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MAN, FOOD AND MACHINERY: FROM BIOLOGICAL SYSTEMS TO PHYSICAL MODELS IN FOOD PRESERVATION

By

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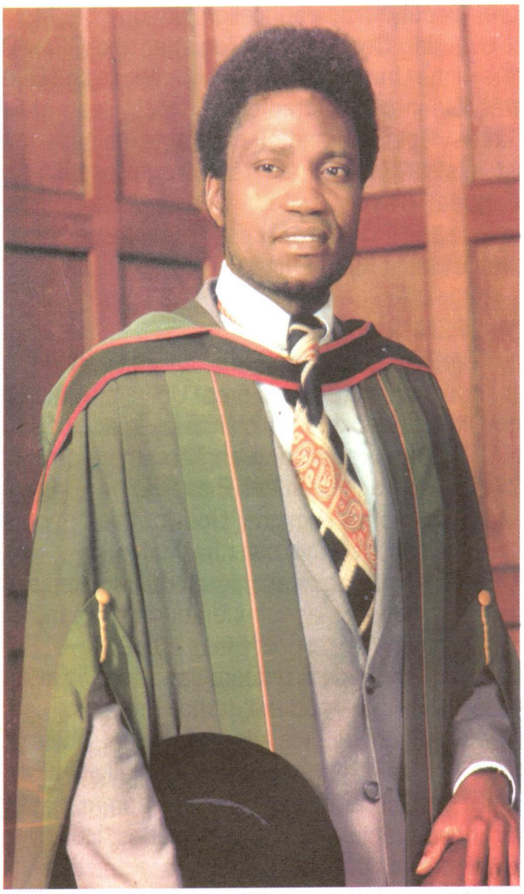

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1.0 COURTESIES

The Vice-Chancellor and Chairman of this Inaugural Lecture, Deputy Vice-Chancellor, Honourable Members of The Governing Council, The Registrar and Other Principal Officers of the University, Deans of Colleges and Directors of Centres, Dean of Postgraduate School, Dean of Students, My Lords Spiritual and Temporal, Business men and Industrialists, Royal Fathers here present, Academic Colleagues, Distinguished Quests, Members of my Immediate and Extended Family, Gentlemen of the Print and Electronic Media, Great UNAABITES

2.0 OPENING

Today, I feel highly honoured to be called upon to present the 20th Inaugural Lecture of this great University, the University of Agriculture, Abeokuta, which has been adjudged to be the best in Nigeria in recent times. I am, therefore, glad to be part of this noble achievement. Please join me in giving Glory and Adoration to the Almighty God for this opportunity and his Blessings on my family over the years.

By University tradition, an inaugural lecture is a formal occasion which takes about one hour of presentation in the form of a summary of, or an aspect of, a Professor's academic contribution to research and beneficial knowledge to the larger society, and the demonstration of scholarship. Thus, whether one hour is adequate or not, and considering the fact that this gathering is essentially that of a mixed audience, I shall comply by giving the summary of the fields which I have practiced for a few decades. However, I would like to assure you that because of space and time, if anything is inadvertently left out in this lecture, it is certainly in my custody.

3.0 HISTORICAL BACKGROUND

As many of us here present today would recall, the Holy Bible tells us that when God created the world, everything was perfect until man sinned and got separated from God since good and evil could not dwell together; man was, therefore, punished for his disobedience (Genesis, Chapter 4, verses 1 and 2). In the process, both Adam and Eve knew themselves; Eve conceived and delivered Cain and Abel, both senior and junior, respectively. Abel was a keeper of sheep while Cain was a tiller of ground. The tilling of soil refers to land preparation prior to planting of crops; thus, implying that land clearing and use of farm implements had existed while the blacksmiths had been playing useful roles since the time of Cain. The Bible also revealed to us (verses 3 to 8) that Cain jealously killed Abel while they were in the field because the Lord blessed Abel's offering to Him and did not accept Cain's. A second punishment thereof was an enormous curse on Cain "when thou tillest the ground, it shall not henceforth yield onto thee her strength----- "(verse 12). So the suffering of man started in that order with a clear vision to produce food of Plant and Animal Origin. Naturally, therefore, man began to look for various ways of improving the returns for his labour and using, for a start, crude implements. This signified the beginning of technological awareness and development in order to improve living standard which eventually led to the emergence of civilization sequentially.

The first agricultural revolution, we are told, started about 8000 years ago, involving a change from hunting groups to normadic living, from one farmer to organized group of farmers aimed at producing massive harvest. At first gold was discovered and later copper was developed for making various implements and later, bronze was made from an alloy of copper and tin, brass from an alloy of copper and zinc and were found to be harder metals than copper. That became the end of Stone Age wherein stones were shaped for use as implements. The production of iron and iron Age also marked the beginning of modern events. The second revolution, which was industrial, began about 300 years ago and it had its major focus on production of tools, equipment, steam engine and means of transportation. The third revolution was the Technological Revolution which started and air planes were developed along the line with electricity, man also landed in the moon. The fourth revolution was that of Information Technology services, including cellular and GSM phones, have become very valuable commodity. Here in Nigeria, the memories of the Green Revolution, Operation Feed the Nation, Better Life, etc, are still frequently noted. That appears to be good but the implication is that man's wants continue to be too numerous that the entire life is spent on how to survive in a dynamic world. Today, self-sufficiency in food and fibre for a rapidly burgeoning population is a major focus of agricultural policies in most countries, wiping out poverty and creating rapid industrial and economic base for national development when such policies are properly implemented.

In general, food production beyond house-hold levels needs to be mechanized, starting from land preparation, through planting, harvesting and post-harvest storage, processing and packaging. Man, therefore, needs to cross the boundaries between biological and physical sciences in order to achieve practical values from innovative scientific explorations; new tools and techniques of commercial imperatives cost effectiveness and sustainability, for the society to value and adopt.

4.0 INTRODUCTION

The biological nature of food naturally attracts several post-harvest changes leading to spoilage, including damage caused my microorganisms and environmental conditions. For example, mould flourish in damp places especially in still air, yeasts are agents of fermentation and usually prefer moderate temperatures but can service under adverse conditions. Bacteria on the other hand, requires wet conditions air, moisture and humid heat. The common methods of preserving foods are drying to remove moisture content, freezing to make water unavailable in liquid state, salting and other forms of heat treatment-pasteurization or sterilization, canning, etc. in this lecture, the developments in the special area of food freezing, using cryogenic liquid nitrogen will be highlighted because of its technological characteristics. Nitrogen boils at a temperature of 196^{0}C at atmospheric pressure; it is non-toxic, non-flammable and was derived from air liquefaction processes. It is widely used for various industrial processes, including cryogenic recovery or recycling of waste materials, since it can embrittle certain metals, ceramics and polymers. The use of liquid nitrogen has also had extensive application in the field of cryosurgery, e.g. long-term preservation of biological tissues and organs for transplantation, and low temperature surgery, especially controlled destruction of tissues as in cancer tumours at -50^{0}C (Rubinsky and Onik, 1991). It is also commonly used for spray cooling of hot metals, rapid freezing of foods by direct contact with cryogens, preservations of cell and tissues of human bodies shortly after clinical and legal death (Humphry, 1980).

So, some people are looking for immortality "when the final hour comes, a team of technicians would stand by his or her side, ready to inject him/ her with organ - preserving fluid as soon as legal death is pronounced. He/she will be laid in a mobile rubber bag comprising of aluminum foil and the corpse will be rushed in ambulance to the laboratory and stored in liquid nitrogen at 196^{0}C indefinitely until the day when the technology to revive him will come, he will be reanimated, and will continue to live a good life ….". So is the magnitude of the natural desire of man for continued existence, with anxieties, fears, joys, dignity or sorrows, and yet looking for immortality.

The idea for using such technology was that of Muhlestein in the USA, and started with 32 patients immersed in liquid nitrogen and paying as much as $120,000 with a surcharge of $10,000 for non-US citizens as at 1995. However, the technology was still experimental and the procedures unproven. A club called Alcor Life Extension Foundation was formed in Scottsdale, USA and in 1967 the first body to be frozen cryogenically was that of Professor of Psychology, Jim Bedford in what looks like yesterday's vision of tomorrow, i.e., nanotechnology the science of constructing minute machine that could use molecules as operational components. Hence, matter could be manipulated in atom-by-atom, and may eventually be the start of creation of a new world. A member of Alcor Life Extension Foundation club, Bridge also a former Librarian said, "I have told my friends to save my letters and I've stored a huge amount of stuff on computer over the years. I have access to a lot of information now I am, so if I come back minus my memory, I can regain part of it by reading about who I was. I would like to come back as a full body, though I might swap it for a robot body. I don't want to wear glasses or get tired, and I want to be able to see at least 10 miles away. I would like to go to the moon and visit other planets". So much are the expectations of members of the clubs, and it was noted that men outnumber the women by about 2 to 1. Therefore, the general tendency is that man has a natural desire for self perpetuation of existence and if the opportunity arises, he will resist the termination of life using every means available to him.

On Monday, March 5th, 1979 at about 2.00pm a lecture on Cryogenic freezing system was delivered (Fig. 1) while this lecturer was a student on the M.Sc degree programme in Food Engineering at the University of Leeds in the United Kingdom. The lecture generated a long session of discussion and at the end of which this lecturer derived his PhD research focus. Several questions were asked but were not answered directly for lack or relevant and empirical information; viz:

(i) What range of droplet sizes are involved?
(ii) What are the shapes of droplets? Are they spherical?
(iii) At what velocities do the droplets emerge or travel?
(iv) How would heat transfer to a single droplet be different from that involving several droplets or spray?
(v) When a single droplet hit a food surface, does it breakup into smaller droplets?, bounce off?, bound and rebound?, bounce and roll off from the food surface?, hit another droplet and forms and agglomerate of increased mas

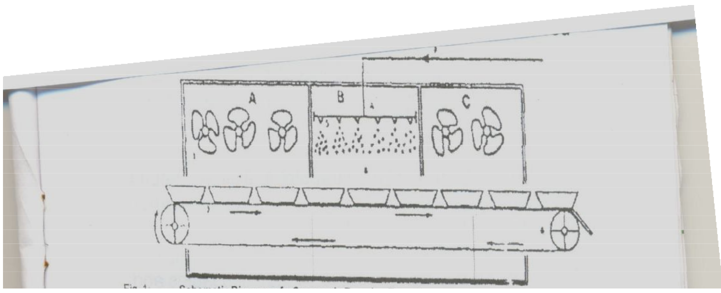

Fig. 1. Schematic Diagram of a Cryogenic Freezing Tunnel

(a) Pre-cooling section, (b) Freezing section, (c) Equilibration section,
(1) Nitrogen vapor recirculation fans; (2) Food products;
(3) Conveyor belt; (4) Liquid nitrogen distribution header; (5) Spray nozzle;
(6) Conveyor belt drive; (7) Liquid nitrogen feed pipe (insulated); and (8) Liquid nitrogen sprays.

(vi) Could a droplet hit the food and flatten out instead of breaking up into smaller size if the Weber number is sufficiently low?
(vii) If a droplet leaves the ejector or spray nozzle, does it change in size on its way to the food surface due to the effect of temperature differential? If a change occurs, what size gets to the food surface?
(viii) Are droplets mono-or poly-dispersed in terms of sizes or are they uniformly distributed?
(ix) If droplets are mono-dispersed, would large and small droplets have the same pattern of evaporation or behaviour as heat transfer progresses?
(x) What happens if a droplet does not touch the food at all?
(xi) What surface areas of droplets actually contact the food?
(xii) How will heat transfer from nitrogen droplet on a hot plate differ from that on a warm solid food?
(xiii) What are the typical values of surface resistance or heat transfer coefficients between such droplets and food surface?
(xiv) Moisture is present in the air, in the freezer and invariably in the foods to be frozen as water content; how does the presence of moisture affect the rate of heat transfer to the droplets or from the foods being frozen?
(xv) Will the mechanism of heat transfer to a single droplet be the same as when several droplets or sprays bombard the food surface?

The Chairman of this occasion, Sir, distinguished ladies and gentlemen, I have tried in the last two decades or so to find solutions to the problems identified as earlier mentioned and indeed, the topic of this lecture is derived from the general concept of food preservation from the viewpoint of processing, freezing and cold storage, and engineer's belief in history.

5.0 CONTRIBUTION TO KNOWLEDGE BY THE INAUGURAL LECTURER

In order to understand the nature of heat transfer associated with the use of the freezing equipment shown in Fig. 1, this lecturer proposed a study which had five (5) components, viz:

i. To establish a process for producing single droplets of liquid nitrogen;
ii. To develop a method for contacting a food sample with a single droplets and examining the existing heat transfer;
iii. To investigate the nature of heat transfer to a single droplet resting on a food surface;
iv. To investigate the type and mode of heat transfer to droplets falling freely in air' and
v. To extend the knowledge obtained from single droplets to typical food freezing conditions where several droplets or sprays would bombard the food surface.

5.1 Development of Heat Transfer Concept for Individual Droplets

A model was developed, where individual droplets of different sizes could be generated and allowed to fall freely in air as if it was in freezing equipment or allowed to drop on a food substance (gelatine slab). The model relies on high speed cine photography with close up facility to monitor droplet sizes or change in size and movement/velocity and to also be able to vary the temperature of the surrounding air in the freezing compartment. Figure 2 show such an arrangement and Figure 3(a) and (b) show the cross-sections of the spray area, indicating the nozzle position relative to food.

5.2 Heat and Mass Transfer Associated with Droplets' Free Fall

In Figure 4, droplets were formed and allowed to fall freely in air at a predetermined air temperature. The first task was to determine the actual surface are and volume of each droplet. This was achieved by taking a complete revolution around the symmetric axis of hypothermic needle with the droplet attached (Fig. 5). By applying numerical integration, the following expressions were derived for the surface area, A and droplet volume, V on the photographic print-outs:

$$A = \frac{2}{3}\pi\left(\frac{1}{M}\right)^2 Y \frac{x_o}{2} + \sum_{j=1}^{(n-1/2)} X_{2j} + 2\sum_{j=1}^{(n-1)/2} X_{2j+1} \quad \ldots\ldots (1)$$

$$V = \frac{\pi}{6}\left(\frac{1}{M}\right)^3 Y \frac{(x_o)^2}{2} + \sum_{j=1}^{(n-1/2)} (X_{2j})^2 + \sum_{j=1}^{(n-1)/2} (X_{2j+1})^2 \quad \ldots\ldots (2)$$

Heat transfer rate, q, to a droplet on an average rate basis, and heat transfer coefficient; for a spheroid, at time, t is given by:

$$q = hA\Delta T = h(\pi D^2)\Delta T = -\lambda \frac{dm}{dt} \quad \ldots\ldots (3)$$

At time $t + \delta t$

$$q = \delta q = h\pi (D - \delta D)^2 \Delta T \quad \ldots\ldots (4)$$

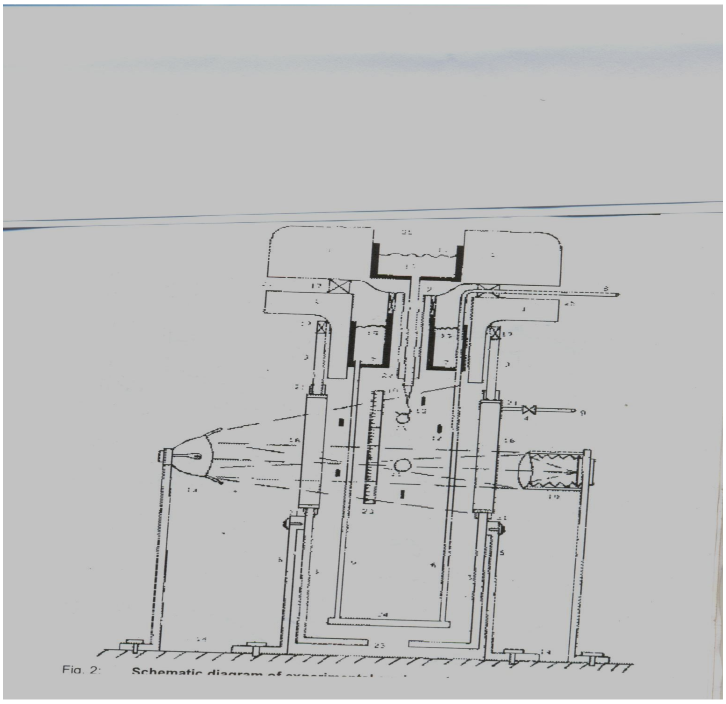

Fig. 2: Schematic diagram of experimental equipment

(1) Polystyrene isulation, (2) long brass dropper pipe, (3) rectangular column insulated with 6-cm thick polystyrene foam, (4) shut-off valve, (5) mounting support for rectangular column, (6) four copper tubes carrying cold nitrogen liquid, (7) heat exchange reservoir, (8) copper vent tube 9mm diameter, (9) connection to Edward's high vacuum pump, (10) hypodermic needle (25 gauge) and wire loop insertion, (11) falling liquid nitrogen droplets, (12) thermocouple positions, (13) dropper reservoir, (14) working table and clamps, (15) liquid nitrogen pool, (16) double-walled Perspex viewing window, (17) wire wool, (18) lane beam floodlight quartz Model 3142. 1000 W, (19) high-speed Michel cine-camera, model HS-16F4, (20) one-meter ruler, (21) Araldite glue, (22) heat exchanger central tube, (23) liquid nitrogen droplet, formation period, (24) liquid nitrogen header pipe, (25) opening to the atmosphere.

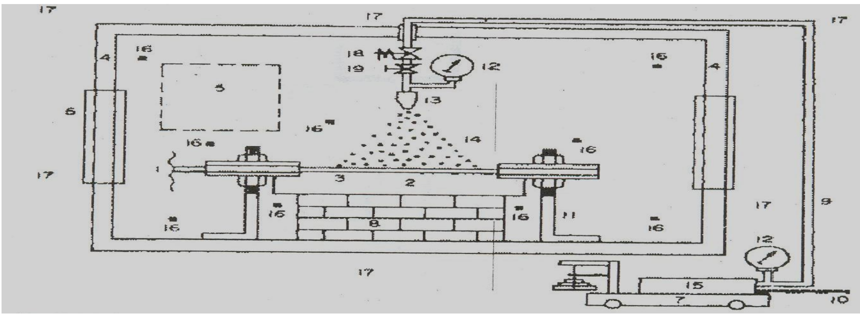

Fig. 3(a): Schematic diagram of experimental equipment

(1) power lead, (2) mica support, (3) platinum plate, (4) expanded polyurethane insulant, (5) venting flap, (6) viewing window, (7)platform weighing scale, (8) brick (9) insulated nitrogen feed pipe, (10) pressure relief line, (11) plate stand and clamp, (12) pressure gauge, (13) nozzle, (14) liquid nitrogen spray, (15) liquid nitrogen Dewar vessel, (16) thermocouple location for measuring the internal temperature of the box, (17) thermocouple location for measuring the external temperature of the box, (18) solenoid valve, (19) hand operated valve.

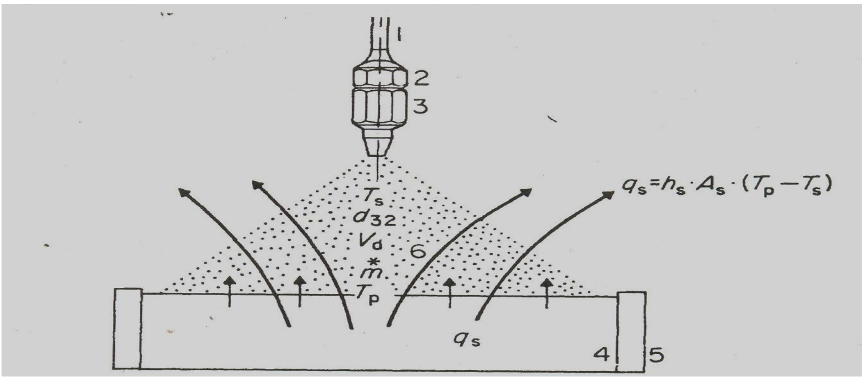

Fig. 2: Schematic diagram of experimental equipment

Fig. 3(a): Cross-sectional view of a spray model
(1) brass pipe, (2) brass flare nut,
(3) nozzle and adaptor, (4)(gelatine-slab, (5)Perspex ring, (6) saturated spray.

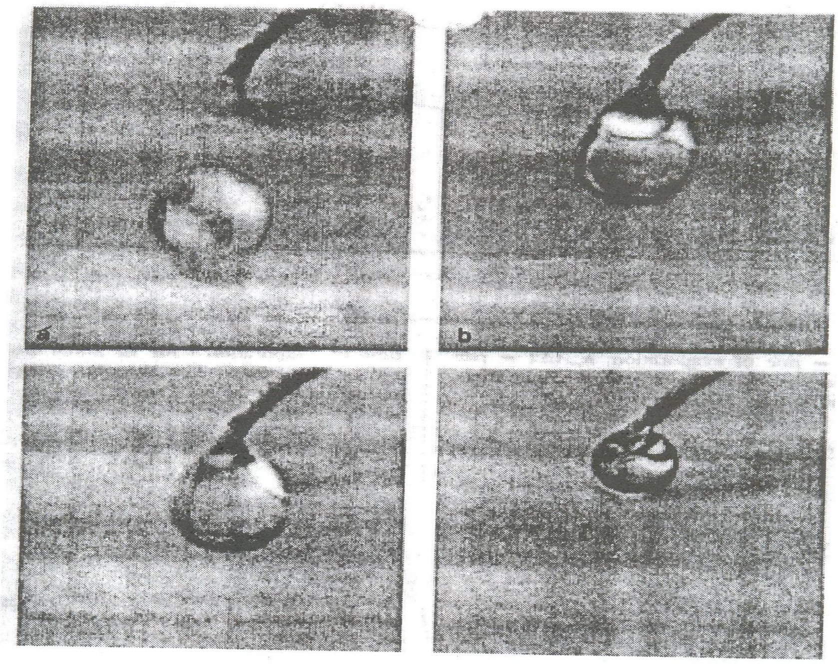

Fig. 4:Enlarged photographic prints of droplets during formation and free fall in air

(a) 1.09-mm diameter droplet falling in air at -80^{0}C, (b) 1.21-mm diameter droplet formed at + 30^{0}C with severe ice patches, (c) 1.21-mm diameter droplet formed at + 10^{0}C with ice patches (d) 0.6-mm diameter droplet during formation at +20^{0}C with ice patches.

The average rate of heat transfer by combing Eqns. (3) and (4) is

$$h_{av}\pi D^2 \Delta T + h_{av}\pi D\,\delta D\,\Delta T + h_{av}\frac{\pi}{2}(\delta D)^2\,\Delta T = \frac{\pi}{6}\lambda\rho\left[3D^2\frac{\delta D}{\delta t} - 3D\frac{(\delta D)^2}{\delta t} + \frac{(\delta D)^3}{\delta t}\right] \quad \text{........ (5)}$$

AS $\delta t \rightarrow 0$, $\delta D \rightarrow 0$ and: $\delta D/\delta t \rightarrow dD/dt$:

$$h_{av} = \frac{1}{2}\frac{P_1\lambda}{\Delta T}\frac{dD}{dt} \quad \text{.........(6)}$$

From various plots of t vs. D, the gradient dt/dD is $\frac{1}{2}\frac{P_1\lambda}{h_{av}\Delta T}$

$$Nu = 2.0 + 0.75\,Re^{1/2}\,Pr^{1/3} \text{ (For heat transfer)} \quad \text{.........(7)}$$

$$K_c = \frac{D_c}{D} \quad \text{......... (8)}$$

$$Nu_{diff} = 2.0 + 0.81\,Re^{1/2}\,(Pr_{diff})^{1/3} \text{ (for mass transfer)} \quad \text{.......... (9)}$$

$$\frac{dm}{dt} = \frac{h_{av}A\Delta T}{\lambda} \quad \text{............. (10)}$$

$$\frac{dm}{dt} = \frac{\pi D K_a \Delta T\,(2.0 + \beta D^{1/2})}{\lambda} \quad \text{............. (11)}$$

$$t = \left(\Phi_{D-Di}^{3} - \Phi_{D-Df}^{3}\right)\frac{\lambda P1}{6K_a\Delta T} \quad \text{......... (12)}$$

$$\Phi = \frac{96}{\beta^4} - \left\{\frac{\beta^3 D^{1/2}}{48} + \frac{\beta^2 D^{1/2}}{16} - \frac{\beta D^{1/6}}{4} - \ln\left[\frac{(2)^{1/2}}{\beta} D^{1/2} + \right] \frac{1}{2} \ln\left(1 + \frac{2}{\beta} D^{-1/6}\right)\right\} \qquad \ldots\ldots\ldots\ldots\ (13)$$

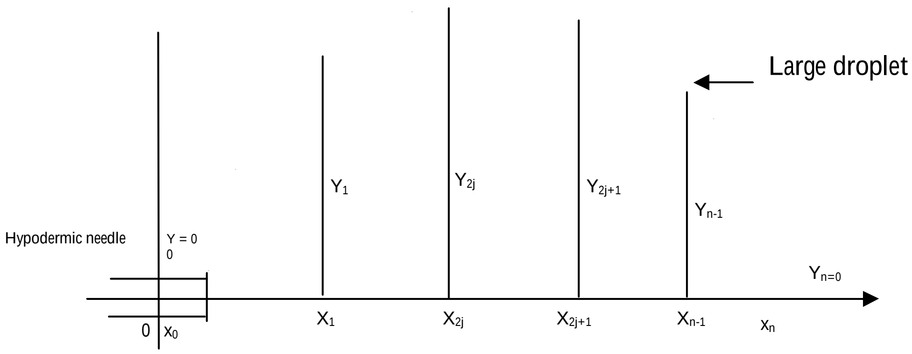

Fig. 5: Cross section of droplet before revolution around symmetric axis of hypodermic needle

Eqns. (12) is the desired result for any initial size of droplet to assume a new size after an elapsed time, t while on its way to the food surface from an ejector nozzle. Thus, when applied to a typical cryogenic freezing system, where the spray mean diameter D32 was 145 m, approximately 30% contribute to temperature reduction in the freezer. The distance moved (m) when plotted against time (t) gave the velocity of droplets (Fig. 6) and was published by Awonorin (1989). The initial acceleration by droplet during the fall and the final/terminal velocities were also measured.

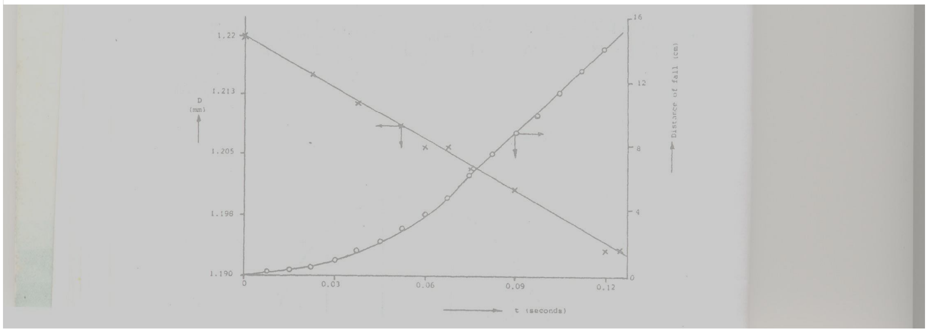

Fig. 6: An evaporating liquid nitrogen droplet falling in air at 50°C (Di=1.22mm)

5.3 Heat Transfer Model of Droplets on a Food Surface

The first publication on boiling heat transfer characteristics of liquid nitrogen droplets on a food (gelatine) slab surface under typical food freezing conditions (Figures 7a & b) was presented by Awonorin and Lamb (1988; 1990). Heat transfer consideration was given to the film boiling phenomenon to organic liquids, especially from the well established “spheroidal state” or the “stable film boiling” conditions described by Leidenfrost (1756). Droplets are well supported by vapour film cushion on the solid surface and the film exhibits resistance to heat transfer as well as insulating the droplet from the solid food surface (Fig. 7a). This phenomenon has been widely used for studies involving the evaporation of some liquid droplets, e.g., water, benzene, carbon tetrachloride, etc, (Baumeister *et al.,* 1966; Keshock and Bell, 1970; Hassan, 1981) on metal surfaces. An energy balance for a single droplet at rest on a solid food surface gives the instantaneous heat transfer rate, where:

$$\lambda \frac{dm}{dt} = -h(V)A(V)\Delta T_{mn} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

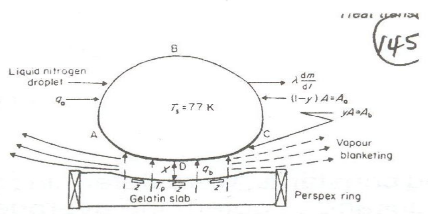

Fig.7(a)

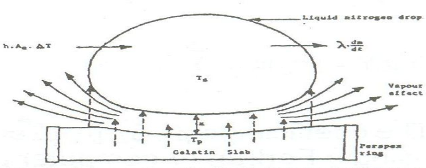

Fig. 7(b)

Fig. 7(a):**Cross-section of a liquid nitrogen droplet on a solid surface during Leidenfrost boiling**
------► Conductive convective heat transfer; ——→ Vapour blanketing effect

Fig. 7(b):**Cross-section of liquid nitrogen droplet on a food substrate during Leidenfrost boiling** ------► , conductive-convective heat transfer; ——→ Vapour blanketing beneath the droplet; q_a and q_b air droplet and solid droplet heat transfer rate from the top and bottom surfaces of droplet, respectively; X, vapor film thickness; Z, thermocouple locations.

$$\lambda \rho_1 \frac{V_o}{t_f} = h_{av} A_{av} \Delta T_{mn} \quad \text{......... (15)}$$

For a small droplet:

For a large/non spherical droplet:

$$A_{av} = 1.25\left[\frac{\rho_1 \cdot g . d_{av}^2}{4\delta_1 \cdot g_c}\right]^{1/4}\left[\frac{4}{d_{av}^2}\right]^{1/4}\left[\frac{\pi d_{av}^3}{6}\right]^{5/6} = 1.03\left[\frac{\rho_1 \cdot g . d_{av}^2}{4\sigma_1 \cdot g_c}\right]^{1/4} . d_{av}^2 \quad \text{......... (16)}$$

$$h_{av}\left[\frac{1.29 K_2^{0.25} . V_0^{0.83} - \left(3.89 * 10^{-8} K_2^{0.25}\right) + 1.2 K_1 . V_{0s}^{0.92}}{V_o}\right] \text{......... (17)}$$

$$h_{av} = h_{av}\left(K_v . C_{pv}, \rho_1, \rho_v, d_o, \mu_v, \lambda, g, \Delta T_{mn}\right) \quad \text{........ (18)}$$

$$\frac{h_{av} . d_o}{K_v} = \psi\left(\frac{K_v^2 . \Delta T_{mn}}{\mu_v^2 . C_{pv} . \lambda}\right)^{\beta 1}\left(\frac{d_0^3 \cdot \rho_1 \cdot \rho_v . C_{pv} \cdot g}{\mu_v . K_v}\right)^{\beta_2}\left(\frac{C_{pv} . \mu_v}{K_v}\right)^{\beta_3}\left(\frac{\rho_1}{\rho_v}\right)^{\beta_4} \quad \text{......... (19)}$$

$$Y = \Psi \chi_1^{\beta 1} \chi_1^{\beta 1} \ldots\ldots \chi_n^{\beta n} \quad \text{.................. (20)}$$

$$\text{Log } Y = \log\Psi + \sum \beta^{1} \log \chi_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots \ (21)$$

The coefficients β_1, β_2, β_3, β_4 and constants, were determined using a Fortran IV computer package to determine average values of heat transfer coefficient. The changes is size of droplets with the could be found from the photographic prints shown in Fig. 8 and corresponding plots are shown in Fig. 9 including the instantaneous heat transfer data (Fig 10). The changes in size of such droplets with time could be found from the photographic prints shown in Fig. 8 and corresponding plots are shown in Fig. 9 including the instantaneous heat transfer data (Fig. 10). The time required to evaporate a given size could be computed empirically as in Eqn. (21) according to Awonorin and Lamb (1990).

$$tr = \Phi(Kv)^{\alpha 1} (\Delta T)^{\alpha 2} (pv)^{\alpha 3} (p_1)^{\alpha 4} (\lambda)^{\alpha\mu 5} (\mu_v)^{\alpha 6} (C_{pv})^{\alpha 7} (D_m)^{\alpha 8} (r_i)^{\alpha 9} (g)^{\alpha 10} \qquad \ldots\ldots\ldots(22)$$

Thus, applying Buckingham Pi method (Buckingham, 1915; Massey, 1971),

$$(\pi_1, \pi_2, \ldots\ldots\ldots\ldots\ldots\ldots \pi_n) = 0 \qquad \ldots\ldots\ldots \ (23)$$

Hence,

$$\frac{t_r}{\sqrt{r_i}} = g = \Phi \left(\frac{K_v.\Delta T}{P_v.D_{m.\lambda}}\right)^{\alpha 1} \left(\frac{P_1}{P_v}\right)^{\alpha 2} \left(\frac{C_{pv}.\mu_v}{k}\right)^{\alpha 3} \left(\frac{\mu_v}{P_v.D_m}\right)^{\alpha 4} \left(\frac{D_m}{r^{1.5}\sqrt{g}}\right) \qquad \ldots\ldots\ldots\ldots(24)$$

The constant, Φ and coefficients, α_1 to α_5 in Eqn. (24) may be determined by applying experimental data.
Thus, Eqn. (24) may be written as:

$$Y = \Phi X_1^{\alpha 1} . X_2^{\alpha 2} \ldots\ldots\ldots\ldots\ldots X^{\alpha n}_n \qquad \ldots\ldots\ldots\ldots \ (25)$$

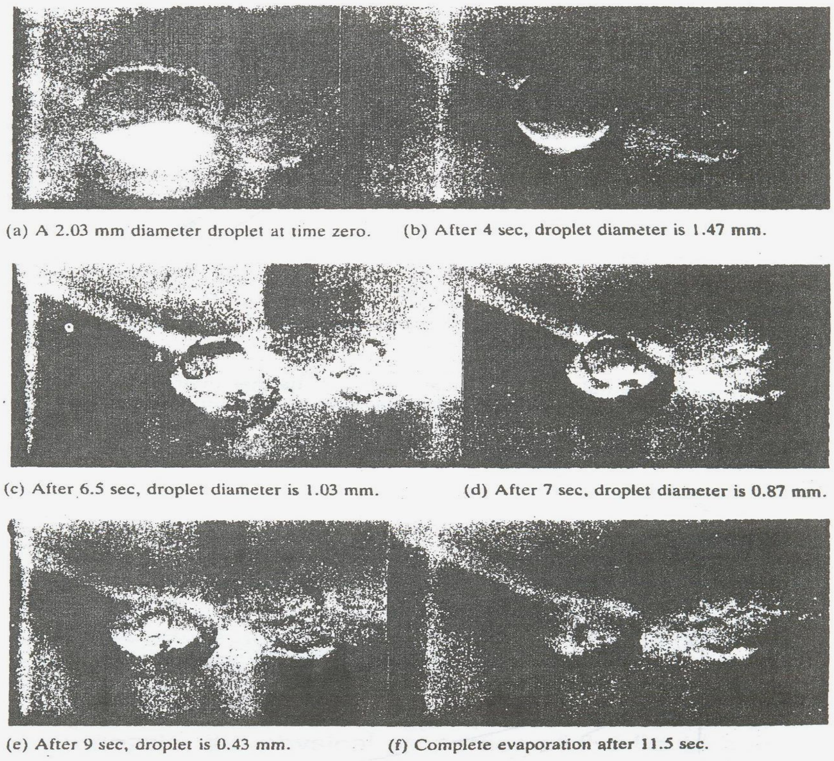

Fig. 8: Evaporation times of liquid nitrogen droplet at a slab surface temperature of 50°C and a magnification of x24.

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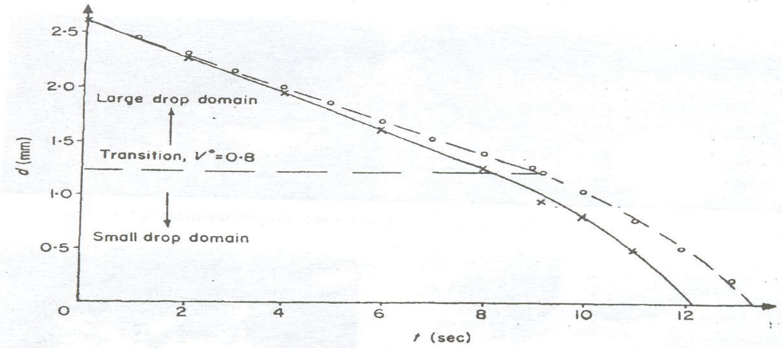

Fig.9: **Experimental and theoretical results of changes in drop diameter, d with elapsed time, t, for a 2.6-mm initial-diameter droplet and ΔT_{mn} = 175K**
O, theoretical results, (Baumeister et al., 1966); x, experimental results

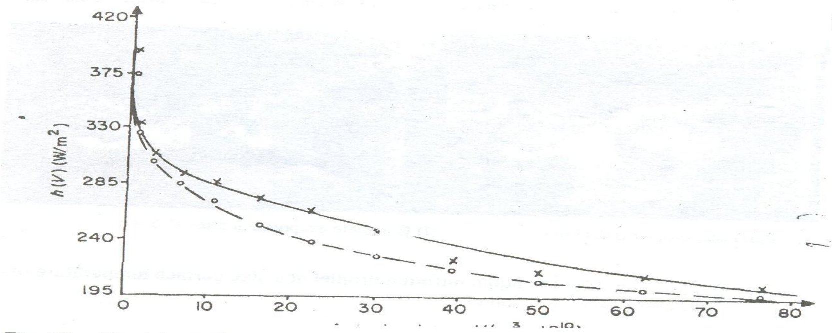

Fig.10. **Heat transfer coefficients to a 2.6-mn initial-diameter droplet as a function of droplet volume at ΔT_{mn} of 175K**
O, theoretical results (Baumeister et al., 1966); x, experimental results.

Hence,

$$Log\ Y = log\ \Phi + \alpha_1 \log X_1 + \alpha_2 \log X_2 + \ldots\ldots\ldots\ldots \varepsilon \qquad (26)$$

where, ε = error term

The minimum error can be obtained by partial differentiation of each coefficient equated to zero for $\varepsilon^2 << \varepsilon$, thus:

$$\frac{\partial \sum \varepsilon^2}{\partial \Phi} = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

$$\frac{\partial \sum \varepsilon^2}{\partial \alpha_1} = 0 \quad (\text{for I} = 1 \text{ to } 5) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$$

$$t_r = 25.0\sqrt{\frac{r_i}{g}}\ \frac{(P_v.\Delta_{m\lambda})^{0.75}}{K_v.\Delta T)}\ \frac{(P_1)^{0.5}}{(P_r)}\ \frac{(K_v)^{0.73}}{C\mu_v \mu_v}\ \frac{(\mu_v)^{0.75}}{\mu_v D_m}\sqrt{\frac{gr_1 3)^{0.33}}{D_m}} \qquad \ldots\ldots\ldots\ldots (29)$$

5.4 A model for heat transfer to Sprays of Liquid Nitrogen in Cryogenic Food Freezing

We have seen in the previous sections the mechanism of heat transfer to moving/falling droplets and to droplets in contact with the food surface. In order to apply such results of the individual droplets to sprays of liquid nitrogen during cryogenic freezing of foods (Fig. 3b), it is important to consider the nature of coverage and the steady state droplet size distribution. The distribution depends on size and type of spray nozzle, the physical properties of the liquid being sprayed and the atmospheric condition into which the droplets are sprayed. The technology of spray system is, however, based on effective surface coverage with depositions, application of aerosols which involves the mechanism of airborne particles, their deposition and interaction with surfaces at low and high Reynolds numbers, drift effects, under-or over-dosing of pesticides, biocides and other agrochemical inputs/application rates, etc, are frequently encountered in the agricultural operations, food processing and environmental sciences.

Three types of distribution are considered (Awonorin, 1989):

Rosin-Rammler:

$$Y = 100ex \left(\frac{d}{D} \right)^{\beta} \quad \ldots\ldots(30)$$

Nukiyama and Tanasawa

$$\Delta N = ad^2 \exp(-bd^{\beta}) \quad \ldots\ldots\ldots\ldots (31)$$

Log Normal Distribution:

$$\Delta N = \frac{N}{\sqrt{2\pi} \log \chi} \exp(-[\log d - \log D^1]^2 / 2\log^2 \chi) \quad \ldots\ldots\ldots(32)$$

where, N is the total number of drops, x is the geometric standard deviation obtained from D' which is the geometric mean size groups. However, Eqn (30) predicts too may small droplets, while Eqns (31) and (32) usually predict too few small drops, with too may very large droplets, although Eqn (30) is suitable for sprays of pure liquids; this also has been applied to liquid nitrogen sprays in cryogenic freezing of foods (Bonacina et al., 1974).

Mugele and Evans (1951) developed a very useful monograph for the determination of mean spray size, d_{32} and maximum possible diameters of droplets, d_{max} from a given spray if the pressure and fluid properties are known, This nomograph was used in our studies. Thus, from energy balance, the average heat transfer coefficient, h*, at the food surface could be determined from:

$$q = h * A * \Delta T_m = m_f . \lambda \qquad \ldots\ldots(33)$$

The heat transfer coefficient of the sprays, h_s, can be obataine: $h^* = \varepsilon_{ss} . h_s$

Hence,

$$h_s = \frac{m . \lambda}{\varepsilon_{ss} . \Delta T_m} \qquad \ldots\ldots\ldots(34)$$

Equation (34) described heat transfer to sprays in the same way as earlier proposed by Bonacina et al. (1974). In order to be able to compare the food results with standard heat transfer data, the liquid nitrogen was sprayed on a hot metal plate at various controlled temperature (Awonorin. 1989). The empirical data obtained for the heat transfer coefficient was:

$$h = 3.7\pi \frac{K_v}{d_{32}} \frac{(P_1 V d_{32})^{1/2}}{\mu_v} \frac{(C\mu_v \mu_v)^{1/3}}{(K_v)} \frac{(\mu_v C\mu_v \lambda)^{1/4}}{K_v^2 \Delta T} \frac{P_1 - P_v)^{1/3}}{\mu_v} \qquad \ldots\ldots\ldots\ldots(35)$$

5.5 Studies on Reconstitution of Gari Granules into Paste

Gari is a pre-gelatinized starchy food obtained as dried granules from processed cassava (*Manihot* esculenta crantz) roots, and is a staple of most Africans.

In this section, a quantitative analysis of energy transport mechanism in steady state natural convection during the production of a paste, known as "Eba" in the Yoruba speaking areas of Nigeria was carried out. So, in thus lecture, paste and "Eba" will be used interchangeably. The texture and eating quality of the paste are highly influenced by the particle size of granules, starch content, period/ days of fermentation, ration of the quantities of water to gari sample and effectiveness in the utilization of thermal energy required by the starch to form a gel.

A model has been proposed (Fig. 11), which evaluated the unique contributions of simultaneous energy transport by free convection, radiation and evaporation in relation to the total transferable energy during the reconstitution process involving water/gari mixture changing to a semi-solid (thick) conductive paste. The following basic facts were considered (Sobowale *et al.,* 2006):

I. For any given sample of paste, and regardless of the starch content of granules, a certain quality of the boiling water is required to reconstitute a known quantity of gari granules.

II. Heat is lost by free convention, assuming no fans are operated in the vicinity, and that the limiting resistance is a boundary layer of vapour film. So the intensity of energy transfer will be dependent on the driving force effects of temperature potential, exposed area and thermal resistance at the paste/vessel surface.

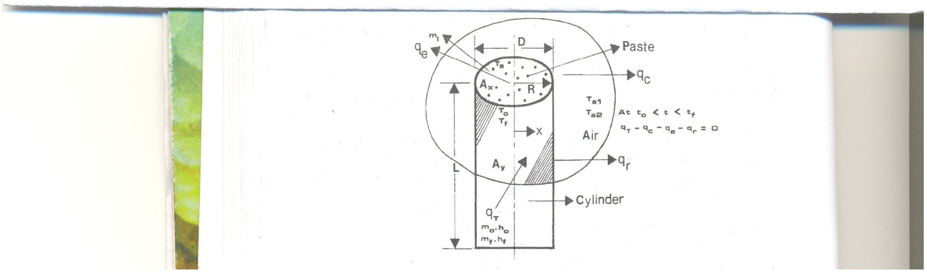

Fig. 11 A model for energy transport mechanism in a water gari mixture during reconstitution at 100ºC

III. Moisture is lost simultaneously with heat in the form of water vapour from the mixture/paste to the surrounding air (Fig. 12), while the starch would absorb water and swell. Similarly, in the process of mixing/ stirring to obtain a consistent texture, more volumes of water vapour are lost to the surrounding air, which affect the final texture. In other words, the paste could be soft or hand as the case may be.

IV. Temperature profiles in the pastes would be transient, such that temperature at any point would also be a function of position in the paste or vessel, and its distribution would also change with time of reconstitution.

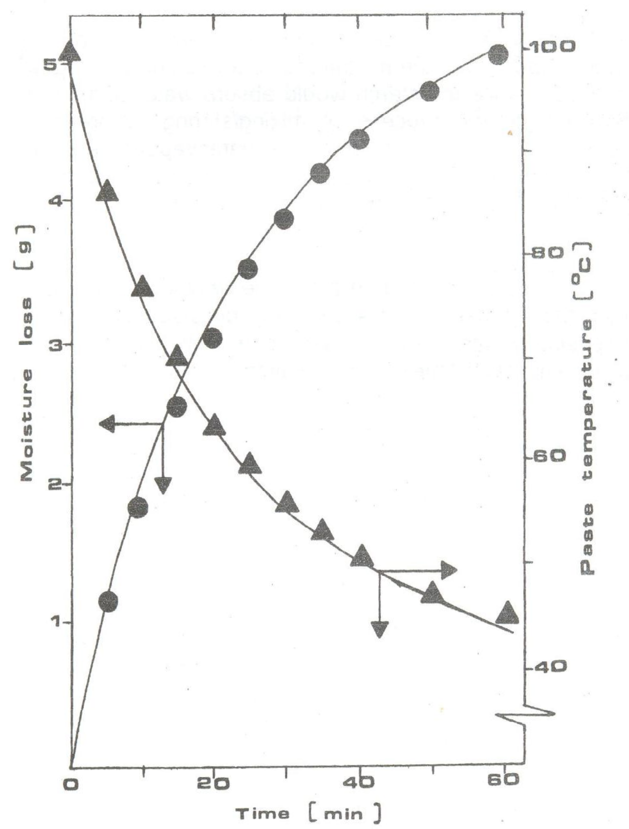

Fig. 12: Moisture loss and temperature changes with time during reconstitution of gari
Data ● Moisture loss, ▲ Temperature changes

In the model shown in Fig. 11,
Evaporative energy

$q_e = m_1.\lambda$ ...... (36)

Convective energy

$q_c = h_c.A_\chi.\Delta T_m$ ...... (37)

where, x=R and t0

$$K \frac{dT}{d\chi} = h_c.(T_a \quad T_S)$$ ....(38)

Radiative energy

$q_r = A_y.\varepsilon.\partial.(T_s{}^4 \quad T_{a2}{}^4)$ .... (39)

where, ε = Emissivity of type B stainless steel surface = 0.6 (Holman, 1976).
Hence, the total heat energy transferred, q_T:
$q_T = q_e + q_c + q_r$ ....(40)

$q_T = m_o.h_o \quad m_f.h_f = (m_a \quad m_1)C_p.(T_o \quad T_f)$ ....(41)

Equation (41) gives the relation between the various energy transport mechanism, excluding radiation effect which is relatively small and could be ignored without any loss of accuracy. The correlation of results using dimensionless relationships, are similar to those obtained for general heat transfer processes:

$$Nu = C(Gr.Pr)^m . \left(\frac{D}{L}\right) \quad \ldots\ldots(42)$$

$$Nu = 0.48(Gr.Pr)^{0.4} \quad \ldots\ldots\ldots\ldots(43)$$

(Correlation coefficient, r = 0.88)
and

$$Nu = 0.5(Gr.Pr)^{0.4} . \left(\frac{D}{L}\right)^{0.15} \quad \ldots\ldots\ldots\ldots(44)$$

where, (D/L) represent the ratio of vessel diameter to its length or height if used in the correlation of data (correlation coefficient, r = 0.9). Fig. 13 shows the variations of the two modes of heat transfer (convective and evaporative) with time of reconstitution, while Fig. 14, shows the empirical relationship in dimensionless form which took the number of mixing/stirring of a paste into consideration.

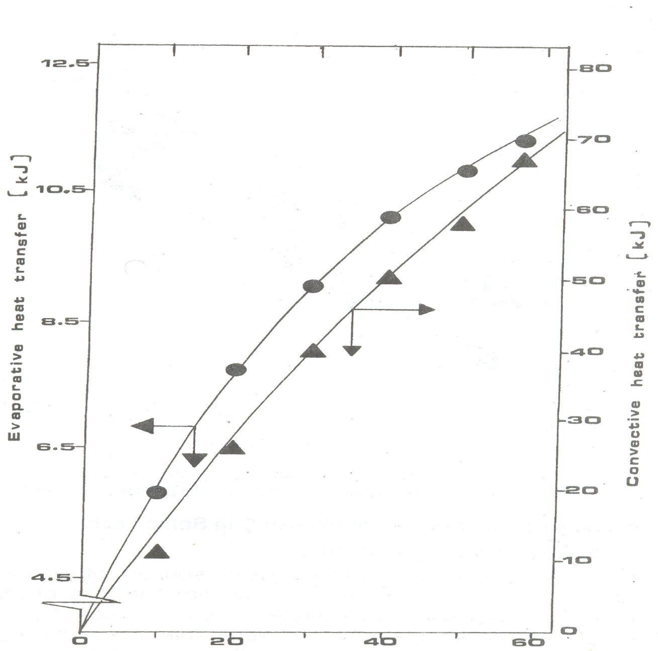

Fig. 13: The variations of convective and evaporative heat transfer with time of reconstitution

Data: ●, Evaporative heat transfer; ▲, Convective heat transfer

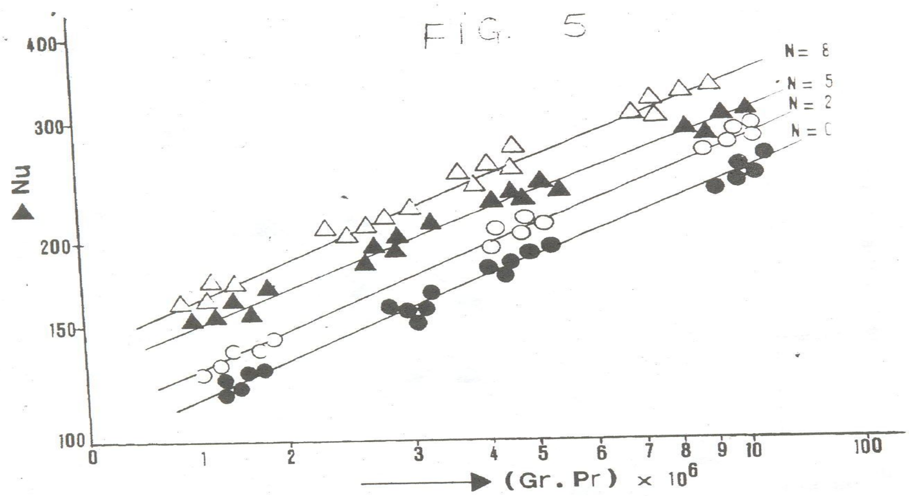

Fig. 14: The variations of Nusselt number (Nu) with Rayleigh number (Ra) as influenced by the number of mixing/stirring (N) of the paste during reconstitution

5.6. Degradation Kinetics of Vitamins C in Some leafy Vegetables during Blanching

Green leaf vegetables are important sources of vitamin C (ascorbic acid) and minerals in the diet. The loss of most nutrients, especially during processing or storage depends on the method used and type of vegetable. Since the major vitamins are both water soluble and thermally unstable during processing, it is of particular interest because much of the procedures used in its preparation prior to consumption (washing, cutting, slicing, squeezing and drying) invariably result in nutrient losses.

Blanching is a heat treatment and a first step in industrial processing or parboiling pr parboiling in domestics food preparation prior to cooking or drying. Most vegetables are blanched prior to freezing or dehydration. It helps to control enzymatic activities responsible for colour and flaour instability in the vegetables.

We have carried out extensive studies on three vegetables- *Corchorus olitorius, Amaranthus hybridus and telfarria occidentalis,* known locally in Yoruba land "Ewedu", "Tete" and "Ugu", respectively. The vegetables were subjected to different blanching temperatures (55 to 90^{o}C) and time (2 to 10minutes). Thus, the degradation changes occurring at a given blanching temperature, T over a period, were determined using the general relation (Labuza and Kamman, 1983):

$$\frac{dC}{dt} = \pm k(kT)C^{n} \qquad \text{..........(44)}$$

where,
k= specific rate constant for the changes; and
n= order of reaction
The reaction causing the changes could be of zero order, but first-order reaction is common for food products, hence, according to Kincal and Giray (1987)

$$\text{In L} \frac{C_a}{C_{ao}} = kt \qquad \text{..........(45)}$$

The intensity of heat on the degradation process was evaluating using the Arrhenius relationship:

$$k = k_o e^{Ea/RT} \qquad \text{..........(46)}$$

The activation energy, Ea evaluates the level of energy required to cause degradation to occur. Thus, higher values of Ea, are indications of slower reaction that caused degradation and would be expected to depend on the type of vegetable.

The data were then subjected to basic empirical analysis to determine the effectiveness of temperature and time on the degradation. Thus,

$Y = aX^b$ ……….(47)

or

$Y = b + b_1X_1 + b_1 X_2 + e$ ……….(48)

where, Y is the Vitamin C level, X_1 and X_2 are temperature, T and time, t, respectively, and e is the error term of regression. The results are summarized in Tables 1 and 2, and Figures 15 and 16.

Table 1:Degradation rate constants, activation energy, and pre exponential constants for three vegetables at different blanching temperatures

Vegetable Sample	Blanching temperature (0C)	Degradation rate constant, k (S-1) x 10-4	Activation energy, Ea (KJ/g-mol)	pre-exponential constant, ko (S-1) x 10-3	Correlation factors	
					R2	SE
Corchorus Olitorius	55	4.22	16.23	1.23	0.97	2.63
	60	4.71				
	70	7.01				
	80	6.41				
	90	6.94				
Amaranthus Hybridus	55	4.57	14.99	1.25	0.99	2.11
	60	5.56				
	70	6.69				
	80	6..74				
	90	7.71				
Telfairia Occidentalis	55	3.74	36.00	2.09	0.95	2.82
	60	4.37				
	70	6.54				
	80	7.49				
	90	12.90				

R^2 = Coefficient of multiple determination
SE= Standard error of mean values

Table 2: Regression data for ascorbic acid degradation in three leafy vegetables during blanching

Table 2: Regression data for ascorbic acid degradation in three leafy vegetables during blanching

Vegetable sample	Coefficient of Eqn. (48)			Correlation factors	
Trait	β0	β1	β2	R2	SE
Corchorus olitorius	0.645	0.651	0.512	0.968	2.48
Amaranthus hybridus	4.659	0.699	0.039	0.969	2.12
Telfeira occidentalis	7.577	0.663	0.039	0.959	2.01

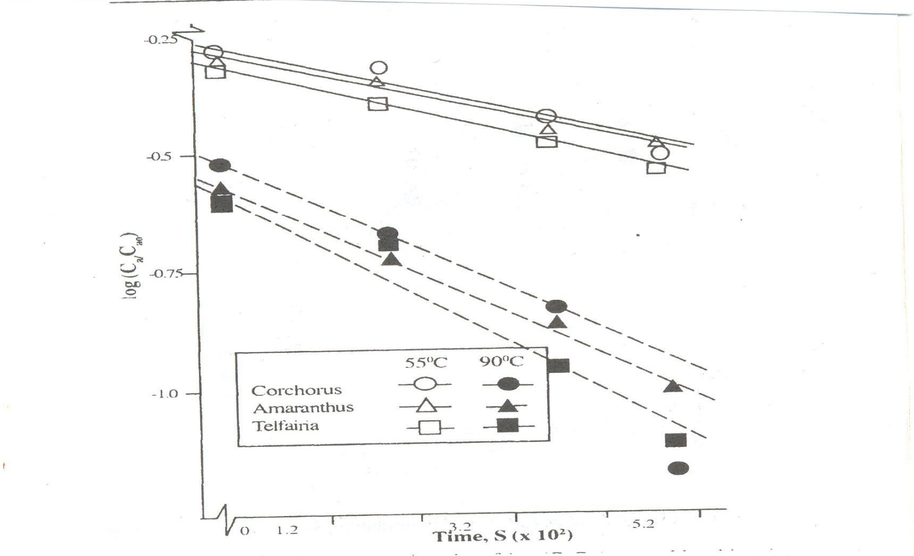

Fig. 15: Arthenius plots of ascorbic acid degradation for three leafy vegetables

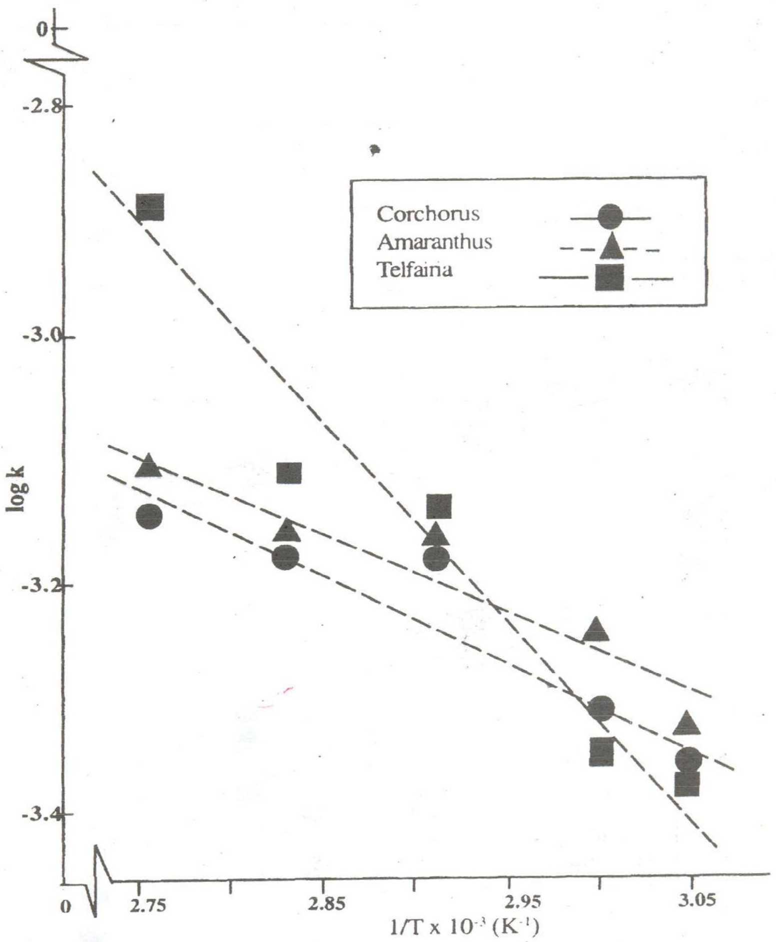

Fig. 16: Arhenius plots of ascorbic acid degradation for three leafy vegetables

6.0 CONCLUSION

Mr. Vice-Chancellor, Sir and distinguished ladies and gentlemen, in the course of this lecture, I have taken you through a summary of landmark research efforts and contribution to knowledge in an area where both theory and practice are harnessed in order to achieve the ultimate goal of preserving food and the addition of value. I have presented only three areas of research where my contributions to knowledge in food processing and storage have been very briefly highlighted because of space and time. Of course, there are other notable and elaborate studies, for example, on livestock processing and waste utilization in the form of animal feeds, drying method for soya bean and quality of the extracted oil, osmotic dehydration of pineapple slices, cowpea storage, hazard analysis and safety standards for “robo”- a popular snack food in Western Nigeria, etc. Even so, I would like to assure this gathering that, in its totality my scientific and professional contributions were based on a general scope for engineer’s approach to the solution and concept of food preservation. I must, however, add that in the course of my adventure, it has been most challenging and exciting as well as rewarding, not in terms of money, but in the form of stimulating discoveries and advancement.

Let me now highlight specific areas where, as the popular saying that “at the end of dark alley comes a bright light,” new grounds have been established:

6.1 Cryogenic Freezing of Foods

- In food freezing using liquid nitrogen, I have developed very versatile heat transfer equations which were well supported by empirical validations in unique way that attracted the attention of other researchers and, in particular, the frozen food industry. The copy of my Ph.D. thesis in the library of the University of Leeds is, perhaps, one of the most consulted as evidenced from very long entries of signatures and names of such individuals. It was only recently that I signed a document for allowing more than 10% of the thesis to be photocopied by anyone consulting it.

- It was shown that the average convective heat transfer coefficients between the food surface and individual droplets (h) were in the range of 685 970 W/m^2K and 175 240 W/m^2K for sprays. It was also found that in deep freezing using liquid nitrogen sprays, only about 25% of the heat transfer potential of the droplets is actually realizable. This factor was found to be as a result of poor surface/ fractional coverage, å (13 to 19%) of the food with spray because non-uniform sprays would continue to arrive as spraying occurs and depending on the spray geometry and pressure fluctuations in the Dewar storage vessels. So, $\varepsilon = \frac{h}{h_d}$
- Our observations concerning moisture contamination with nitrogen droplets indicated rapid rates of evaporation which led to higher instantaneous heat transfer coefficients. We attribute these conditions to be a result of break-up of droplets as they penetrate the porous ice masses or particles on the food surface with increased exposure of droplet's cross-sectional area to heat transfer.
- In terms of evaporation losses between the spray nozzles and food surface, approximately 30% of liquid nitrogen infeed to the freezer occurred, although these are not total losses since the extremely cold gases would still be held in the pre-cooling section of the freezer. As a useful information $h \alpha \Delta T^{-0.17}$ (or $d_{32}^{-0.17}$ or $55(m)^{0.21}$ and maintained the general convective relationship,

where: $N_{nu} = N^{0.5}_{RE}\ N^{0.3}_{PR}$ and $m^* = dm.A$ over the spray area (A) in an actual freezer.

- For a given quantity of food to be frozen (product loading, M), a certain quantity of liquid nitrogen (m) will be required whether or not the liquid nitrogen (m) will be required whether or not the liquid or food is introduced into the freezer slowly or rapidly. We have reported values for (M/m) to be in the range of 1.09 to 1.17 (Awonorin, 1996) for a particular mass flux density () of nitrogen sprays (Awonorin, 1989). This is useful information for the frozen industry and manufacturers of cryogenic freezers.

- Losses in food nutritional value for some water soluble vitamins (thiamine, riboflavin and niacin) as result of drip from cryogenically frozen foods were practically insignificant (0.5 to 0.6%) and microbial destruction due to the freezing speed was in the order of six-folds. However, for meat samples stored in household deep freezers at -20^{o}C, retention of these vitamins are 70, 77 and 87%, respectively, while the drippings upon cooking contained about 3 to 14% of such vitamins during 3 months of frozen storage. Much lower retentions of vitamins (40 to 70%) and increased drip/cooking losses (37 to 58%) were recorded for meat samples which were subjected to some forms of temperature abuse frozen and refrozen meat.

6.2 Reconstitution Studies

- The release of moisture (m) to the surrounding air and temperature within the paste (T) were empirically related to the reconstitution time (t) in our correlation data.
- Evaporation and heat transfer by convection played significant roles and vapour film or steam properties at the paste surface control the rates of heat and mass transfer during the reconstitution process. ($m = 0.7t^{1/2}$ and $T = t^{-1/3}$).
- Without stirring the paste, the dominant mechanism was convective,

accounting for 70% of the total energy transferable, whilst the balance of 30% was attributable to evaporative heat transport. Stirring the paste led to spontaneous release of moisture and accelerated outward flow, which completely reversed the mode of energy transport, and accounted for 67% of the total energy transported. The transport mechanism practically reduced to convective heat transfer if the vessel surface is covered with a lid as often practiced to ensure maximum utilization of heat energy content of the boiling water, and stratification may, therefore, occur at the paste surface.

- Radiation heat transfer accounted for less than 2% of the energy transferred with or without stirring the paste.
- Surrounding air temperature and humidity increased by about 50 and 70%, respectively, as a result of the release of moisture during stirring and mixing. Such humid heat, if released on a continuous production basis, e.g., in a restaurant kitchen or food preparation areas would result to dampness, formation of dew on walls and windows, peeling off of paints from wall surfaces, and proliferation of microorganisms in the local environment. This is costly and could also adversely affect the standard of hygiene practice in the processing areas.
- The volumetric swelling capacity of the granules during reconstitution was found to be in the range of 388 to 405%. These values were dependent on the use of correct water to gari mixture ratio of 1.5 to 1.0 for maximum swelling within the range of starch content of samples in experiment and water temperature of 90 to 100^{o}C
- The result of the paste samples placed in commercial coolers or warmers, as often referred to, showed that a period between 3½ and 6¼ hours is recommended for storing of gari paste and maintaining its consistency and acceptability based on heat preservation or the assurance of minimum level of hotness (50^{o}C) if its consumption is

not immediate.

6.3 Degradation of Vitamin C in Blanched Vegetables

- The reaction rates were slower in *Amaranthushydridus* ("Tete") and *Corchorus olitorius* ("Ewedu") than *Telfairia occidentalis* ("Ugu") based on the results of the kinetic model. So, whether the vegetables are to be frozen or dried, blanching as a pretreatment would cause heavier losses of Vitamin C in "Ugu" than "Tele" or "Ewedu".

7.0 FUTURE RESEARCH, POLICY ISSUES AND THE WAY FORWARD

Mr. Vice-Chancellor, Sir, in the course of my academic career, certain facts have emerged, and I wish to point some of them out to guide in our future commitments.

7.1 Research

I must admit that I was lucky to have received western education via the overseas scholarship in the course of my studies, so most of the experimental equipment and facilities used for the cryogenic investigations were based in the overseas institutions. I was privileged to attend. Somehow, I am worried, so to speak, that most of the basic equipment used for training several years back, whether outdated or most recent appears not to be insight. But without basic facilities, what type of training are we imparting to our students especially in science oriented programmes? This is a food for though for all of us as stakeholders in the system, including government.

7.2 To Academic Colleagues and Staff Unions

Every profession has its standard of practice to facilitate competence in the attainment of the set goals and objectives of such bodies. To us in the academics, we must embrace high ethical practices, integrity, reliability and professionalism in our dealings. We must avoid those things that are inimical to intellectual development because in the absence of genuine intellectuals, we would have pseudo-intellectuals, who will take a lead in corrupt practices. Therefore low integrity, dubious and dishonest staff should be shown their ways out of the academic system. This specifically calls for a greater sense of humility, honesty, uprightness, patriotism, productive service and willingness to accept changes and challenges, embracing dialogue and guaranteeing peace in the system.

Staff Unions should continue to seek dialogue and uphold the culture of peaceful learning environment that usually characterizes a university system. Some staff have pre-occupied their life styles with acts of indiscipline and lack of patriotism. The atmosphere is fouled with stories of sexual harassment, plagiarism and examination malpractices. This clearly shows lack of commitment and devotion on the part of such staff, and the system should employ appropriate step to stop this kind of behaviour through disciplinary process. In spite of this, a good number of truly dedicated and well disciplined staff are still to be found in our universities today.

7.3 To Students

No nation can play down on the education of its young citizens, i.e., students are not born to suffer in life but to exploit the riches on earth by making maximum use of the abundance pf opportunities available in the society. So education should equip students with skills needed for a productive and creative future life. It is, however, a shame that the great majority of our institutions of higher learning in this country today are locked in frantic battle to wipe out cultism and other negative vices on campuses. Such vices do not contribute to national or societal development, but rather tend to corrupt morals.

Students should emulate great people in the society, who have distinguished themselves through hard work, dedication and honesty. Be law abiding, don't behave or operate like a vagabond, eschew cultism; no one can serve two masters at the same time, so choose God not the Devil; and those of you doing evil must change. Go the extra mile to expose dishonest practices and cult activities.

Try and understand government and its policies, university management and their actions, which are usually taken in good faith and people's welfare in mind. Even in our various homes, we do not have everything that we want; hence, our youth should desist from actions capable of disrupting peace and harmony on campuses and society in general when making requests. Remembers that life is classified into stages, therefore, exercise patience while pursuing your missions, and note that after graduation, you too will soon become a stake holder in the system.

Students should strive to work hard in their academic work, regard the library as a second home, respect constituted authorities and live in harmony with one another and the community. One of the virtues of university education is to create a good image for the university and for yourselves, so immediate and expanded campuses have indicated the need to eschew bad examples, indecent dressing, and to you for public life after graduation, when it will be your turn to collectively run the affairs of this country.

With regards to poor conduct of examinations meant for entry into tertiary institutions, the observed criminal practices have eaten deep into our educational system right from the secondary schools which serve as feeders for institutions of higher learning. The present initiative of the Education Ministry is a national re-orientation and a bold step meant to discourage dishonest practices in the conduct of relevant examinations. I urge you to see the present process as a starting point and a catalyst for transformation. Remember that reforms are usually dynamic and could not be achieved without its share of criticism. I am aware of some provisions made by the present government, either at State or Federal level concerning credit facilities through some agencies and banks. If you are in a final year of graduation, you should make effort to apply for such facilities in order to develop the practical skills being acquired in this university.

At this point, I wish to specially recognize the maturity which the students of this university have consistently demonstrated over the years to ensure peace, especially when compared with their colleagues in other institutions. I urge all UNAABITEES to continue to be peaceful and be proud so that for ever, UNAAB will remain great.

7.4 To Management of Tertiary Institutions

The present time in our national development calls for self-sacrifice and a high degree of patriotism, transparent leadership, accountability and unique contributions to a pool of ideals which will guide the nation's formation of policies on economic growth and other sectors. An important culture of the university is sponsorship for research and the attendance of conferences, international seminars, workshops and exhibitions by staff members. Today, this culture appears to be going through a process of death and care must be taken to revive it. I would like to say here that the issue of lack funds is well noted, but perhaps we can place this aspect topmost on our priority list. This should go hand-in-hand with an effective program for commercialization of research findings in order to improve the internally generated revenue-base in our universities.

Again in some tertiary institutions, certain Chief Executives exhibit total disregard to laid down procedures or more recently the due process, coupled with incompetence, lack of sense of direction and maladministration. This is certainly not helping the academic system.

For more of us in the University of Agriculture Abeokuta (UNAA) we have been extremely lucky to have good leadership beginning from the establishment of the University in 1988. two Vice-Chancellors had served with honour and dignity and, today, UNAAB has not only been rated to be best amongst all universities in the country but also its current Vice-Chancellor, Prof. Israel Folorunsho Adu also adjusted to the best Vice-Chancellor in recent times. The success story is that of steadfastness, openness and understanding among students and staff. I therefore urge both staff and students to uphold and sustain theses virtues so the UNAAB will remain the greatest at all times.

7.5 To Parents

In times like these, the need for parents to interact with their children in order to influence their lives and transform the society cannot be overemphasized. We need to look at our family system and constantly monitor our children at school so that they will develop the right attitudes and values.

In our present realities as a nation, it is not enough to expect to receive quality education freely for the sake of the "right of every citizen". This will be unrealistic in the present circumstance, so it is only logical not to leave the entire cost of university education to the already over-stretched public funds or the government. As stake holders, we need to offer support in this sector.

7.6 To Government

It is noted here that most great countries of the world have well focused agricultural policies which integrate mechanized production methods with large investment in post-harvest technology. Governments in such countries are observed to be stable and policies are vigorously implemented. We also need to do that in the country if we are to succeed in our fight against poverty and the achievement of food security. Industrial development is a achievement of food security. Industrial development is a key to job creation and a necessity for national or international development.

The university system has a number of major roles to play in Nation building by producing high-level manpower and extending the frontiers of knowledge based on tripodal mandate of teaching, research and extension. This, however, require adequate and sustained funding not only for capital development but also for recurrent expenditure and other activities. The level of funding of education in this country should be greatly improved to meet internationally acceptable standard.

The Direct Teaching and Laboratory Cost (DTLC) which Government introduced recently to cater for consumables and practical needs in the Nigerian Universities is a good development which government should continue to support for effective teaching and learning.

Government should encourage dialogue with staff unions in resolving issues to avoid instability and closures of the system. The issue of brain drain should be addressed to sustain quality education. Any loss of trained manpower is bound to affect our aspiration to build a better society through self-reliance technologically and economically.

The bold steps taken by the Federal Government to clean up the society of corrupt and dishonest practices and the introduction of Due process into public finances are highly commendable. Although the journey may be tough and rough as government is leading the path towards salvation, but surely we will one day have a morally and ethically sound Nigeria. We play and hope that successive governments will continue to maintain such stand.

8.0 TRIBUTES AND ACKNOWLEDGEMENTS

Mr. Vice-Chancellor, Sir and Distinguished Members of the Audience, I would like to acknowledge some of the notable individuals and corporate bodies, who have made significant contributions to the success stories of my life and made unique impact in the course of my academic career. To save time, I shall specifically mention a few names, but if I don't mention yours, please pardon me as it would not be deliberate.

Let me start by giving Honour and Glory to the Almighty God for giving me good health, including my family and for sparing my life, for his love, grace and inspiration, for sustaining me to this professional height, and for granting me this rare opportunity to deliver this Inaugural Lecture. I say "Thank You JESUS"

I sincerely appreciate and give special thanks to my late parents, Mr. and Mrs. Awonorin, for their love, parental and Godly care, labour, kindness, prayers and deep investment towards my academic and professional development.

I would like to pay some tributes to members of my family-brothers and sisters for their moral, financial supports, including those of illustrious sons of this country, Late Chief I. Dina, a former Permanent Secretary in the Western Region of Nigeria, and Prof. C.O. Taiwo, formerly the Provost of the College of Education, University of Lagos, now retired. May the grace and love of God be with you.

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