local condition leads to the poor performance of most irrigation systems today. In this study, three furrow irrigation water advance models - Walker and Skogerboe model, Michael's advance model and Philip and Farrell model were verified and evaluated for their prediction of water advance distances under specific field conditions at the Galma Irrigation Scheme where fifteen irrigation events were monitored. The models were applied to all events and results were compared with field measurements. Linear regression and t test analysis were used to evaluate the models. Walker and Skogerboe model performed best ($R^2 = 0.999$ and absolute error = 4.40%) followed closely by Michael's advance model ($R^2 = 0.984$ and absolute error = 9.67%) which performed reasonably well while Philip and Farrell model exhibited low performance ($R^2 = 0.950$ and absolute error = 37.08%).

KEYWORDS: Furrow irrigation model, advance and recession, infiltration characteristics, furrow geometry, tomato crop.

1. INTRODUCTION

The pressure of human survival and the need for additional food production requires increased intensities of irrigated agriculture throughout the world because rain-fed agriculture limits agricultural production. It has been estimated that as little as 15-20 percent of the total land cultivated worldwide is irrigated and contributes as much as 30-40 percent of gross agricultural output (FAO, 1993). However, in Nigeria, irrigated agriculture represents about 8% of the total agricultural crop output and 4% of the total cultivated area (FAO, 2005). Majority of this land is irrigated using surface methods which constitute as much as 95 percent of common irrigation activities (FAO, 1993).

Surface irrigation method is favoured over other methods on the basis of lower capital and operating cost, the simplicity of maintenance, the utility of unskilled labour but management is more complicated (Walker and Skogerboe, 1987). Furrow irrigation is a common type of surface irrigation in Nigeria for the cultivation of maize, vegetables, sweet potatoes, e.t.c. It provides better water management on the farm, but in most cases the design and management of the furrow system is not optimal for water use in the arid and semi-arid region with unique infiltration characteristics. Infiltration characteristics are important parameters in the design and management of irrigation systems. The characteristics determine advance and recession times, depth of infiltration and the uniformity of water application during irrigation (Jobling and Turner, 1973; FAO, 1993). Infiltration parameters can change spatially and temporally within a field (Esfandiari and Maheshwari, 1997; Walker and Skogerboe, 1987; Eldeiry et al., 2004). Geometry of furrows causes infiltration to be more complex compared with that in border irrigation (Esfandiari and Maheshwari, 1997).

In furrow irrigation system, the two basic considerations (inflow rate and application time) are not easily met because the solution is unique for a given land slope and infiltration characteristic of the field. In practice, the required inflow rate for a furrow system is obtained by field measurements of the rate of advance of the wave front as water flows down the furrow, and the corresponding rate of recession of the

trailing water edge after cessation of inflow. The two curves (advance and recession) should be approximately parallel for satisfactory water application and distribution efficiencies (Mudiare, 1987; Esfandiari and Maheshwari, 2001).

Design and management of furrow irrigation remain primitive due to limitations of existing on-farm distribution systems, an absence of field measurements, a lack of proper training and a reluctance to change established techniques (McClymont, 1999). Furrow design parameters are often chosen with limited or no analysis of unique local conditions. One of the major constraints to the improvement of furrow irrigation performance has been the difficulty in assessing the many variables associated with the furrow irrigation systems and their interactions, and to utilize these in irrigation management. One potential for improving the efficiency and performance of furrow irrigation systems lies in the use of simulation models to predict furrow irrigation performance and assess changes in management variables, which can lead to improvements in irrigation efficiency (Hornbuckle et al., 1999). A number of such models have been developed which aim to simulate surface irrigation systems. The most common approaches include hydrodynamic, zero-inertia, kinematic wave and volume balance models (Esfandiari and Maheshwari, 2001; Walker and Skogerboe, 1987).

In order for such models to be adopted by practitioners, confidence in the model predictions needs to be demonstrated through adequate field verification, with agreement between measured values and those predicted by the simulation model. There have been several efforts by researchers (Hornbuckle et al., 1999; Esfandiari and Maheshwari, 2001; Eldeiry et al., 2004) to evaluate furrow irrigation models; however, the need for continuous evaluation cannot be overemphasized. Model for border irrigation design and simulation have been tested for specific field conditions in Northern Nigeria in the past (Dalhat, 1988; Oyeboode, 1989; Adamu, 1990) but the suitability of the furrow models under specific field conditions are not well known. The objective of the study reported herein is to evaluate three furrow irrigation advance models under unique field condition.

This paper reports the findings of an evaluation study on three furrow irrigation advance models for their applicability and accuracy on silt-loam to loam soil of Galma Irrigation Scheme, Zaria. An adequate knowledge of the design parameters through the use of these models will result in an efficient irrigation system which reduces water wastage; improve management, higher yield and income for farmers.

2. MATERIALS AND METHODS

2.1 Furrow Irrigation Models

Furrow irrigation models are derived from volume balance analysis and accurately simulate furrow irrigation (Larry, 1988). It is primarily applied to the water advance phase and are recommended when quick estimates of system performance are required (Walker and Skogerboe, 1987; Zerihum and Sanchez, 2003). The three furrow irrigation models evaluated in this study are discussed below:

2.1.1 Walker and Skogerboe Model (1987)

The power advance solution of the volume balance analysis is based on the simple power advance function and the modified Kostiakov & Lewis infiltration equation utilizing the equations in the Lewis & Milne equation. The Walker and Skogerboe equation can be written as;

$$X = \frac{qt}{\sigma_y A_0 + \sigma_z kt^a + \frac{f_0 t}{1+r}} \quad (1)$$

where: X = distance along the furrow length (m), q = Inflow rate (m^3/s), A_o = inlet flow area, (m^2), t = elapsed time since the irrigation started, (min), f_o = basic infiltration rate ($\text{m}^3/\text{m}/\text{min}$), k, a = Kostiakov & Lewis infiltration empirical parameters, r = time exponent of advance equation, y = surface storage shape factor, which is defined as a constant of 0.70-0.80, z = subsurface shape factor.

2.1.2 Michael's Advance Model (1968)

Michael (1968) simulates the hydraulics of surface irrigation (border and furrow) at the farm level. He applied the modified Kostiakov - Lewis infiltration equation into the general solution of the Lewis & Milne equation as presented by Philip and Farrell (1964) and obtained a particular solution to predict the water front advance for small time, t as;

$$X = \frac{qt}{f_o + y} \left(\frac{1}{\Gamma(2)} - \frac{\beta t^a}{\Gamma(2+a)} + \frac{\beta^2 t^{2a}}{\Gamma(2+2a)} - \frac{\beta^3 t^{3a}}{\Gamma(2+3a)} + \frac{\beta^4 t^{4a}}{\Gamma(2+4a)} - \dots \right) \quad (2)$$

where: y = average depth of flow (m), Γ = gamma function.

$$\beta = \frac{k\Gamma(r+1)}{f_o + y} \quad (3)$$

This equation simulates water advance on the basis of the infiltration characteristics, stream size and average depth of flow. It ignores the surface storage.

2.1.3 Philip and Farrell Model (1964)

Philip and Farrell (1964) presented analytical solutions to the Lewis & Milne volume balance integral equation using several infiltration equations. One of their solutions which apply Philip's (1957) infiltration equation, as the only input, in their general solution arrived at a particular solution which predicts the length of advance distance as:

$$X = \frac{q}{A} \left(1 - \ell^{\frac{4-A}{\pi S^2}} \operatorname{erfc} \left(\frac{2}{\pi} \frac{At^{\frac{1}{2}}}{S} \right) \right) \quad (4)$$

where: S = sorptivity ($\text{m}^2/\text{min}^{0.5}$), A = parameter related to saturated hydraulic conductivity (m^2/min), erfc is the error function complementary.

This equation ignores surface storage because it assumes that the cumulative infiltration, $Z(s,t)$ is independent of surface water depth and dependent only on intake opportunity time (Walker and Skogerboe, 1987). This model also assumes the depth of flow along the furrow to be zero, which in practice is not true.

2.2 Field Experimentation

2.2.1 Location of Experimental Site

The field experiment was carried out at Galma Pilot Irrigation Scheme, Zaria, Nigeria ($11^\circ 05' \text{ N}$, $7^\circ 44' \text{ E}$), at an altitude of 686 m above the mean sea level. The scheme covers an area of about 350 ha. Rainfall is between the months May & September with a mean annual rainfall of 1088.5 mm for the year, 2006. Mean monthly temperatures range from 30°C to 35°C . The soil of the experimental site ranged from silt-loam to loam and the bulk densities ranged between 1.40 g/cm^3 & 1.62 g/cm^3 .

2.2.2 Experimental Procedure

Fifteen irrigation events were monitored in five furrows of length 40 m and furrow width of 0.8 m each from the months of December to March during the 2006 / 2007 irrigation season. The average furrow slope was 0.9%. Measurement stations were established by the use of stakes at every 6 m along the furrow length, where advance and recession times were recorded. Cutthroat flumes of 100 mm width were installed at the upper and lower end of the furrow to measure the inflow rate and runoff, respectively. Inflow rate ranging between 0.105 m³/min and 0.117 m³/min for 9.4 min to 10.5 min were given to each furrow. The field was planted with tomatoes, by the sides of the ridges, as a test crop.

Cardboard paper was placed in the furrow and used to trace the furrow shape at three different points along each furrow preceding each irrigation event. The furrow geometry data collected were used to derive relationships between the depth of flow in the furrow and the corresponding top width, wetted perimeter and flow area (Walker and Skogerboe, 1987).

Each furrow was marked at 6m interval along the furrow length. The travel time for water to advance to each stake point was recorded and the recession of the water was determined by noting the times when water just disappeared from each established point. The advance and recession functions for each set of irrigation events were calculated by the two-point fitting using data collected from the field.

The volume balance technique, known as the two-point method, presented by Elliott and Walker (1982) and also by Walker and Skogerboe (1987) using data from the irrigation advance phase was applied to find the parameters of the infiltration equation pertinent to each irrigation event. Infiltration data were generated from the parameters of the modified Kostiaikov ó Lewis equation for each event to which Philipòs equation was fitted.

2.3 Evaluation of Indices for the Models

The accuracy of the different models for predicting advance distance in furrow irrigation were evaluated by comparing the observed values of measurements on the field, X_o and the predicted values based on the fitted advance model, X_p . Here a linear regression analysis of the observed and predicted advance distance was used to find the average pattern of variation of data. The form of regression equation used is.

$$X_p = c + \lambda X_o \quad (5)$$

where: c = intercept, λ = slope of the best fit line. The goodness of fit of the above equation to data was determined by calculating the coefficient of determination, R^2 and the standard error of estimate, σ . The absolute error, E in percentage was computed for each model, to measure the goodness of fit, as follows;

$$E = \left(\frac{X_o - X_c}{X_o} \right) 100 \quad (6)$$

Furthermore, the accuracy of the different models was evaluated by plotting the observed advance distance, X_o during irrigation event and the predicted, X_p and examining where these points fall in relation to a 1:1 line passing through the origin. t-paired test was applied to determine the significance level between the means of the observed values and the predicted values. The t-test was also used to determine the significance of the intercept and coefficient of regression (slope) for the regression equations.

2.4 Validation of the Models

In order to validate the various models, advance distances were predicted by a given model by inputting the various variables required by the models. The advance distances were then computed and compared

with the observed distances. Predicted advance distances with an error not exceeding 12% limit is satisfactory as suggested by Mudiare (1982).

3. RESULTS AND DISCUSSION

3.1 Furrow Shape Parameters

The average furrow shape parameters obtained from calculation are summarized in Table 1. These values agree with those obtained by Eldeiry et al. (2004).

Table 1. Average furrow shape parameters

Irrigation number	α_1	α_2	σ_1	σ_2	γ_1	γ_2	σ_z	σ_y	C_2	C_1	A_0 (m ²)
4	1.76	0.54	1.15	1.54	2.17	0.59	1.36	0.8	0.708	1.409	0.006
5	1.85	0.57	1.18	1.57	2.28	0.61	1.56	0.8	0.711	1.435	0.005
6	1.44	0.45	0.99	1.45	2.01	0.55	2.55	0.8	0.708	1.394	0.005

α_1 and α_2 are the top width parameters, σ_1 and σ_2 are the area shape factor parameters, γ_1 and γ_2 are the wetted perimeter factor parameters, σ_z is the subsurface shape factor, σ_y is the surface storage shape factor, C_1 and C_2 are the inlet flow area parameters, A_0 is the inlet flow area.

3.2 Infiltration Characteristics

The average infiltration parameters of modified Kostiakov-Lewis equation and Philip equation are shown in Table 2.

Table 2. Average values of the modified Kostiakov-Lewis equation and Philip equation parameters.

Irrigation number	Kostiakov-Lewis equation			Philip equation	
	k	a	f_0	S	A
4	0.0178	-0.282	0.00252	0.010654	0.002481
5	0.0226	-0.371	0.00237	0.012223	0.002334
6	0.0248	-0.598	0.00226	0.010427	0.002244

Negative values were observed for all values of the time exponent in the modified Kostiakov ó Lewis equation. This negative value for the exponent is physically impossible (Esfandiari and Maheshwari, 1997). The reason for this may be that the irrigation advance decreases quite slowly and stays nearly constant at some points along the furrow due to uneven slope observed in the furrows on the field (Serralheiro, 1995). Also depending on the particular combination of L , $L_{0.51}$, Q and f_0 , a low value of the time exponent of the power advance equation is required for $-a\theta$ to be positive in the modified Kostiakov ó Lewis equation. Relatively high values of f_0 , which may be due to inaccuracy in determining the outflow, may also be responsible (Serralheiro, 1995).

3.3 Performance of the Models

Evaluating the performance of the furrow irrigation models involves determining their overall accuracy to predict water advance for a given field condition. Table (3) shows the values of the various indices for the different models for the irrigation events.

Table 3. Values of λ , N, σ , R^2 and E for the different models for predicting advance in irrigation events 4, 5 and 6 respectively.

Irrigation number	Model	λ	N	σ	R^2	E (%)
4	M ₁	1.0619	6	0.84	0.9984	6.94
	M ₂	1.0048	6	1.72	0.9772	11.30
	M ₃	0.3952	6	6.85	0.9570	34.67
5	M ₁	1.0238	6	0.41	0.9993	2.78
	M ₂	1.0571	6	1.97	0.9760	13.01
	M ₃	0.3524	6	7.34	0.9387	33.01
6	M ₁	1.0286	6	0.00	0.9978	3.47
	M ₂	0.9905	6	0.52	0.9979	4.72
	M ₃	0.3048	6	7.84	0.9540	43.56

Table 4. Average values of λ , N, σ , R^2 and E for the different models for predicting advance.

Model	λ	N	σ	R^2	E (%)
M ₁	1.04	6	0.42	0.999	4.40
M ₂	1.02	6	1.40	0.984	9.67
M ₃	0.35	6	7.34	0.950	37.08

N is the number of observed and predicted advance distances, M₁ is the Walker and Skogerboe model, M₂ is the Michaelis advance model, M₃ is the Philip and Farrell model.

The performances of the models for predicting advance distance for the irrigation events monitored at the Galma Irrigation Scheme were quantified by calculating λ , σ , R^2 and E. Considering the number of irrigation events (15) in the evaluation of the models, Table (4) shows that Walker and Skogerboe model predicted the advance distances in the furrows with a higher accuracy ($\lambda = 1.04$, $\sigma = 0.42$, $R^2 = 0.999$ and E = 4.40%) when compared with the other two models which is in agreement with the findings of Eldeiry et al., 2004. The slope and error of estimate values indicate an unbiased prediction and very low prediction error by the model. This means, the Walker and Skogerboe model is superior to the other two models for predicting advance distances at this site, especially for evaluating furrow irrigation systems. The reason for this may not be far from the input parameters which include; the modified Kostiakov & Lewis infiltration parameters, surface storage factor and time exponent of the advance equation.

The performance of the Michaelis Advance model for predicting advance was relatively high too as the average λ , σ , R^2 , and E values were 1.02, 1.40, 0.984 and 9.67%, respectively. The slope value shows an unbiased prediction. However, the lower value of R^2 and higher values of σ and E indicate that the advance distances predicted with the model will result in slight errors compared to the Walker and Skogerboe model. The reason for the average performance might be related to the average depth of flow along the furrow which was used in computation which was not a true representation of the depth of flow measured at the various stations. There was either an increase or a decrease from the actual depth of flow measured at the various measurement stations established along the furrows.

The performance of the Philip and Farrell model for predicting advance was very poor with average λ , σ , R^2 and E values of 0.35, 7.34, 0.950 and 37.08%, respectively. The slope value shows very high under prediction while the σ and E values indicate very high prediction errors by the model. The reason for the poor performance of the Philip and Farrell model is probably related to the fact that the model uses only Philip's infiltration parameters to predict advance distances as compared to Walker and Skogerboe, and Michaelis Advance models that use surface storage factor and time exponent of advance equation, and

average depth of flow, respectively in addition to the modified Kostiakov ó Lewis infiltration parameters. The reason may also be associated with the assumption employed in developing the model, which is, the model assumes the depth of flow to be zero. However, in practice this is not true. It should be recalled too that Philip established his equation for infiltration into a uniform homogeneous soil (Philip and Farrell, 1964; Serralheiro, 1995). Therefore, it is not surprising that such an equation type did not perform well in predicting advance distance in heterogeneous soil profile such as the one obtained at this site. For these reasons, the Philip equation is not able to predict infiltration accurately. The modified Kostiakov ó Lewis equation is similar to the Philip's equation except for a variable exponent in its first term (Esfandiari and Maheshwari, 1997). As shown in Table (2), the values of the time exponent are very low compared with the fixed value (0.5) of the time exponent in the sorptivity term of the Philip's equation. Furthermore, Philip's infiltration parameters used in the evaluation of the model were obtained by fitting Philip infiltration equation into data generated from the modified Kostiakov ó Lewis equation which could result in some computational errors.

The t - test shows that the table value for 5 degrees of freedom and 5% level of significance (2.571) is higher than the calculated values (0.8292, 2.3107 and 0.7266) for M_1 , M_2 and M_3 , respectively. It implies that the difference between the means of the calculated values by the models and the observed values is not significant statistically at 5% level of significance.

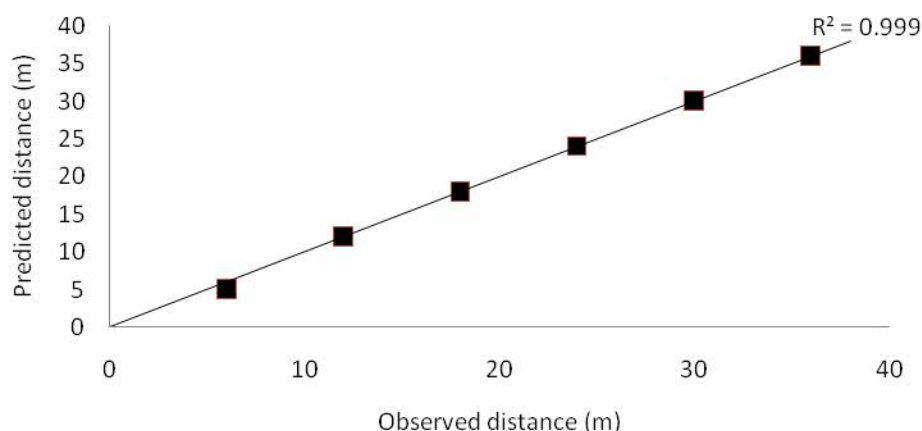


Fig 1: Plot of observed distances versus predicted distances by Walker and Skogerboe model

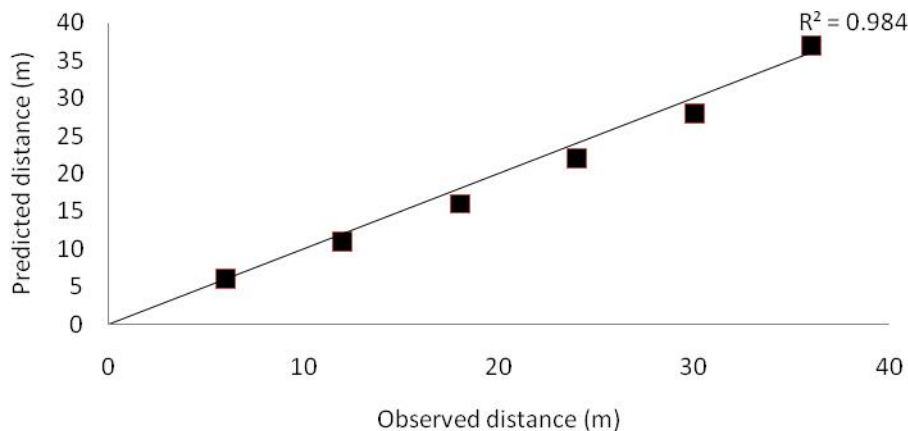


Fig 2: Plot of observed distances versus predicted distances by Micheal's Advance model

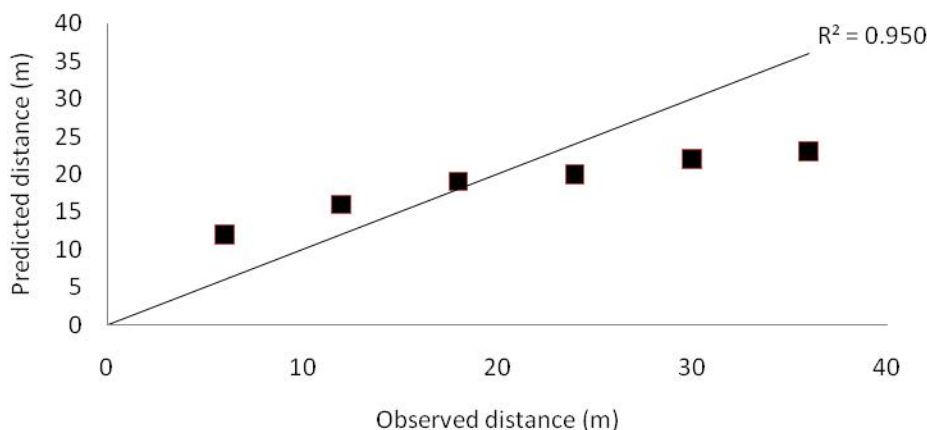


Fig 3: Plot of observed distances versus predicted distances by Philip and Farrell model

The t - test for significance of the intercept and coefficient of regression (slope) for the regression equations of the various irrigation events show that the values were not significant at 5% level for the regression equations using values predicted by Walker and Skogerboe, and Michael's advance models while that of Philip and Farrell model were all significant at 1% level.

Figures 1 - 3 show plots of observed distances versus predicted distances for the average of the irrigation treatments using the different models for predicting advance distance. The data for all the advance distances with the Walker and Skogerboe model falls on the 1:1 line except for the first point (see Fig 1). This shows that there was a good fit with the observed distances. The data for the predicted distances by the Michael's advance model falls very close to the 1:1 line signifying little variation from the observed distances (Fig 2). There was a considerable scatter of data points for the predicted distances by Philip and Farrell model except for the one data point mid-way of the entire length (Fig 3). This shows no agreement between the observed and predicted distances.

4. CONCLUSIONS

In conclusion, the performance of the Walker and Skogerboe model and Michaelis advance model were satisfactory though the Walker and Skogerboe model was found to provide the best fit for simulating furrow irrigation under the field conditions encountered in this study. The predictions by Philip's model were very poor with respect to the indices used to compare. This study has also shown that apart from the critical influence of the soil infiltration characteristics on the design and performance of surface irrigation, furrow geometry is also an important parameter for determining advance distance and should be included among the design parameters in installation and maintenance of furrow irrigation systems. Therefore, the application of these models under verified field conditions would lead to the determination of accurate discharge rate and application time that would optimize irrigation performance, minimize water wastage and allow proper growth of the crop.

NOTATIONS

A parameter related to saturated hydraulic conductivity (m^2/min)

A_0 inlet flow area (m^2)

a Kostiakov & Lewis infiltration time exponent

c intercept

C_1 and C_2 are inlet flow area parameters

E absolute error (%)

f_0 basic infiltration rate ($\text{m}^3/\text{m}/\text{min}$)

k Kostiakov & Lewis infiltration constant ($\text{m}^3/\text{m}/\text{min}$)

L length to the end of the field (m)

$L_{0.51}$ one & half the length of the field

M_1 is the Walker and Skogerboe model

M_2 is the Michaelis advance model

M_3 is the Philip and Farrell model

N number of observed and predicted advance distances.

q inflow rate (m^3/min)

r advance equation time exponent

S sorptivity ($\text{m}^2/\text{min}^{0.5}$)

t time from beginning of irrigation (min)

X advance distance (m)

X_c calculated distance (m)

X_0 observed distance (m)

X_p predicted distance (m)

y mean depth of flow (m)

β beta

Γ gamma function

λ slope of the best-fit line

σ_y surface storage shape factor

σ_z subsurface shape factor

σ_1 and σ_2 area shape factor parameter

α_1 and α_2 top width factor parameters

γ_1 and γ_2 wetted perimeter factor parameters

REFERENCES

- Adamu, J.Y. 1990. Prediction of advance and recession curves and design of a border irrigation system. M.Sc Thesis, Ahmadu Bello University, Zaria.
- Dalhat, M.K. 1988. Evaluation of irrigation performance under high water table conditions. M.Sc. Thesis, Ahmadu Bello University, Zaria.
- Eldeiry A., Garcia L., El-Zaher A.S.A., and Kiwan M. EL-Sherbini, 2004. Furrow irrigation system design for clay soils in arid region.
www.hydrologydays.colostate.edu/Papers_2004/Eldeiry_1_paper.
- Elliott, R.L. and Walker, W.R. 1982. Field evaluation of furrows infiltration and advance functions. Transactions of ASAE. 25(2):396-400.
- Esfandiari, M., and Maheshwari, B. L. 1997. Application of the optimization method for estimating Infiltration Characteristic in Furrow Irrigation and its comparison with other methods. agricultural water management, Vol. 34, 169 ó 185.
- Estandirari M., and Maheshwari B.L. 2001. Field evaluation of furrow irrigation models. Journal of Agricultural Engineering Research, 79(4):459-479
- FAO, 1993. Guidelines for designing and evaluating surface irrigation systems. FAO Document Repository. www.fao.org/documents.
- FAO, 2005. Aquastat, FAO's information system on water and agricultural. www.fao.org/nr/water/aquastat/countries/nigeria/index.stm
- Jobling, G. A., and Turner, A. K. 1973. Physical model study of border irrigation. Journal of the Irrigation and Drainage Division, ASCE, 99, 493 ó 510.
- Hornbuckle, J. W., Christen E. W. and Faulkner, R. D. 1999. Improving the efficiency and performance of furrow irrigation using simulation modeling in South ó Eastern Australia. Environmental Engineering Department, University of New England, Armidale, New South Wale, Australia.
- Larry, G.J. 1988. Principles of farm irrigation system design. John Wiley and Sons. New York.
- McClymont, D. 1999. Furrow irrigation design optimizer (FIDO v2). A Paper presented at the multiple objective decision support system conference, Sheraton Hotel ó Brisbane, 1 ó 6 August, 1999.
- Michael, A.M. 1968. Evaluation of hydraulic characteristics influencing border irrigation design. Ph.D Thesis, Department of Agricultural Engineering, Indian Institute of Technology, Kharagpur. 420p
- Mudiare, O. J. 1982. Development of design procedure for an automated border dyke system. M.Sc. Thesis, University of Saskatchewan, Saskatoon, Canada.
- Mudiare, O.J. 1987. Estimation of design inflow into irrigation borders using advance and recession Curves. Nigerian Journal of Engineering. Vol 4(2):1-9
- Oyebode, M.A. 1989. Development of design procedure for border irrigation system. M.Sc. Thesis, Ahmadu Bello University, Zaria.
- Philip, J.R., and Farrell, D.A. 1964. General solution of the infiltration-advance problem in irrigation hydraulics. Journal of Geophysics Research. Vol 69 (4):621-631.
- Philip, J.R. 1957. The Theory of infiltration: 4. Sorptivity and the initial moisture content. soil science. 84:257-264.
- Serralheiro, R.P. 1995. Furrow irrigation advance and infiltration equations for a mediterranean soil. Journal of Agricultural Engineering Research. Vol. 62: 117-126.
- Walker W.R. and Skogerboe G.V., 1987. Surface irrigation theory and practice. Utah State University, USA.
- Zerihum, D. and Sanchez, C.A. 2003. A draft procedure for development of management curves for basins irrigation on the coarse texture soil of the Yuma MESA.
www.ag.arizona.edu/aes/yac/researchdawit.

DEVELOPMENT OF A DIGITAL CONE PENETROMETER

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ABSTRACT

Penetrometers are instruments used in soil tillage and dynamics, site explorations, road and foundation construction and crop root growth and development research. They may have either a flat or a cone probe, depending on intended use. They may also be of the static, dynamic, proctor, pocket or digital type.

A digital cone penetrometer that reads directly and displays values of soil resistance to penetration in digits via a 7-segment display has been designed and developed in this study. The instrument is made up of mechanical and electronic parts. The mechanical part consists of the handle, graduated pressure shaft, spring loaded pressure chamber, penetration shaft and a cone probe. Following the recommendations in ASAE Standards, the dimensions of the cone selected are: enclosed angle of 30°, cone-base area of 323mm², and diameter of 20.27mm; mounted on a 15.88mm diameter shaft. The electronic part is made up of an infra-red displacement sensor/transducer which senses and converts changes in the displacement of the pressure shaft to digital value that indicates the measure of soil resistance to penetration or soil strength. Readings obtained on the 7-segment display during the field test ranged from 001 to 276 corresponding to pressure shaft displacements of 0.00cm to 17.00cm. The instrument was therefore found useful for measurement of soil resistance to penetration (cone index) usually required in soil strength analysis for agricultural machinery design and development and other related fields.

KEYWORDS: Cone penetrometer, soil tillage, soil strength, cone index

1. INTRODUCTION

According to Onwualu and Watts (1993), one of the most useful methods of expressing soil strength is its resistance to the penetration of a conical metal probe referred to as penetrometer resistance (Cone index). Cone index is widely used in many engineering, applications including site explorations, foundation and highway construction (Sanglerat, 1987; TrofimenKov, 1988). In agricultural applications, it is extensively used in assessing impedance to root growth and crop establishment (Ball and O'Sullivan, 1982; Canarache, 1990), soil compaction (Wismer and Luth, 1974; Ohu et al, 1988; Bueno et al, 2006;), and the effectiveness of tillage operations (Carter, 1988). Apart from the more traditional uses, penetrometers are part of standard equipment in soil bin facilities where they are used for checking the uniformity of the soil in the bin before actual tests (Sun et al, 1986). They are also useful in assessing the strength status of the soil before and after tillage and compaction experiments.

Despite the importance of penetrometer to researchers and other workers as already stated; the authors of this article discovered that the instrument is not readily available for purchase in the country by those who need them. Also dealers on scientific/engineering equipment and laboratory instruments that actually know the instrument are scarce, and when you see any, the cost at which such dealers give out the instrument after importing them with hard currency is usually on the high side. These situations led to the conception of the idea to develop an indigenous design using locally available materials and following certain standard recommended dimensions of the probe. It is also intended to demonstrate that the instrument can be locally developed and mass produced at affordable price after the design is standardized. It is also noted that this is the first known indigenous attempt of this kind.

Onwualu (1991) developed a computer controlled penetrometer used in assessing soil strength in-situ in a soil bin facility at the Technical University of Nova Scotia, Halifax, Canada, now known as Dalhousie University. This was developed in response to his research need as at then and following standard specifications in the ASAE Standards. The basic specifications for a penetrometer are described in ASAE standard S313.2 (Hahn and Rosentrator, 1989). The standard specifies a cone having an enclosed angle of 30° , which is mounted on a polished shaft. Two cone-base sizes are specified: 323mm^2 , 20.27mm diameter cone mounted on a 15.88mm diameter shaft; and a 130mm^2 , 12.83mm diameter cone mounted on a 9.53mm shaft for hard soils. The cone and the shaft are pushed into the soil at a specified speed of 30mm/s. Cone penetrometer is rarely available and importing them could be quite expensive. Therefore the objective of this work is to develop a digital cone penetrometer that will be used for agricultural soil tillage studies.

2. MECHANICAL DESIGN AND MECHANISM OF OPERATION OF THE CONE PENETROMETER

The mechanical part of the cone penetrometer is made up of the following major components (Figs. 1 and 2): the handle, the graduated pressure shaft, the pressure chamber consisting of a cylinder with a spring inside, the soil penetration shaft, and the cone probe.

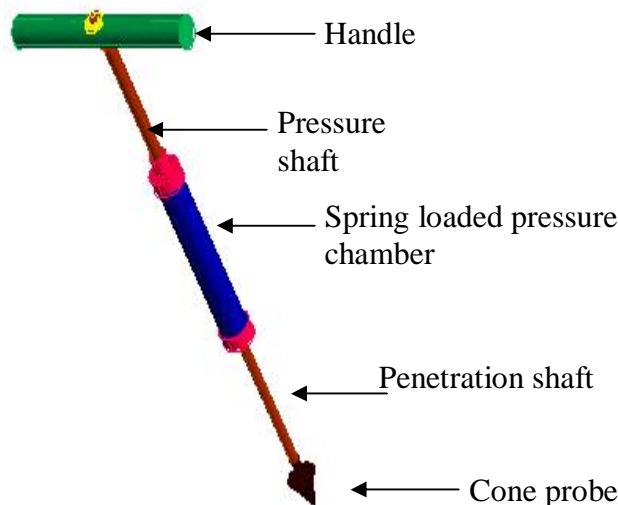


Fig. 1. 3D-drawing of cone penetrometer

As the operator holds the instrument vertically over a soil surface and through the handle pushes into the soil; applied pressure goes from the handle through the pressure shaft, compressing the spring in the cylinder. The penetration shaft is then pushed by the compressing spring and it penetrates into the soil by the attached cone probe at the tip of the shaft. The speed of penetration is usually about 30mm/s; and soil resistance to penetration is measured by the change in displacement of the pressure shaft as it compresses the spring in the cylinder. The pressure shaft moves down into the cylinder as it compresses the spring, and at the end of penetration to the required soil depth, it returns back to its original position as the applied pressure is removed and the spring regains back its initial length before compression.

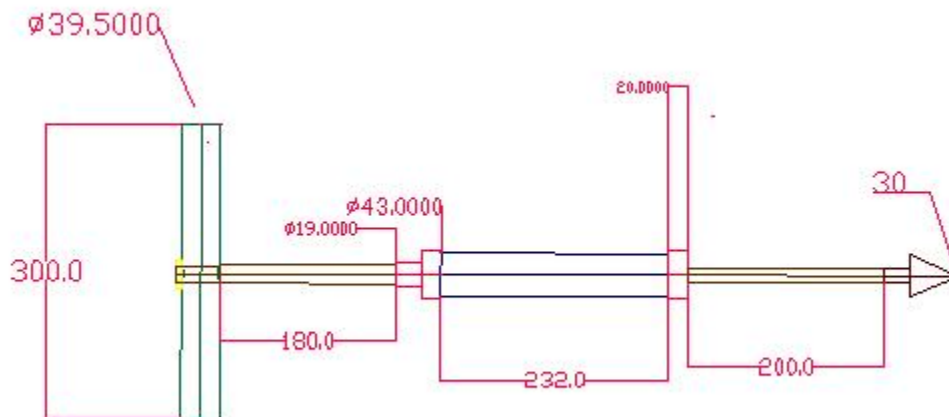


Fig. 2. 2D-drawing of cone penetrometer with (dimensions in mm)

3. ELECTRONIC DESIGN AND CONSTRUCTION

An attempt has been made to design and construct a resistive sensor and transducer which converts the displacement of a graduated shaft compressing a spring in the penetrometer assembly to its digital equivalent by means of an infra-red transmitter and receiver. The electronic network of components used to achieve this include : infra-red transmitter and receiver, an astable oscillator, three 74192 digital counter I.C.s, three 7447 digital 7-Segment decoders, three 7-Segment display units, a monostable timer, and other general components like capacitors, resistors, diodes, switches, connecting wires, etc. The block diagram of the electronic design is as shown in Figure 3.

3.1 The Infra- Red Sensors

These are transducers that transmit infra-red signals when their electrical properties are altered (i.e. for the infra-red transmitter) or change their electrical properties when they receive infra-red signals (i.e. for the infra-red receiver). The infra-red sensors are of two types: the IR-transmitter (IRTx) and the IR-Receiver (IR-Rx).

3.1.1 The Infra-red Transmitter (IRTx)

In appearance, this looks like a white LED (Light Emitting Diode) but it is different because the IRTx does not produce any constant light when you supply a 5VDC to it unlike the LED. However, the polarity of the IRTx is similar to that of the LED. The IRTx produces and transmits infra-red signals in a direct line of sight when it is clocked by an oscillating negative voltage.

The strength of the IR-signals generated from the IR-Tx can be increased by increasing the DC voltage to the transmitter from 6VDC to less or equal to 12VDC, increasing the current supply and also by streamlining the infra-red rays to prevent them from scattering. In this design, the oscillating negative voltage is from an astable (555) timer.

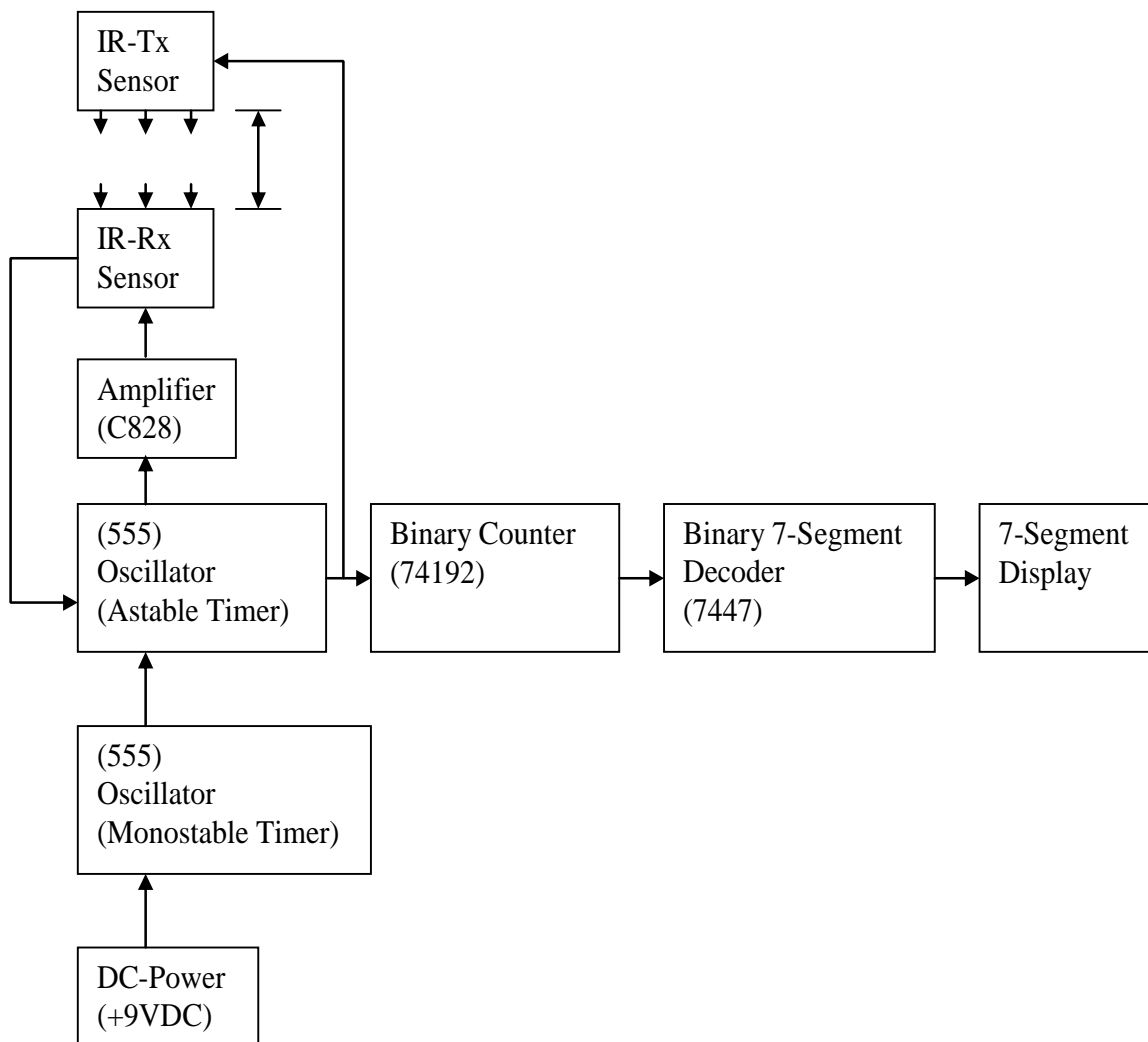


Fig. 3. Block diagram of the digital Cone penetrometer

The general circuit diagram for the electronic design of the digital cone penetrometer is presented in Fig. 4.

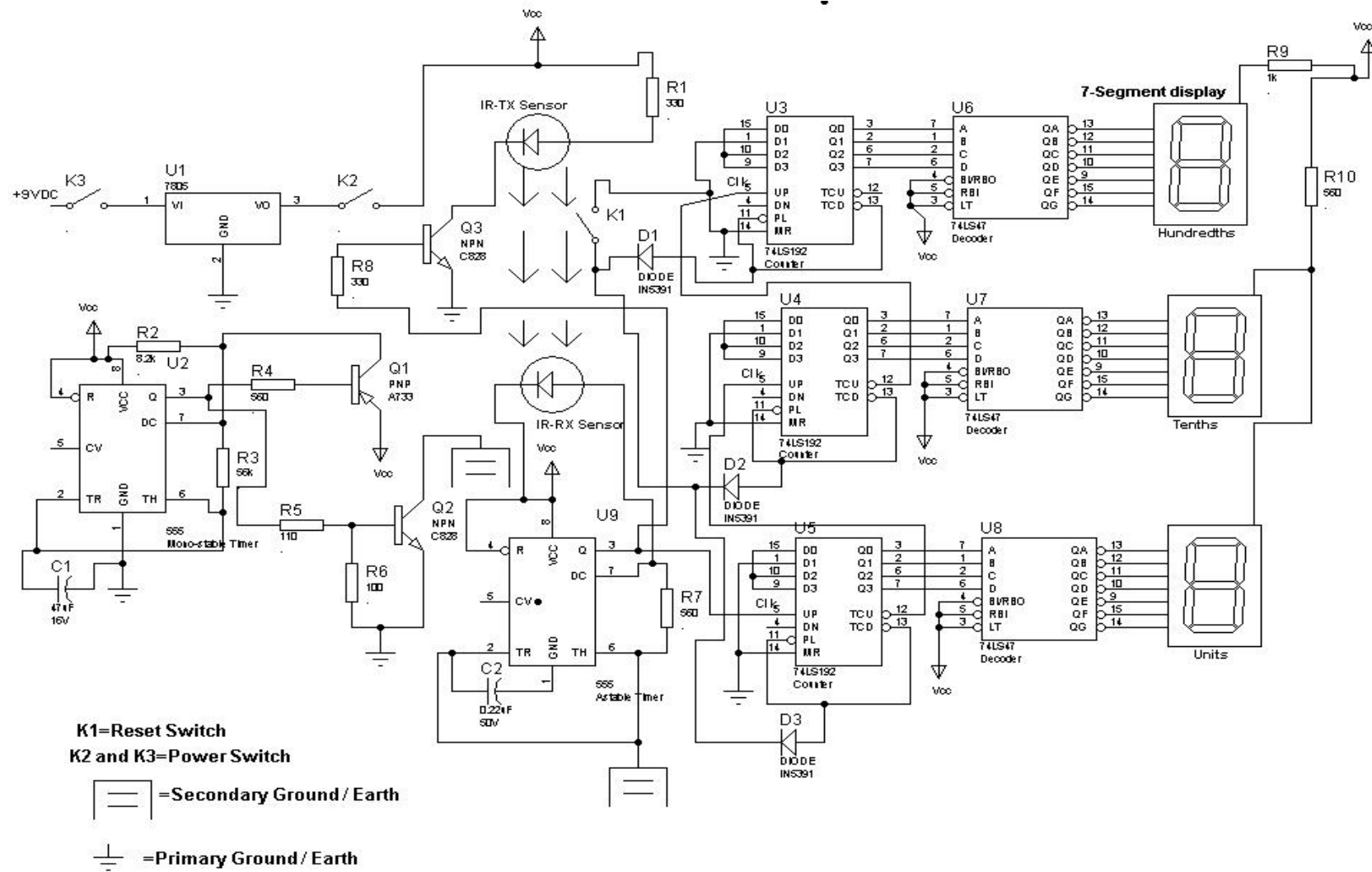


Fig. 4. General circuit diagram for the electronic design of digital cone penetrometer

3.1.2 The Infra-red Receiver

In appearance, this looks like a black LED and it also behaves like a diode. In the dark (absence of light), it allows current to pass easily in one direction. That is to say that it has high impedance in its reverse bias direction and low impedance in its forward bias direction. But in the presence of light, the IR-Rx has low impedance (to the flow of electric current) in its reverse bias direction. Hence, its impedance in the reverse bias direction decreases more as the intensity of the infra-red signals (falling directly on it) increases. If the IR-red signals from the IRTx are placed directly in front of the IR-Rx, its impedance in the reverse bias direction will be highly reduced. But by increasing the distance between the transmitter (IR-Tx) and receiver (IR-Rx), the strength or intensity of the IR-signals on the IR-Rx will be decreasing; thereby increasing the resistance/impedance of the IR-Rx in its reverse bias-direction. This makes the IR-Rx a resistive-sensor. It is possible to convert the analog resistance (in the mechanical soil penetrometer) to corresponding varying electrical signals which could be processed and displayed in digital form.

IR-Rx is placed as a resistance material between pin 8 and pin 7 of the same astable timer (oscillator) (Fig. 4), which controls the transmission of the IR-signals. When the IR-Rx (sensor) has very low reverse impedance (in the closest position of the IR-Tx to the IR-Rx), the astable timer/oscillator oscillates very fast up to 300 Hz. But when the IR-Rx-sensor has very high reverse impedance (i.e. in the threshold farthest position of the IR-Tx from the IR-Rx), the oscillator oscillates very slowly to the tune of < 0.3 Hz.

It is at this point that the monostable timer of 1Hz comes in to be used in stopping the oscillator after every one second of their being switched on at same time. Break in oscillation has been incorporated to allow the digital displays to display the frequency which the oscillator oscillates as to represent corresponding analog soil resistance to penetration.

3.2 The Astable Oscillator

This is a simplified circuit that is formed from delicate connections of two resistors (or resistant materials), and one capacitor to a 555 timer I.C. (Integrated Circuit). The 555 timer I.C. on its own has transistors, resistors, operational amplifiers, etc inside it. The time operation of the 555 is based on the process/principle that allows the switching of the internal transistors only when the external capacitor has charged to a threshold level. And the rate at which the energy stored on the capacitor can be discharged across the internal transistors is determined by the values of the external resistances connected to the I.C. Thus, the higher the value of the external capacitor, the more the time it will take for the capacitor to charge to its threshold level that will then allow it to switch the internal transistors. Also, the higher the values of the external resistances, the more the time it will take to discharge the charges stored in the external capacitors. When the charges on the capacitor have been discharged to minimum threshold, the internal transistors will switch off thus allowing the process of charging and subsequent discharging to repeat itself in an oscillating manner.

When the internal transistors of the 555 timer are switched on, a negative (-ve: i.e. a low) voltage is sent out from the output pin (pin 3) of the 555 timer I.C. But when the internal transistors are off, a positive (+ve: i.e high) voltage is sent out from the output pin (pin 3) of the I.C. IR-Rx has been used in the oscillation as one of those external resistances that determine the frequency at which the oscillation will take place. The same oscillator is used (in a bid to miniaturize the electronic design) for clocking the IR-Tx so that it can keep producing the IR-signals.

3.3 The Monostable Timer

This is a special design with the 555-timer I.C., which has the ability to permanently switch a low (-ve) output from its output pin 3 after giving out a +ve output from the pin for one second. This one second is set by the value of the external capacitor and resistor attached to the I.C.

The monostable timer drives the oscillator I.Cs. by supplying the +ve voltage for the oscillators groundable pin (i.e. pin 1 of the astable 555 timer). When the monostable timer has permanently given out a low voltage from its output pin, it will make the oscillation to stop oscillating because its pin 1 is no longer grounded. Thus the oscillator is open circuited at this point. This enables the counters to display the numbers representing the frequency at which the oscillator just counted.

3.4 The 74192 Digital Counters

The 74192 digital counter is an electronic I.C. that displays in binary form the number of clocks of negative signal which it receives into its pin 5 (clock - input pin). It can display in binary form (i.e. ones and zeros: e.g. 0000=0, 0001 = 1, 0010 = 2, 1000 = 8, etc) clocks ranging from 0 (i.e. first -ve clock) to 9 (i.e. 10th +ve clock input). Hence, at this 10th +ve, clock, the 74192 gives out a +ve output (i.e. low) from its pin 12 (called the \bar{Q} carry \bar{O}).

In this design, the +ve output from the (primary) 74192 counter at its 10th count is used as a +ve clock input to another 74192 called the secondary counter. And its own 10th count (i.e. 100th count of the primary counter), the secondary counter sends out a +ve output from its own pin 12. This +ve output from the pin 12 of the secondary counter is thus used as the +ve clock input to the third digital counter (called the tertiary counter).

This arrangement allows the primary counter to represent on its output the binary form of units, while the secondary counter represents the binary form of tenths and tertiary counters represent the binary form of hundredths. Hence, the binary numbers are displayed in their equivalent decimal forms by the use of one 7447 digital decoder and one 7-segment display on each 74192 counter.

3.5 The 7447 Segment Decoders

This is also an 8 by 8 pins (i.e. 16 pins) I.C. just like the 74192. It has the ability to convert binary numbers (of four line data base i.e. four line wire connection paths) to their equivalent 7-line data base, which can light a 7-segment display unit so as to display the decimal form of that number that it receives. In this design, one 7-segment decoder is used in each of the three 74192 counter. And each of the 7447 decoder supplies one 7-segment display unit.

3.6 The 7-Segment Display

This is an array of 7-light emitting diodes. Three LEDs are rectangularly arranged so as to represent numbers 0 to 9 depending on the set of LEDs that are powered ON at any point in time. Thus, six of the 7-LEDs are equally spaced around a rectangular space that has length = 2 x width while the remaining one LED is placed at the center of the rectangular space. Fig. 5 shows the picture of the completed digital cone penetrometer while Fig. 6 shows the instrument being tested for measurement of soil cone index.

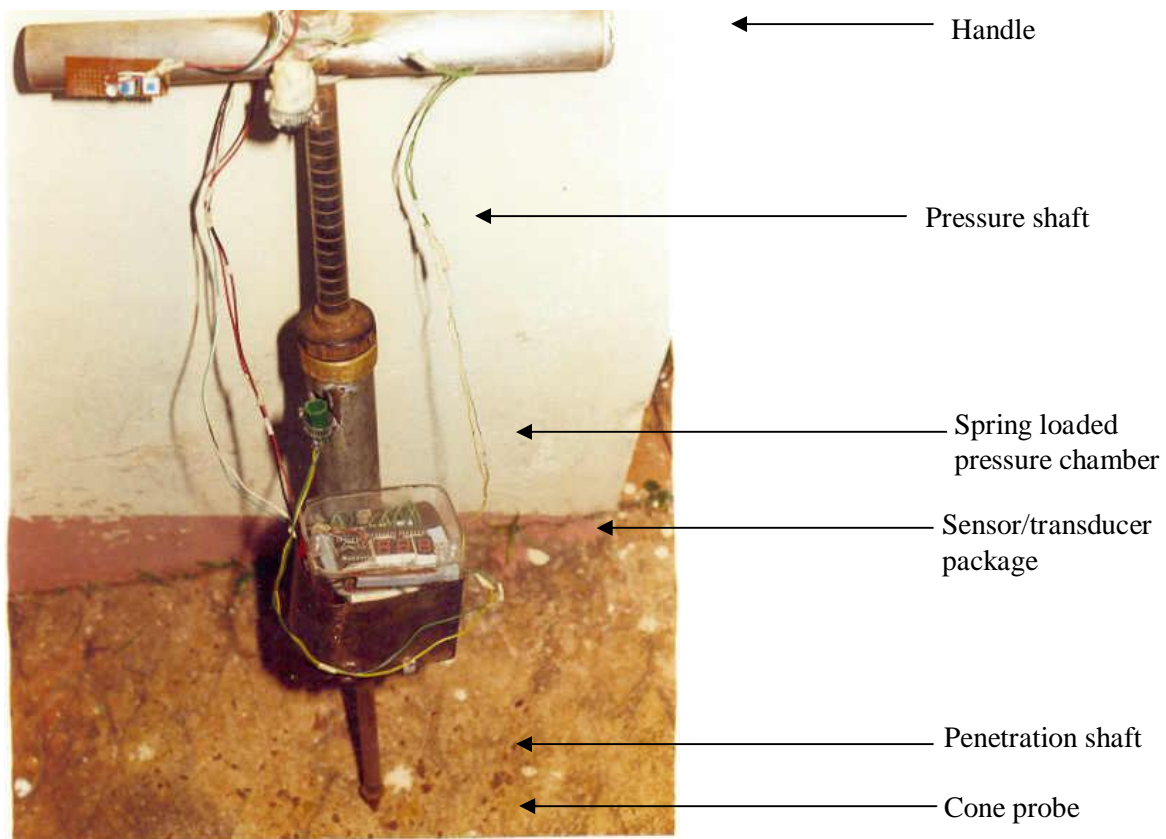


Fig. 5. Completed digital display of the cone penetrometer



Fig. 6. Penetrometer being tested in measuring soil resistance to penetration.

4. RESULTS

The instrument was tested by using it to measure soil resistance to penetration in the field (Fig. 6) and the results obtained are as shown in table 1.

Table 1: Results of Testing of Digital Cone Penetrometer

Number of trials	Pressure shaft displacement (cm)	Penetrometer readings
1	0.00	001
2	5.00	004
3	7.00	007
4	9.00	019
5	10.00	074
6	11.00	104
7	13.00	152
8	14.00	200
9	15.00	224
10	17.00	274

5. CONCLUSION

A digital cone-penetrometer that reads directly and displays values of soil resistance to penetration in digits via a 7-segment display has been designed, constructed and tested. The instrument is reliable for testing soil resistance to penetration. The design is simple and the materials are readily available. This makes it possible to easily reproduce for commercial production for basic research in soil mechanics, tillage and soil dynamics.

REFERENCES

- Ball, B.C. and O'Sullivan, M. F. 1982. Soil strength and crop emergence in direct drilled and ploughed cereal seedbeds in seven field experiments. *J. Soil Science*, Vol. 33, pp. 609 ó 622.
- Bueno, J., C. Amiama, J. L. Hernanz and Pereiar, J. M. 2006. Penetration resistance, soil water content, and workability of grasslands soils under two tillage systems. *ASABE Transactions* Vol. 49, No. 4, Pg.875-882.
- Canarache, A. 1990. PENETR ó A generalized semi ó empirical model estimating soil resistance to penetration. *Soil and tillage Res.*, Vol. 16, pp. 51 ó 70.
- Carter, M.R. 1988. Penetration resistance to characterize the depth and persistence of soil loosening in tillage studies. *Can J. Soil Science*, Vol. 68, pp. 657 ó 668.
- Hahn, R.H. and E.E. Rosentreter (Editors) 1989. Soil cone penetrometer. ASAE Standard S313.2, ASAE Standards (36th Edition). ASAE, St. Joseph, MI.
- Ohu, J.O., G.S.V. Raghavan and Mckyes, E. 1988. Cone index prediction of compacted soils. *Trans. of the ASAE*, Vol. 31, pp. 306 ó 310.
- Onwualu, A.P. (1991). Tillage tool factors affecting sandy soil interaction with plane blades in a Soil bin. PhD Thesis, Technical University of Nova Scotia, Halifax, Canada.
- Onwualu, A.P. and K.C. Watts 1993. Real ó time measurement of cone index in a soil bin. *Computers and electronics in agriculture*, Vol. 9, pp. 143 -ó157. Elsevier Science Publishers B.V., Amsterdam.
- Sanglerat, J. V. 1987. *The Penetrometer and soil exploration*. Elsevier, Amsterdam.
- Sun, T.C., J.D. Jarrel and Schafer, R. L. 1986. Computer instrumentation for the NSDL soil penetrometer. *Comput. electron. Agric.* Vol. 1, pp. 281 ó 288.
- Trofimenkov, Y. G. 1988. Determining the mechanical characteristics of soils from static penetration data. *Soil Mech. Found. Eng.*, Vol.25, pp 45-49.
- Turner, J.D. 1988. *Instrumentation for engineers*. Macmillan Education Ltd, Houndmilk.
- Wismer, R.D. and Luth, H. J. 1974. Off-road traction prediction for wheeled vehicles. *Trans of the ASAE*, Vol. 17: 8 ó 10, 14.

ECOLOGICAL PROBLEMS IDENTIFICATION WITHIN WATERSHEDS IN NIGERIA

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ABSTRACT

The ecosystems, their goods and services, and their current state in Nigeria are defined. The paper presents various environmental indicators of ecological problems and identifies the environmental problems that beset our current developmental efforts and activities.

The ecosystem approach is presented as optimizing the array of goods and services which the ecosystems produce while preserving or increasing their capacity to produce in the future. Thus, the ecosystem approach reorients the boundaries of management, emphasizing a holistic and systemic approach that recognizes ecosystems as functioning as whole entities. It looks beyond the traditional jurisdictional boundaries since ecosystems often cross state and national boundaries. The ecosystem approach takes a long, futuristic view.

This paper presents ecosystem processes at the micro level, but sees them in the larger frame of landscapes and decades, working across a variety of scales and time dimensions. It integrates social, economic and environmental information, linking human needs with biological capacity of the ecosystem. Thus, management is not successful unless it preserves or increases the capacity of an ecosystem to produce goods and services, *ad infinitum*.

KEYWORDS: Ecosystems, environmental impacts, ecological problems and indicators, ecosystem approach.

1. INTRODUCTION

Gorshkov et al. (2004) noted that the persistence of an environment suitable for life for any appreciable period of time is only possible with a substantial area of the earth's surface being occupied by natural ecosystems undisturbed by anthropogenic activities. Once the natural biotic mechanisms of environmental control are destroyed, both local and global environment rapidly degrade to a state unfit for life. The stabilizing effect of natural ecosystems, therefore, cannot be over-emphasized.

Ecology may be defined as the science of the relationship between life and the environment in which it exists. Ecological problems would then refer to environmental conditions which negatively affect life. Such conditions can definitely be controlled or minimized by management in order to sustain life and productivity or yield.

The primary goals of management of the natural resources on a watershed are: (1) to ensure the preservation of a quality environment, including aesthetics and recreation, while maintaining a desired level of productivity, and; (2) to ensure a continuous yield of useful and diverse products, such as plants, animals and materials, by establishing a balanced cycle of harvest (extraction) and renewal (inflow). In both cases, the action of management is required to reinforce the natural biotic mechanisms of environmental control.

2. THE ENVIRONMENT

Environment comprises land, water and air, which make up the natural environment, as well as the built environment including cultural landscapes, socio-economic activities and structures. The environment has the attributes of providing a life support system for human existence and survival, a source for the air we breathe, the water we drink, the food we eat, the space we live in, the raw materials we use, and the sink for the wastes we generate. Indeed the continuation of human civilization and progress on earth is dependent on the environment. It contributes to the quality of life as humans appreciate the countryside, wild life, peace, quiet and the finer cultural heritage of the past. However, it may have adverse effects on life because a poor environment means poor health, more stress and social unrest. The environment contributes directly to economic growth by creating business opportunities in leisure, tourism and pollution abatement. Also, resources for the production of consumer goods and services come from the environment.

Naturally, the environment possesses the quality and mechanism to act as a sink by absorbing human wastes, protecting and sustaining itself through self-purification processes, and hence encouraging further utilization. However human interference with these natural processes has accelerated the rate of degradation of the environment to hazardous levels. The results are accelerated soil erosion, floods, soil degradation, adverse climate change, deforestation, and loss of biodiversity.

3. ECOSYSTEMS, THEIR GOODS AND SERVICES

Ecosystems are the primary producing, solar-powered, factories that yield the most basic necessities of life such as food, fibre and water, all at efficiencies unmatched by human technology. Ecosystems also provide essential functions and services like air and water purification, climate control, nutrient cycling, and soil production. Harvesting the bounty of ecosystems roots our economy, and provides employment for 70 percent of our population as accounted for by agriculture, forestry and fishery, only.

Ecosystems also provide places for religious expression, aesthetic enjoyment, and recreation. Millions of people make pilgrimages to outdoor holy places, vacation in scenic regions, or simply pause and relax in a garden or park. They provide a psychological and spiritual backdrop for our lives. In every respect, human development and security are closely linked to the productivity of ecosystems and the future security of life rests squarely on their continued viability. Table 1 summarizes the primary goods and services which are provided by ecosystems.

Table 1. Primary goods and services provided by ecosystems

Ecosystem	Goods	Services
Agro-ecosystems	Food crops Fibre crops Crop genetic resources	Maintain limited watershed functions (infiltration, flow control, partial soil protection) Provide habitat for birds, pollinators, soil organisms important to agriculture Build soil organic matter Sequester atmospheric carbon Provide employment
Forest Ecosystems	Timber Fuelwood Drinking and irrigation water Fodder Non-timber products (vines, bamboos, leaves,	Remove air pollutants, emit oxygen Cycle nutrients Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) Maintain biodiversity Sequester atmospheric carbon

	etc.) Food (honey, mushrooms, fruit, other edible plants; game) Genetic resources	Moderate weather extremes and impacts Generate soil Provide employment Provide human and wildlife habitat Contribute aesthetic beauty and provide recreation
Freshwater Ecosystems	Drinking and irrigation water Fish Hydroelectricity Genetic resources	Buffer water flow (control timing and volume) Dilute and carry away wastes Cycle nutrients Maintain biodiversity Provide aquatic habitat Provide transportation corridor Provide employment Contribute aesthetic beauty and provide recreation
Grassland Ecosystems	Livestock (food, game, hides, fibre) Drinking and irrigation water Genetic resources	Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) Cycle nutrients Remove air pollutants, emit oxygen Maintain biodiversity Generate soil Sequester atmospheric carbon Provide human and wildlife habitat Provide employment Contribute aesthetic beauty and provide recreation
Coastal Ecosystems	Fish and shellfish Fishmeal (animal feed) Seaweeds (for food and industrial use) Salt Genetic resources	Moderate storm impacts (mangroves; barrier islands) Provide wildlife (marine and terrestrial) habitat Maintain biodiversity Dilute and treat wastes Provide harbours and transportation routes Provide human and wildlife habitat Provide employment Contribute aesthetic beauty and provide recreation

4. ENVIRONMENTAL PROBLEMS IN NIGERIA

(i) Deforestation

Deforestation in Nigeria is a very serious threat to long-term environmental sustainability. The rainforest in Nigeria is being depleted at an annual rate of 3.5 percent. In the 1980s, about 400 hectares of forest and woodland out of every 1000 hectares suffered from deforestation while only 25 hectares were reforested on an annual basis (UNDP Nigeria, 1996). According to the FAO, the remaining forest area in Nigeria will likely disappear by 2020 if the current rate of forest depletion continues unabated (FGN, 2000). In fact, poverty has been linked to forest depletion. Deforestation also affects a wide range of environmental situations, including water resources integrity, soil degradation, drought and desertification. Ninety per cent of the rural population in Nigeria depends on the forest for livelihood and survival. Vegetation

removal accelerates rainfall runoff and increases soil erosion, diminishing land productivity and aggravating local flooding.

(ii) Biodiversity Loss

Nigeria has a considerable diversity of habitats, from savanna forest in the extreme north to freshwater swamp forest in the south. Several plant and animal species exist in the country, and she derives all her food and a broad array of medicines and industrial inputs from both wild and domesticated components of biodiversity. About 248 species of mammals are found in these various vegetation zones of Nigeria, while 274 are found in the forests. There is high diversity of primates which are important to be conserved.

Despite the unquantifiable value of the rich biodiversity resources, the general ecosystem is under threat of mass elimination of species and genetic resources through the impact of man's activities. Uncontrolled logging and felling of trees are rampant and with increased pressure from hunters, poachers and bush burning, Nigeria's wildlife is declining. Animals that have recently disappeared to the neighbouring Cameroun include the cheetah, the pygmy hippopotamus, the giraffe, the black rhinoceros and the giant eland. The World Atlas of 1991 estimated that at least 50% or more gorillas are killed in Nigeria than born each year. Almost all surviving species of antelopes are threatened mainly due to over hunting. Leopards (*Panthera pardus*) that were common species are now rare, particularly because they are killed for their skins. There are about 2000 elephants remaining in Nigeria, but they are scattered and declining due to poaching and deforestation. Similarly, birds, tortoises, monkeys, crocodiles and monitor lizards are declining in population.

(iii) Drought and Desertification

Drought and desertification occur mainly in the northern parts of Nigeria and affect states like Kebbi, Sokoto, Katsina, Kano, Jigawa, Yobe, Kaduna, Borno, Bauchi, Zamfara, and Gombe. Others are Niger, Taraba, Adamawa, Plateau, and Nassarawa. Borno, which is one of the most affected states has about 55 per cent of its land under siege from desert encroachment (FEPA, 1992). The human factors associated with desertification include over cropping which diminishes soil fertility, and productivity, over-grazing and devegetation, disruption of soil stability, mismanagement of water resources, and salinization of croplands from irrigation projects. Climatic factors such as drought, and wind erosion are quite devastating and generally result in widespread famine, population migration, cattle and human deaths, and soil loss. Drought and desertification bring about severe disruption of the socio-economic development of the affected areas. Solutions include tree planting, afforestation, reduction in fuel wood consumption, control of over grazing and public education.

(iv) Soil Erosion

It is estimated that over 90% of Nigeria's total land area is under, rill and gully erosion (FGN, 1997). The spectacular gullies that have destroyed vast areas of land in Nanka, Agulu, Oko in Anambra State, Okigwe in Imo and parts of Abia, Enugu and Ebonyi States, present a vivid picture of the disastrous effect of gully erosion in Nigeria. There are currently over 2,000 active gullies spread across the country (FGN, 1997). Erosion reduces soil productivity and agricultural returns, pollutes watercourses, threatens infrastructure and lives and causes impoverishment of the people. The common erosion types in Nigeria are coastal erosion (prevalent along the coastal states like Lagos, Ondo, Delta and Rivers) due to excessive incursion of sea waves which wash off the land into the sea; gully erosion (most visible in Anambra, Enugu, Imo, Ekiti, Gombe, Kogi and Benue states; rill and interrill or sheet erosion, usually unnoticed but slowly removing the topsoil by surface runoff down the slope, found in Plateau, Anambra, Imo, Sokoto and Kwara states, among others; and wind erosion which is common in dry climates with low annual rainfalls. Examples of states where wind erosion occurs are Kano, Sokoto, Borno, Yobe and Zamfara.

Erosion results in the depletion of farmlands, loss of forest resources and reduction in agricultural outputs. It also results in pollution of surface water bodies, loss of land resources for other developmental purposes, destruction of properties and social amenities, as well as loss of lives in severe cases.

(v) Flooding

Flooding is a common occurrence in many parts of Nigeria. Generally, floods result mostly from poor watershed management, due to heavy rainfall. Human activities such as unplanned rapid urbanization, blockage of river/drainage channels, agricultural practices, dam construction and deforestation, lead to flooding. This environmental problem is felt in several parts of the country especially in the low lying areas of southern Nigeria where annual rainfall is quite heavy, such as Calabar, Warri, Port-Harcourt and Lagos; in the floodplains of the major rivers such as the Niger, Benue, Gongola, Sokoto, Hadejia, Katsina-Ala, Donga, Kaduna, Gurara, Ogun and Anambra; and in the flat, low lying areas around Lake Chad.

(vi) Air Pollution

The quality of air has deteriorated as a result of non-environment friendly activities and practices such as bush burning and gas flaring. Almost any airborne substance can be a pollutant when it occurs in excess. Pollutants such as dust and smokes, and toxic substances such as lead, sulphur and nitrogen oxides, methane, carbon dioxide, vehicular emissions and domestic fires are common in Nigeria. Pollution from the petroleum industry is so pervasive that it has generated social conflicts and frequent riots, which have attracted the attention of government as constituting security threat to the country. Nigeria still flares about 40% of the natural gas it produces. Some of the adverse environmental effects of petroleum production in Nigeria is the deposition of acid rain resulting in corrosion of roofs of houses scorching of vegetation and acidification of soil and water resources which is common in the Niger Delta.

(vii) Industrial Pollution

Industrial pollution has increased with expansion in industrial activities in Nigerian cities. Environmental problems resulting from industrial pollution vary considerably depending on the type of industrial process involved, the scale of production and the manner of handling the resultant waste products. Air pollution, for example has been recorded in the neighbourhood of cement factories and oil industries as a result of lime stone crushing and gas flaring while water pollution is experienced in areas of operation of textile mills, tanneries, petrochemical and paint industries with untreated waste waters discharged into streams and open drainages. Mining wastelands also exist in other parts of the country, especially Adamawa, Bauchi, Plateau, Bornu, Enugu, Niger and Yobe states. Emission from the industrial sector has been implicated in the acidification of the country's environment.

(viii) Climate Change

Climate change has become a source of concern in recent times especially because of its implications for ozone layer depletion and sustainable development. The reports of the Inter-Governmental Panel on Climate Change indicate that the last decade has been the warmest in hundreds of years and many parts of the world have suffered major heat waves, floods, droughts and extreme weather events. Global warming is the effect of greenhouse gases (GHG) particularly carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), chlorofluorocarbons (CFCs) and ozone (O₃) generated by human activities. Effects of climate change include rise in sea level, desertification, erosion and flood disasters, pole-ward shift of agricultural zones, biodiversity loss and chaotic climate patterns. Although Nigeria's contribution to the total volume of global greenhouse gas emissions is low (0.3% in 1996, UNDP, 2003), the amount has been increasing.

The climatic changes that may occur as a result of global warming may have significant implications for Nigeria. For instance, with a one-meter rise in sea level, Nigeria could lose over 18,000 square kilometers of coastal land, and well over 3.8 million people affected (CCA, 2001).

(ix) Water Pollution

Water pollution is a serious environmental problem in Nigeria. Nigeria's water supply is inadequate both in quantity and quality. Pollutants released into the water, soil and air find their way into the human body through the food chain. Water related diseases constitute about 80 per cent of the total disease burden in Nigeria. Most of the existing industries discharge their effluents without any form of prior industrial treatment into the rivers, lagoons, estuaries and the sea. Some of these are known to contain such toxic substances such as DDT, dyes, cadmium, etc, that ultimately contribute to pollution of water and destruction of aquatic life. A confirmation of serious and wide spread water pollution in Nigeria is the level of incidence of water-related diseases. Other non-point sources of water pollution are from agricultural and urban storm runoff water.

(x) Environmental Sanitation

Health care delivery and sanitation are still grossly inadequate in Nigeria. Inadequate sanitation is a major cause of the degradation of the quality of ground and surface water. Environmental sanitation characterized by inadequate waste management, excreta and sewage management, unsafe water supply, poor market and abattoir sanitation, breeding of pest and vectors of public health importance, and poor food sanitation, are among the very serious environmental problems in Nigeria. Communicable but largely preventable diseases like guinea worm, measles, tuberculosis, diarrhea, schistosomiasis, typhoid, cholera and dysentery are still prevalent and account for significant high morbidity and mortality. Indeed, in developing countries 80 per cent of all diseases result from a combination of poor hygiene, contaminated water and poor sanitation. This obviously is why inadequate water and sanitation hinders socio- economic development particularly against the backdrop of unstructured urbanization and rapid population growth. These environmental sanitation-related diseases exacerbate poverty by diminishing productivity and household income. Besides, a dirty, filthy environment with its attendant health consequences, prevailing in most of our cities, can discourage tourists and investors, undermining the economic benefits of tourism to the country.

(xi) Noise Pollution

Noise pollution is any undesirable, excessive sound that is a nuisance or is harmful to persons. Abnormal noise is common in Nigerian cities from the blaring of motor vehicle horns, music shops, bulldozer operators, market music, welders, mechanics, barking of dogs, night club music, and sounds from aircraft engines especially supersonic jets while landing or taking off. Noise can annoy, confuse and cause psychiatric disorder and stress. Noise pollution can result in hearing loss, and anxiety. It is clear that noise pollution degrades the environment by devaluing the quality of life.

(xii) Solid Waste Management

Heaps of municipal solid wastes and unsightly waste dumps are common sights in major Nigerian cities and towns. The per capita waste generation for Nigeria is about 0.5 kg per person per day. This figure may seem small at the individual level, but at the national level, the figures can become staggering. With urban population on the increase, Lagos city alone generates about 500,000 metric tonnes of solid waste each day. It is common to see streets overtaken by garbage and drainages filled with solid wastes, thereby blocking accessibility to roads.

5. ECOLOGICAL PROBLEMS AND THEIR IMPACTS

(a) Agriculture

Alteration in vegetative cover as a result of large-scale deforestation and land clearing affects the microclimate and leads to the loss of the carbon sink (absorption) functions of forests. This contributes to global warming and climate change. Soil degradation is common in the savannah and semi-arid areas especially during heavy rainfall and floods. Fauna and flora are disturbed by agricultural activities. Some habitats are destroyed while some fauna relocate. The overriding impact is the loss of biodiversity. Agrochemicals such as pesticides and fertilizers pollute the environment, causing collateral damage to soil and aquatic life and affecting public health. The hazards get to humans through the food chain.

Irrigated farming may increase the incidence of malaria, bilharziasis (Schistosomiasis), and river blindness (Onchocerciasis). Due to the peasant nature of Nigerian agriculture, relatively small environmental changes may translate into severe socio-economic impacts. Loss of vegetation cover and poor soil and water management practices may lead to reduced crop yields, low incomes and food insecurity.

(b) Afforestation and Deforestation

In general, afforestation and reforestation exert positive effects on the environment. However, the following concerns may arise in afforestation and reforestation projects: increase in the risk of wild fire; introduction of alien (new) tree species could change the ecosystem negatively and provide habitat for dangerous pests; access to new plantations of forests is usually restricted, thus affecting movement of the local people and their livestock.

(c) Fisheries

Possible acute decline of certain species of fish due to over-fishing may result in complex changes in the aquatic ecosystem. Dangerous fishing practices such as the use of Gammalin 20 etc., and explosives, may poison the food web and damage the substrate. Also, fishing structures such as jetties have the potential to enhance coastal sedimentation. Waste management problems also arise both from fisheries and the processing of fish. In addition to providing habitat for snails and mosquitoes, effluents from fish farms (aquaculture) could cause water pollution downstream, if untreated.

(d) Irrigated Agriculture

High water tables and water logging could result from excess irrigation water, seepage from reservoirs and from irrigation canals. Apart from negative effects on soil tractability and crop development, this leads to high salt content in the root zone causing reduced soil fertility. Pollution and salinization of groundwater may arise from deep percolation of irrigation water losses which carry nutrients and leachate from the surface to groundwater bodies. Also, irrigation water may be available to upstream farmers while those downstream are starved of the resource, causing community strife and social problems. A major socio-economic impact of irrigated agriculture is forced population relocation, especially in large-scale schemes.

(e) Livestock

Overgrazing, when vegetation consumption by livestock exceeds its natural growth leads to a disturbance of the ecological system. Soil degradation also arises from overgrazing as the exposed soil is subject to wind and water erosion. Livestock may affect water supply especially where wells and boreholes are the main water sources, and herds may pollute surface water bodies. Animals harbour certain pests and

disease-causing agents and these could be hazardous to human health, especially of their handlers. Negative impacts on socio-economic conditions may occur due to changes in the numbers, type, health or location of animals. For instance, concentration of livestock in an area could cause farmer-pastoralist conflicts. This is a very common impact in the country due to the prevalent nomadic herding (free ranging) regime.

(f) Biodiversity

Biodiversity is the degree of nature's variety including both the number and frequency of genes, species and ecosystems. Operationally, it can be considered at three different levels: genetic diversity, species diversity and ecosystem diversity. Genetic diversity is the sum total of genetic information contained in the genes of individual plants, animals and micro organisms that inhabit the Earth. Species diversity refers to the variety of living organisms on Earth, while ecosystem diversity relates to the variety of habitats, biotic communities, and ecological processes in the biosphere, as well as the tremendous diversity within ecosystems in terms of habitat differences and the variety of ecological processes.

Biological resources have made substantial contributions to man's welfare, especially in rural areas. In Nigeria, game constitutes about 20 per cent of the mean annual consumption of animal protein by people in rural areas. Globally, human beings have used about 7,000 kinds of plants for food, although only 20 species supply 90 per cent of the world's food, and just three - wheat, maize and rice - supply more than half.

Ecosystems such as forests, agro-ecosystems, grasslands, freshwater and coastal ecosystems (including coral reefs) and the biodiversity contained within them, also provide essential services that contribute in numerous ways to productive activities. Some examples of such ecosystem services that support livelihoods include provision of natural habitat for wild pollinators that are essential to food crops; natural predators that control crop pests and soil organisms important to agricultural productivity; watershed protection and hydrological stability, including recharge of water tables and buffering of extreme hydrological conditions that might otherwise precipitate drought or flood conditions; maintenance of soil fertility through storage and cycling of essential nutrients; and breakdown of wastes and pollutants. Because of these values, the need to protect, conserve and maintain our biodiversity resources cannot be over-emphasised.

The irreversibility of species extinction, and loss of genetic strains and ecosystem types through habitat degradation and over-exploitation, compromise options for present and future generations. It is therefore not possible to realize sustainable development without an effective strategy for biodiversity conservation and management.

(g) Energy

Nigeria's main environmental challenges associated with energy development and consumption result from oil spills, gas flaring and deforestation. Petroleum development activities in the Niger Delta region, especially, have caused severe environmental degradation. Oil spills, weak environmental regulations and failure to enforce the set regulations are largely responsible for the situation. Nigeria continues to suffer the effects of oil spills, as well as air pollution from the flaring of gas which occurs during the exploitation of oil. By 2008, when gas flaring ends, there should be some positive effects. A reduction in air pollution, an increase in the volume of gas available for domestic consumption and export, and an increase in revenue accruable to Government from the sale of the natural gas are expected. Air pollution from gas flaring, exhaust emissions from vehicles and electricity generators continue to impact negatively on the environment.

The use of biomass has substantial environmental drawbacks. The indoor air pollution from unvented bio-fuel cooking stoves is probably a major cause of respiratory illness in many parts of Nigeria. Reliance on biomass (especially in the form of charcoal) also encourages land degradation. The fuelwood that is being supplied for domestic energy needs results in deforestation. Biogas production from animal wastes can be used to reduce environmental pollution while providing energy for domestic purposes.

(h) Mining

Pollutants of various kinds are produced from mining industries. With particular reference to solid minerals, smoke, dust, and effluents containing mercury and acids are produced depending on the type of mineral ore, and the technologies applied during mining and beneficiation/processing. Deforestation and land degradation are also associated with mining activities as shown by the many large burrow pits in Plateau state and small burrow pits in the Ilesha gold mines, in Osun state. Unchecked, the pollutants discharged from mining and processing could damage the health of especially the local people, reduce output from agriculture, and damage infrastructure and buildings

(i) Tourism

Cultural Tourism

Cultural tourism covers visits to museums, monuments, art galleries, arts theatres, historic sites and other related methods of savouring different cultures. Potential adverse environmental impacts of such activities are damage to monuments, ruins (e.g. old walls in Kano and Benin) and sites, and theft of valuable artifacts; degeneration of areas around popular sites through the frequent passage of visitors; growth of unplanned settlements and the attraction of roadside traders; the corrupting influence of tourists on local culture; and congestion of traffic where the attractions are in built-up areas. It may also cause long-term damage to roads and atmospheric pollution.

Beach Resorts

Beach resorts are found along the nation's coastline, e.g. Lagos Bar Beach, Badagry beach and Tarkwa Bay. Environmental impacts from beach resorts are: damage to natural sand dune systems and coastal wetlands; destruction of natural shoreline features; disturbance of long shore drift by the erection of breakwaters and dykes; damage from excavations; pollution from sewage discharged into the sea; and increased demand on local power supply, refuse collection and such other local public services as policing and fire services. Other effects such as impact of affluent tourists on a society at a lower level of socio-economic development may lead to a corruption of values, materialism and erosion of local culture, resentment by the local people of visitors and violence, while local cultural (even culinary) values may be undermined by the need to cater for foreign visitors.

Mountain and Wildlife (Nature-based) Tourism

Under this type of tourism are national parks, game and forest reserves, nature trails, wildlife sanctuaries and trekking. Some potential adverse environmental impacts include upsetting the ecological balance between animal and plant species with unforeseeable long-term effects. For example, an increased elephant population can hasten the destruction of vegetation. Others are possible depletion of species through visitors' collections, atmospheric pollution from vehicles, soil compaction, accidental fires, indiscriminate disposal of litter harmful to wild animals, and disturbance of animal breeding sites and hunting grounds. Prohibition of access to protected areas may lead to a sense of loss by local people in the support zone, especially if their livelihood is threatened.

Water-based Tourism

The potential adverse impacts discussed under beach resorts are relevant to this type of tourism. Additionally, the following impacts could occur: increased discharge of raw or poorly treated sewage into the water body could affect human health and cause ecological hazards; possible disturbance of fish and other aquatic life, especially from oil spills and leaks from boats; decrease in aquatic resources such as shells, etc. through collection by visitors; and possible resentment of visitors by the local people. It is noteworthy that all forms of tourism could lead to some adverse impacts such as health, prostitution, HIV/AIDS, drug abuse, and crime, if adequate measures are not taken.

(j) Transportation

Transportation could have environmental impacts from construction of roads and bridges involving soil erosion and deforestation; air pollution through emissions from vehicle exhausts including trains and airplanes; and land and water pollution from oil spills and hydrocarbon discharges.

(k) Water Resources Development

Habitat changes associated with the construction of dams and the inundation of river valleys affect fauna (e.g fish) and flora, and fish populations upstream and downstream. The principal effects include: loss of access to upstream spawning areas, especially for migratory fish; change from a riverine to a lacustrine environment in the flooded valley; loss of spawning and nursery areas; and modification of the river discharge below the dam, in terms of water quality (temperature, dissolved oxygen, suspended solids) and flow regimes. Effects of a dam on the environment can be viewed in terms of nested orders of impact.

First Order Impacts

Isolation of sediment sources and alteration of flow regimes;
Significant reduction in peak flows as a consequence of reservoir construction;
Reservoir with a large storage capacity will trap >95 per cent of sediment load transported by the river;

Decrease in water storage capacity of many reservoirs by >1 per cent per annum;
The release of sediment-free water from the reservoir induces soil erosion downstream of the dam.

Second Order Impacts

A complex range of river channel responses to dam construction may manifest, resulting in a Continuum of potential adjustments include erosion, deposition, redistribution, accumulation, and channel changes reflecting the existence of constraints disturbances within the river system.

Third Order Impacts

Alteration in magnitude and frequency of flood discharges and reduction in sediment levels will have direct effects on the lotic fauna downstream.

Long-term interactions of channel morphology and fluvial processes will also be significant.
Channel sedimentation affects invertebrates leading to loss of fish food.

Accumulation of fine sediments at riffles below dams has adverse effects on fish spawning and food-producing capabilities.

Pools can become filled with sediment encouraging establishment of rooted and riparian vegetation. Other impacts on the human population include the social problems and implications of relocation and resettlement as a result of dam construction; and the health problems arising from water-related diseases.

6. INDICATORS OF ECOLOGICAL PROBLEMS

Table 2 shows a set of environmental indicators identified for monitoring ecosystems and environmental sustainability, the definitions of which are given below.

Emissions of Green House Gases (GHG): anthropogenic emissions of the greenhouse gases such as carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆), chlorofluorocarbons (CFCs), and hydrochlorofluorocarbons (HCFCs), together with the indirect greenhouse gases like nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOCs).

Temperature Change: Since the late nineteenth century, the mean global temperature has increased by 0.4 to 0.8°C. The doubling of CO₂ concentration in the atmosphere is believed to have caused an increase in the global mean temperature.

Sea Level Rise: measures the level of sea rise and resultant coastal inundations due to the combined impacts of emissions of GHGs.

Consumption of Ozone Layer Depleting Substances (ODS): the amounts of Ozone Depleting Substances being eliminated, signifying the commitment to phase out the ODS of the countries which have ratified the Montreal Protocol on substances that deplete the Ozone Layer and its Amendments of London (1990), Copenhagen (1992), Montreal (1997), and Beijing (1999).

Ambient Concentration of Air Pollutants in Urban Areas: ambient air pollution concentration of ozone, carbon monoxide, particulate matter (PM₁₀, PM_{2.5}, SPM, black smoke), sulphur dioxide, nitrogen dioxide, nitrogen monoxide, volatile organic compounds (VOCs), including benzene and lead.

Acid Rain: air pollution by substances that form acids and acidify the environment via rainfall. Rainfall acidification is due to air polluted by sulphur dioxide, nitrogen oxides and ammonia.

Arable and Permanent Crop Land Area: the sum of arable land and land under permanent crops, showing land area available for agricultural production.

Use of Fertilizer: extent of fertilizer use per unit of agricultural land area.

Use of Agricultural Pesticides: extent of pesticides per unit of agricultural land area.

Forest Area: extent of forest area as a percentage of total land area of a country.

Wood Harvesting Intensity: total forest fellings as a percentage of the net annual increment.

Percentage of Land Affected by Desertification: area of land affected by desertification in proportion to national territory.

Area of Urban Formal and Informal Settlements: urban residential area in square kilometres.

Percent of Total Population Living in Coastal Areas: total population living within 100 kilometers of the coastline as a percentage of national population.

Algal Concentration in Coastal Waters: concentration of algae growing in coastal waters as a representation of the health of the coastal ecosystem and the effectiveness of measures to reduce nutrient inputs from run-off and effluent discharge.

Annual Catch by Major Species: catch of major species in relation to spawning biomass if available or in relation to the year of maximum catches in a time series.

Annual Withdrawals of Ground and Surface Water as a Percent of Total Renewable Water: total annual volume of ground and surface water abstracted for water uses as a percentage of the total annual renewable volume of freshwater.

Biochemical Oxygen Demand in Water Bodies (BOD): the amount of oxygen required or consumed for the microbiological decomposition (oxidation) of organic material in water.

Algal Concentration in Water Bodies: a measure of the level of eutrophication in water due to an excessive supply of plant nutrients that lead to a shortage of oxygen in water bodies.

Area of Selected Key Ecosystems: the area of selected key ecosystems as a percentage of the total land area.

Protected Area as a Percent of Total Area: the area of protected land ecosystem, inland water ecosystems and marine ecosystems expressed as a percentage of the total area of land ecosystems, inland water ecosystems and marine ecosystems respectively.

Abundance of Selected Key Species: estimates of population trends in selected species to represent changes in biodiversity and the effectiveness of measures to maintain biodiversity.

Table 2: Environmental Indicators

Atmosphere	Climate change	Emission of green house gases (CO ₂ Emission) Temperature change Sea ó level rise ó coastal flooding
	Ozone layer depletion	Consumption of ODS
	Air Quality	Air Pollutants in Urban Areas
Land Oceans, Seas, and Coasts	Acid Rain	Sulphur dioxide, Nitrous oxide etc. concentration in air
	Agriculture	Arable and permanent crop land area Use of fertilizers Grazing density or Livestock stocking density % of peasant farmers Use of Agricultural pesticides Total grazing Area as % of total Land area
	Forests	Total forested area as % of total Land area % of Natural forest % of Plantation forest Forest types (mangroves, Savanna, rainforest, mountain forest) Deforestation rate (Timber harvesting rate, and Fuel wood collection).

	Soil Fertility	% Cultivated land % Fallow land Land in monoculture use Land in multiple cropping use
	Soil Degradation	% Areas affected by water erosion by types (gully, sheet and rill) % Areas affected by wind erosion Soil nutrient depletion rate
	Wetlands	Wetland areas as % of total land area (e.g. coastal mangrove, Hadejia ó Nguru wetlands)
	Drought and desertification	% land affected by drought and desertification Rate (trend ?) of desertification Land area of urban formal and informal settlement
Oceans, Seas and Coasts	Coastal zone	Coastal zone area as % of total land area % of Population living in Coastal area Eutrophication level in Coastal areas
	Fisheries	Total Annual fish catch (all types) Annual marine catch by major species Annual fresh water catch by major species Annual Aquaculture catch Annual mariculture catch
Fresh water	Water Quantity	Total available water ó Groundwater/ surface water % of water extracted Domestic per Capita water consumption
	Water Quality	BOD in water bodies Concentration of faecal coliform in freshwater Nitrogen and phosphorous level (Eutrophication)
	Fresh water zone	Eutrophication level in fresh water bodies % of total Population living around fresh water bodies
Biodiversity	Ecosystems	Area of selected key ecosystems as % of Total area ó Littoral, Mangroves, Rainforest, Wet and Dry savanna, Wetlands, Mountaineous. Protected Areas as % of total area
	Species	Abundance of selected key flora and fauna Threatened species
	Habitat change	Biodiversity Loss Ratio of exotic to endemic species coverage (e.g. Water hyacinth, Nypa palm)

7. ECOSYSTEM APPROACH: THE CHALLENGE TO POLICY MAKING

An ecosystem approach broadly evaluates how the use of an ecosystem affects its functioning and productivity. It is an integrated approach. Currently we tend to manage ecosystems for one dominant good or service such as fish, timber, or hydropower without considering the trade-offs we are making. We may be sacrificing goods and services more valuable than those we get, often those goods and services that are not yet valued in the marketplace, such as biodiversity, flood control, etc. An ecosystem approach considers the entire range of possible goods and services and then attempts to optimize the mix of benefits for a given ecosystem and also across ecosystems.

The ecosystem approach reorients the boundaries of management, emphasizing a holistic and systemic approach that recognizes that ecosystems function as whole entities. It looks beyond the traditional jurisdictional boundaries since ecosystems often cross state and national boundaries.

The ecosystem approach takes a long, futuristic view. It respects ecosystem processes at the micro level, but sees them in the larger frame of landscapes and decades, working across a variety of scales and time dimensions.

The ecosystem approach integrates social and economic information with the environmental information, thus linking human needs with biological capacity of the ecosystem. It maintains the productive potential of the ecosystem. Thus, management is not successful unless it preserves or increases the capacity of an ecosystem to produce goods and services, *ad infinitum*. Managing ecosystems will, therefore, require (1) knowing how they function and what their current state is; (2) engaging a public/stakeholders dialog on trade-offs and management policies; (3) setting an explicit value on ecosystem services (undervaluing ecosystem services has been a primary factor behind many of the short-sighted management practices of the past), and factoring such value into planning processes for ecosystem management; and, (4) involving local communities in managing ecosystems.

8. SUMMARY AND CONCLUSION

If we choose to continue our current patterns of use, we will face certain declines in the ability of ecosystems to yield their broad spectrum of goods and services ó from clean water to stable climate, fuelwood to food crops, timber to wildlife habitat. We can choose another option, but it requires reorienting how we view ecosystems. We need to learn to view their sustainability as essential to our own. Adopting this òecosystem approachö means we evaluate our decisions on uses of land, water, and other natural resources, in terms of how they affect the capacity of ecosystems to sustain life, not only human life but also the health and productivity potential of plants, animals and natural systems. Maintaining this capacity becomes the objective of human and national development, our hope to end poverty, our safeguard for biodiversity, our passage to a sustainable future.

The ecosystem approach emphasizes the need for both good scientific information and sound policies and institutions. On the scientific side, it should (1) recognize the systemic nature of ecosystems, respecting their natural boundaries and managing them holistically rather than sectorally; and, (2) regularly assess the state of ecosystems and study the processes that underlie their capacity to sustain life, so that the consequences of the choices and trade-offs we make can be better understood. On the political side, the ecosystem approach should (1) develop wiser policies and more effective institutions for implementation; (2) assemble information that allows a careful consideration of trade-offs among various ecosystem goods and services, and among environmental, political, social, and economic goals; and, (3) include the public in the management of ecosystems, particularly local communities who are usually the greatest stakeholders in protecting ecosystems.

The goal of the ecosystem approach is to optimize the array of goods and services ecosystems produce while preserving or increasing their capacity to produce these things in the future.

REFERENCES

- Anon 1991. Biodiversity. Issue paper prepared by Environmental Management of (GEP/STAP/I/L/4), UNEP, Nairobi.
- C.C.A. 2001. United Nation System in Nigeria Common Assessment
- F.A.O. 1995. Land and Water Integration and River Basin Management. FAO, Rome
- FEPA 1992. National Policy on the Environment, Federal Environmental Protection Agency, Abuja

FGN (1997). Vision 2010: Report of the Vision 2010 Committee, Main Report, Abuja

FGN (2000). Federal Government of Nigeria Annual Budget Speech 1998, 1999, 2000 and 2002

Gorshkov, V. G. A.M. Makarieva and Gorshkov, V. V. 2004. Revising the fundamentals of ecological knowledge: The Biota-Environment interaction. ecological complexity Vol.1:17- 36, Elsevier Publ.

United Nations Development Programme (UNDP) 2003. Human development report 2003. Oxford University Press, Oxford.

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