FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

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INAUGURAL LECTURE SERIES 58

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This 58th Inaugural Lecture was delivered
under the Chairmanship of:

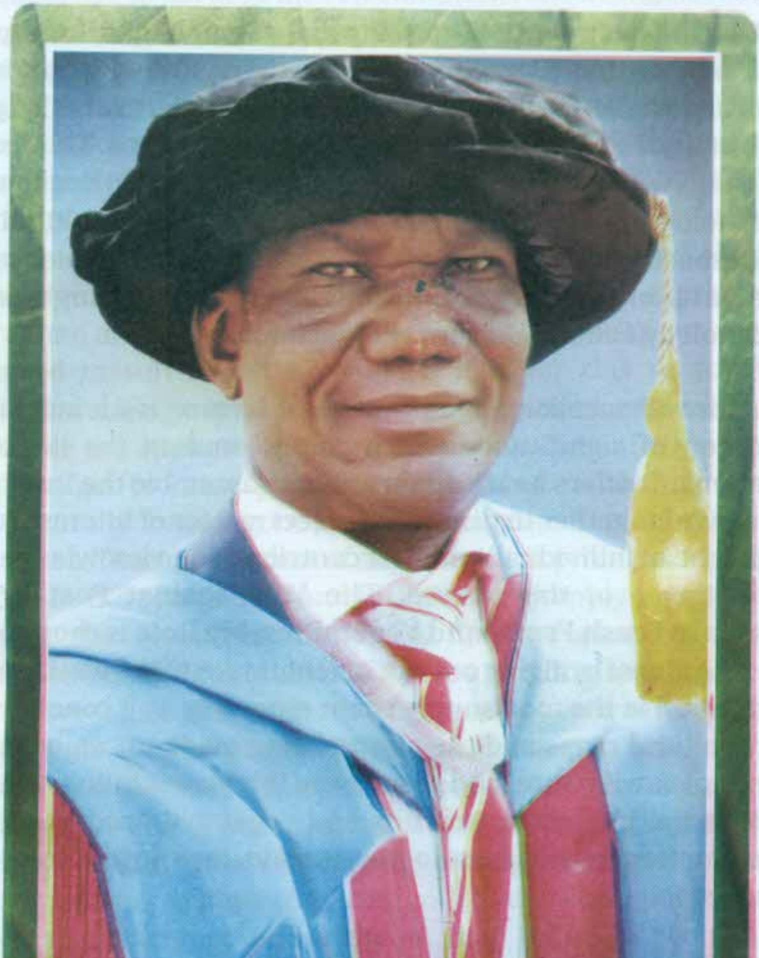
Professor M. A. Akanji, FNSMBM, FAS
Vice-Chancellor
Federal University of Technology, Minna

ISSN 2550 - 7087

Published by:
University Seminar and Colloquium Committee
Federal University of Technology, Minna.

16th November, 2017

Design + Print:
Global Links Communications, Nigeria
✆: 08056074844, 07036446818



Professor Peter Aba Idah

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Preamble

It is with deep sense of humility and immense gratitude to God Almighty that I stand before this distinguished gathering of men and women to deliver the 58th Inaugural lecture of this great University, Federal University of Technology, Minna. This lecture is the 16th from School of Engineering and Engineering Technology, the 5th from the Department of Agricultural and Bioresources Engineering and the 1st from one of the pioneering students of the School of Engineering and Engineering Technology, Federal University of Technology, Minna.

The Vice-Chancellor Sir, an Inaugural lecture is an auspicious occasion of significance which comes once in the life of an academic. It offers a rare opportunity to assemble the "town and the gown" together to discuss a subject matter of interest and to highlight an individual's modest contribution to knowledge. The main theme of this lecture: **The War against Postharvest Losses in Fresh Fruits and Vegetables: My Role** is chosen with the sole aim of bringing out the salient issues of the wastage that is going on in the food supply chain especially as it concerns the horticultural crops and the efforts being made to combat these losses so as to ensure food security. In this presentation, we shall look at the introduction, fruits and vegetable production and consumption, postharvest losses, tomato, my contributions and conclusion.

Mr. Chairman Sir, may I crave your indulgence and permission to present today's lecture.

1.0 INTRODUCTION

Agricultural and Bioresources Engineering as a Profession

Man was created with a catalogue of materials of both living and non-living things intended to provide comfort for him. Man's ability to recognize this fact cannot be underestimated and thus, the expertise to harness the relevant materials in engineering to bring about this comfort. Because each of the catalogues of human problem and desires would require a unique approach to solving it, it will therefore require the use of many engineering branches, some of which are Building, Civil, Electrical, Computer, Chemical and Mechanical engineering. The problems often encountered in agriculture are such that the expertise of a single branch of engineering, some of which are enumerated above is insufficient to provide the needed solution. The expertise of more than one of the branches and varied combinations may be required to solve such a problem. It is for this reason that Agricultural Engineering emerged. Agricultural engineering is therefore the application of any or all branches of engineering knowledge to any process associated with producing agriculturally based goods and management of our natural resources. The whole intent of engineering is problem solving to better the life of mankind and this it does by applying science to convert the resources of nature. This is what led to the emergence of Agricultural and Bioresources Engineering. Hence, Agricultural and Bioresources Engineering often referred to as Biosystems Engineering integrates engineering sciences and design and applied biological sciences for the solution of problems involving plants, animals and natural environment. It deals with patterns of relationship among organisms and their environments, engineering design to develop and manage processes, machines and systems that influence, control or utilize biological materials and organisms for the benefit of the society (Wikipedia Encyclopedia, 2013; Field *et al.*, 2007).

It can be seen that the Agricultural Engineer has a great concern with Bioresources. This concern can be seen in the following light as effort in training, research and public service can conveniently be categorized within three major themes:

1. **Agricultural Systems Engineering**: creating safer, more efficient and environmentally sustainable production system for plants and animals; machinery design for agriculture, horticulture, aquaculture and forestry; building systems for livestock, laboratory and storage of agricultural and food product; instrumentation, monitor and control; standard and safety.

2. **Bioprocessing Engineering**: improving and converting biological materials; added value processing (drying, binding, separating etc) of agricultural crops and animals for use as food, fibre, energy and pharmaceuticals; primary processing of waste materials for land application; quality control in processing operations; handling systems for granular and fibrous materials; energy conservation and utilization; computer image analysis; engineering in support of biotechnology.

3. **Natural Resources Engineering**: managing and protecting resources; soil and water conservation; water management for agricultural use; irrigation and drainage, soil reclamation; utilization of waste materials in plant-soil systems; modeling environmental systems; decision support and simulation.

Engineering combines creativity and practicality on scientific basis. When scientific basis borders on living things, their by-product or their natural resource base, the resulting branch of engineering is variously called Agricultural, Biological, Biosystems, Bioresources and/or Bioenvironmental. Some of such living things and natural resources of great importance are the horticultural crops, especially **fruits and vegetables**.

2.0 FRUITS AND VEGETABLES

Fruits and vegetables are of great nutritional value. They play a very important role in nutrition and health, especially as they contain substances which regulate or stimulate digestion, act as laxatives or diuretics, pectin and phenoic compounds which play a part in regulating the pH of the intestines (Ibeawuchi *et al*., 2015). They are important sources of vitamins and minerals, thus essential components of human diet. Consequent upon this, there had been increased trade/commercial activities surrounding these commodities (Egharevba, 1995). Vegetable production forms a substantial percentage (about 25%) of the major food crops cultivated in the tropics and so it is the source of livelihood for a considerable section of the population (Kra and Bani, 1988).

2.1 Horticultural Crops Production: Global Trend

Food and Agricultural Organization of the United Nations (FAO) predicted that the world population would top eight (8) billion by the year 2030 (Simson and Straus, 2010). Therefore, the demand for food would increase dramatically. As stated in the FAO report "Agriculture: Toward 2015/30" remarkable progress has been made over the last three decades towards feeding the world. While global production has increased over 70 percent, per capita food consumption has been almost 20% higher. According to the report, crop output is projected to be 70 percent higher in 2030 than the current output. Fruits and vegetables will play an important role in providing essential vitamins, minerals and dietary fibre to the world, feeding populations in both developed and developing countries.

The United States (US) continues to dominate the international trade of fruits and vegetables and is ranked number one as both importer and exporter accounting for approximately 18 percent of the $40 billion (USD) in fresh produce world trade. As a group, the European Union (EU) constitutes the largest player, with 15 additional export and import commodities contributing about 20 percent of total fresh fruit and vegetable trade. Within Europe, Germany is the principal exporter, Spain is the principal supplier and Netherland plays an important role in the physical distribution process. In the Southern Hemisphere, Chile, South Africa and New Zealand have become major suppliers in the international trade of fresh fruit commodities, although they remain insignificant in the vegetable trade (Simson and Straus 2010). The estimated world production of fruits and vegetables reached a global production of 508 million tons for vegetables and 469 million tons for fruits in 1996. This trend in production was expected to increase at a rate of 3.2 percent per year for vegetables and 1.6 percent per year for fruits (which means by this year 2017 the estimated world fruit production is expected to hit about 626 million tons per year, while that of vegetable is about 849 million tons per year). However, this trend is not uniform worldwide, especially in developing countries where the lack of adequate infrastructure and technology constitutes the major drawback to competing with industrialized countries. Nevertheless, developing countries will continue to be the leaders in providing exotic fruits and vegetables to developed countries. Most developing countries have experienced a high increase in fruit and vegetable production as in case of Asia and South America.

Asia is the leading producer of vegetables with a 61 percent total volume output and a yearly growth of 51 percent. However, the US continues to lead in the export of fresh fruits and vegetables worldwide particularly in orange, grapes and tomatoes. Brazil dominates the international trade of frozen orange juice concentrate, while Chile has become the major fresh fruit exporter with a production volume of 45 percent. The top six fruit producers in declining order of importance are China, India, Brazil, USA, Italy and Mexico. China, India and Brazil account for almost 50 percent of the world's fruit supply, but since most of this production is destined for domestic consumption; its impact on the world trade is minimal (Simson and Straus 2010).

Nigeria is credited with production of variety of fruits such as mangoes, tomatoes, tangerines and many other indigenous fruits. Many Nigerian indigenous fruits and vegetables are native to different ecological zones of the country. Fruits and vegetables are cultivated in Nigeria for economic purposes both in the rural and urban environments. The annuals such as tomatoes, leafy vegetables, garden eggs and okra are cultivated either as seasonal or irrigated crops (Ubani and Okonkwo, 2011). Staggering figures are usually given as estimated annual production figures. For examples figures like 3.8m tons of onions, 6m tons of tomatoes, 15m tons of plantain and 35m tons of citrus have been quoted as annual production levels for some fruits and vegetables which are really large quantities of food crops (Oyeniran, 1988; Erinle, 1989). In spite of these large figures Nigeria plays less role in the global markets as far as fruits and vegetables are concerned.

The Commercial Manager, sub-Saharan Africa, DHL Aviation, Abayomi Adetola in an article "**Nigeria can become Africa's Fruit Exporter**", published in **Views** on 28th May 2013 noted that there is massive opportunity which Nigeria possess in horticulture, fruit and vegetable export to Europe and how to activate this unique opportunity to earn more non-oil foreign exchange. It was noted that until a year before that year, Nigeria was the only country they have not been picking anything since they have been operating. From Douala alone, it was revealed that no less than 60 tonnes of fresh fruits and vegetables are sent to Europe through DHL alone weekly. Cotonou sends more than 45 tonnes weekly and Accra 65 tonnes weekly all-year-round. Some of the major issues raised bother on health certificate, airports in Nigeria not yet developed for exports of perishables and infrastructural issues such as cold rooms which are not yet developed for the export of perishables. The only known exception is the cargo Terminal at Ilorin International Airport which though ready but has never been put to use.

2.2 Fruits and Vegetable Consumption

Fruits and vegetable consumption per capita showed an increase of 0.38 percent for fresh fruits and 0.92 percent for vegetables per capita from 1986 to 1995. The highest consumption of fresh fruits was registered in China (6.4%), as apparent per capita consumption of vegetables in China went from 68.7 kg per capita in 1986 to 146 kg in 1995 (53.8 % of growth rate), while African and Near East Asian countries showed a decrease in fresh fruit consumption. The lowest consumption of vegetables per capita was registered in Sub-Saharan Africa. The trend towards fresh vegetable consumption in developing countries is one indication of the population's standard of living, but generally, fresh vegetables lose their market share to processed products (Simson and Straus, 2010).

In Sub-Saharan Africa, the level of fruit and vegetable consumption ranges from 27 to 111 kg per capita per year, far below the WHO/FAO minimum recommendation of 146 kg per capita per year. In fact, WHO's recommended consumption standard quality for vegetable is 80g/meal and a total of 400g/day (WHO, 2005). In a study done by WHO to determine which developed countries had national average fruit and vegetable consumptions which were within recommended values, out of the 21 studied countries, only 3 (Israel, Spain and Italy) had acceptable national average intakes of at least 400g/day (Banwat *et al.*, 2012). While vegetable consumption is almost universal in most Sub-Saharan Africa, the consumption of fruits is much less common and varies across countries. Also, the average consumption (in kg per capita per year) is lower for fruits than vegetables in most countries (Dimelu and Odo, 2013). The situation is not different for Nigeria as can be seen from the figures given for expenditure on food by type by National Bureau of Statistics as shown in Tables 1 and 2.

Table 1: Household Expenditure by Type of Commodity: National 2009/10

National

S/N	Commodity	Expenditure Food	Percentage of Food	
1	Maize	745,591,888,308.67	4.75	3.07
2	Rice	1,397,928,262,310.25	8.91	5.76
3	Other Cereal	1,635,936,079,663.30	10.43	6.75
4	Bread & Similar Foods	586,287,068,386.48	3.74	2.42
5	Tubersand Plantains	3,545,548,100,772.56	22.60	14.62
6	Poultry	91,558,294,033.21	0.58	0.38
7	Meats	462,928,721,187.21	2.95	1.91
8	Seafood	670,176,425,506.33	4.27	2.76
9	Dairy Products	174,357,580,933.05	1.11	0.72
10	Oils, Fats and Oil rich nuts	587,208,074,677.47	3.74	2.42
11	**Fruits**	**294,162,613,610.86**	**1.88**	**1.21**
12	**Vegetables excludes pulses**	**2 ,421,106,476,408.03**	**15.43**	**9.98**
13	Beans and Peas	1,517,399,036,392.62	9.67	6.26
14	Sugar, Jam, Honey, Chocolate and Confectionary	174,188,422,160.96	1.11	0.72
15	Non Alcoholic	627,497,560,281.93	4.00	2.59
16	Alcoholic	82,192,845,211.53	0.52	0.34
17	Food consumed in resturants and canteens	182,374,622,152.41	1.16	0.75
18	Other Non-Food Items	490,226,971,084.87	3.13	2.02
	Sub-Total	**15,686,669,043,081.70**		64.68

Source: National Bureau of Statistics (2012)

Table 2 Niger State Household Expenditure

Niger

S/N	Commodity	Total Annual Expenditure Food	Percentage of Food	Percentage of Total Expenditure
1	Maize	64,962,211,159	12.35	9.67
2	Rice	86,908,145,183	16.52	12.93
3	Other Cereal	162,392,460,915	30.87	24.16
4	Bread & Similar Foods	17,736,430,355	3.37	2.64
5	Tubersand Plantains	76,462,938,130	14.54	11.38
6	Poultry	385,363,059	0.07	0.06
7	Meats	11,185,788,902	2.13	1.66
8	Seafood	7,436,118,454	1.41	1.11
9	Dairy Products	1,511,718,518	0.29	0.22
10	Oils, Fats and Oil rich nuts	8,400,127,215	1.60	1.25
11	**Fruits**	**3,835,187,092**	**0.73**	**0.57**
12	**Vegetables excludes pulses**	**24,747,503,312**	**4.71**	**3.68**
13	Beans and Peas	44,929,427,984	8.54	6.69
14	Sugar, Jam, Honey, Chocolate and Confectionary	2,768,383,496	0.53	0.41
15	Non Alcoholic	4,269,306,672	0.81	0.64
16	Alcoholic	21,685,559	0.00	0.00
17	Food consumed in resturants and canteens	1,012,922,639	0.19	0.15
18	Food Items not mentioned above	7,014,033,818	1.33	1.04
	Sub-total	**525,979,752,462.39**		78.26

Source: National Bureau of Statistics (2012)

Generally, situations suggest a significant gap in mean consumption of fruits and vegetables across countries, sectors/locations and economic groups. So in spite of the growing body of evidence on the protective effect of fruits and vegetables, their consumption/intake is still grossly inadequate. World Health Organization Report (2002) has shown that low fruit and vegetable intake is estimated to cause about 31 % of ischemic heart disease and 11 % of stroke worldwide. It is estimated that up to 2.7 million lives could be saved potentially each year if fruit and vegetable consumption was sufficiently increased. It is noted that high consumption of fruits and vegetables can reduce many chronic diseases such as stroke, cardiovascular disease, metabolic disease and some cancers (Nwamarah and Otitoju, 2014). The global production as well as consumption is expected to grow to meet WHO/FAO minimum recommendation for fruit and vegetable.

However, fruits and vegetables in their fresh forms contain high percentage of water. They are living and hence carry out their physiological function of respiration thereby absorbing and releasing gases and other materials from and to their environment. These activities lead to their deterioration in transit and storage, which is more rapid under conditions of high temperature and humidity. As a result, heavy losses are encountered in these crops.

3.0 POSTHARVEST LOSSES (PHL) IN FRUITS AND VEGETABLES

In fruits and vegetables production, much attention is given to increasing production by research on breeding, improved varieties, optimizing fertilizer and crop water requirements, appropriate pest and disease control and other farm management aspects. For example 95% of the research investments during the past 30 years were reported to be focused on increasing production and only 5% directed towards reducing losses (Kader, 2005; Kader and Roller, 2004 and WFLO, 2010). However, much of the researches and energy devoted to production and marketing of fruits and vegetables will be of little value if provision is not made for proper handling to prevent postharvest losses.

Today, one of the most global challenges is how to ensure **food**

security for a world growing population whilst ensuring long-term sustainable development. According to the FAO, food production will need to grow by 70 % to feed the world population which will reach 9 billion by 2050. Further trends like increasing urban population, shift of lifestyle and diet patterns of the rising middle class in emerging economies along with climate change have put considerable pressure on the planet's resources resulting to decline in fresh water resources and biodiversity, loss of fertile land etc. Consequently, there is a need for an integrated and innovative approach to the global effort of ensuring sustainable food production and consumption (Kiaya, 2014).

In the meantime, while the number of **food insecure** population remains unacceptably high, each year and worldwide, massive quantities of food are lost due to spoilage and infestations on the journey to consumers (Kiaya, 2014). Food and Agricultural Organization of the United Nations stated that about 1.3 billion tons of food are globally wasted or lost per year (Gustavasson *et al.*, 2011). In some African, Caribbean and Pacific (ACP) countries, where tropical weather and poorly developed infrastructure contribute to the problem, wastage can be as high as 40 – 50%. In fact, according to the United Nations/FAO report on post harvest loss on vegetables and fruits in Africa, an average outstanding 49 percent is recorded, which means that for every two tomatoes produced, for every two bananas produced, for every two mangoes produced, on the average, only one of it is available for consumption. Obviously, one of the major ways of **strengthening food security** is by reducing these losses. Reduction in these losses would increase the amount of food available for human consumption and enhance global food security. There is a growing concern with rising food prices due to growing consumer demand, increase demand for biofuel and other industrial uses and increased weather variability. A reduction in food losses also improves **food security** by increasing the real income for the producers and consumers.

3.1 What is Postharvest Loss?

The term "postharvest loss" refers to measurable quantitative and qualitative food loss in the postharvest system. Postharvest loss (PHL) can be defined as the degradation in both quantity and quality of food from harvest to consumption. Quality losses include those that affect nutrient/caloric composition, acceptability and edibility of a given product. These losses are generally more common in developed countries. Quantity losses refer to those that result in the loss of the amount of a product. Loss of quantity is more common in developing countries (Kiaya, 2014).

The postharvest system comprises interconnected activities from the time of harvest through crop processing, marketing and food preservation to the final decision by the consumer to eat or discard the food. In this system, postharvest handling is recognized as one of the important areas requiring attention. The large losses from farm to plate are attributed to poor handling, distribution, storage and consumption behaviour (FAO, 2014). Reduction of PHL is of high importance in the effort to combat hunger, raise income and improve food security and livelihood (Kiaya, 2014). Primary challenges in the transportation stage of the supply chain include: poor infrastructure (roads, bridges etc); lack of appropriate transport systems and lack of refrigerated transport systems. In most developing countries, roads are not adequate for proper transport of horticultural crops. Also, transport vehicles and other modes of transport especially those suitable for perishable crops are not widely available. This is true both for local marketing and export to other countries. Most producers have small holdings and cannot afford to purchase transport vehicles (Kiaya, 2014).

Fruits and vegetables even after harvest are still living. They respire, converting metabolites into carbon dioxide and giving off heat, energy and water. There may be rapid metabolic changes associated with ripening and senescence such as a greatly increased respiration rate, accelerated softening, water loss and changes in chemical constituents like pectins, starches, sugars and acids. The sum total of the processes is undesirable textural change followed by biodeterioration of fruits and vegetables. Such fruits and vegetables are rendered unmarketable and unfit for consumption in developed states of the world but may yet be consumed in developing countries due to poverty. This is probably one of the reasons why diseases that are contractible through decaying fruits and vegetables are more rampant in developing countries of the world. Such diseases include several mouth infections, diarrhea and dysentery.

Principal causes of postharvest losses in fruits and vegetables and poor quality in order of importance are mechanical injuries, wilting, water-loss, shriveling, improper curing, over-ripening, sprouting, high respiration rate, chilling injury and decay. Evidence of severe problems of mechanical damage is on the increase and is affecting the trade in fresh fruits and vegetables both locally and internationally (Altisent, 1999; Okhuoye, 1995). These losses account for poor return to growers and increase the cost of industrial raw materials. The degree of loss contributed by each of these factors depends on the plant material involved, the prevailing environmental conditions and the management of food supply system. The high level of mechanical damage and diseases (often encouraged by mechanical damage) are clear indications of the need to improve the techniques of handling of perishable food items like fruits and vegetables.

The fruit and vegetable journey from farm to the consumer is extremely complex and they are subjected to a variety of dynamic loads that could result in this damage. This plays a key role for rejecting fruits at quality inspection. In some cultivars of fruits, bruising can result in product losses up to 50 % (Ayman *et al.*, 2013). In particular, it has been reported that the basic mechanism involved in fresh fruit and vegetable damage are impact and vibrations experienced by the individual items of the fruit conveyed as vehicles traverse abrupt changes in road profiles (Jones *et al.*, 1991). Vibration and shock during transport injure fruits and vegetables especially fruits with soft pericarp (Ayman *et al.*, 2013). It is therefore the road-vehicle-packaging interaction that determines the extent of the mechanical damage suffered by the fresh fruit and vegetable in transit. One of these fruits and vegetables which is of great concern to us in today's lecture is the **fresh tomato fruit**.

4.0 TOMATO

Tomato is an herbaceous plant commonly grown as an annual crop. It belongs to the family called *Solanaceae* and is of the specie *Lycopersicon esculentum*. Tomato originated from the tropical climate of Central South America. It was domesticated in Mexico and later taken to Europe and across the Pacific by the Spanish explorers and Portuguese traders.

The increasing popularity of tomato has resulted in a rapid proliferation of new cultivars which has now increased to several hundreds over the years (Messiaen, 1992). Since the end of the nineteenth century, the crop has increased in popularity in the tropics and sub-tropics until it is now the second most important vegetable crop after potato in the world (Plate 1).

In Nigeria, tomato fruit is virtually part of the daily diet of every family (Okhuoya, 1995). It is consumed either in fresh or processed form. Apart from this consumption at the family levels, sizeable quantities of the fresh produce are canned. The fruit is

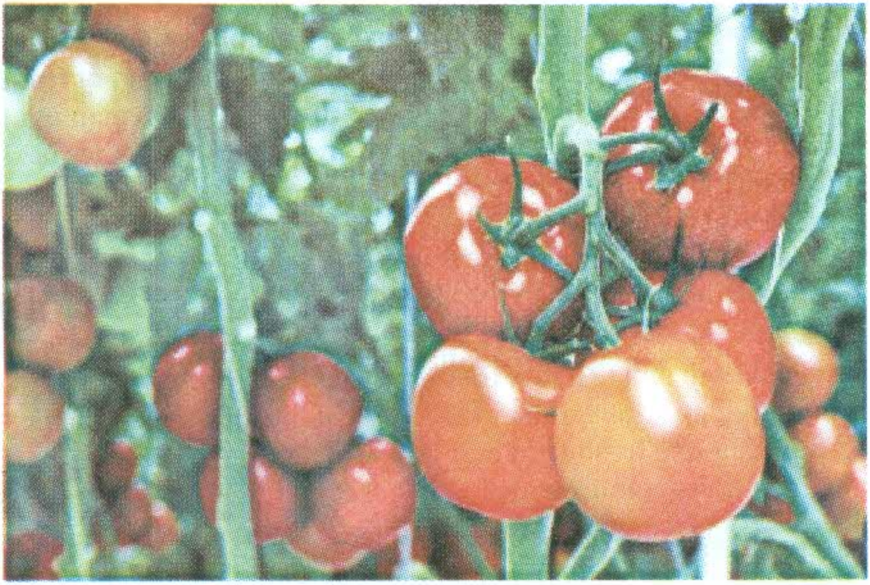


Plate 1: Tomato fruit

very important in the Nigerian economy due to the following reasons:

1. It is a good source of vitamins C and A (Vitamin C is a major constituent (15,000 – 23,000 μg per 100g of the fruit which is very important because man cannot synthesize it) (Messiaen, 1992).
2. The production generates rural employment through widespread cultivation.
3. It also stimulates urban employment for manufacturers of containers (tin can, plastic crates and wooden containers among others).
4. The crop increases farmer's income.
5. The crop also expands export trade.

In many countries, there has been a marked improvement in the average yield and quality of tomato fruits which are directly attributed to improved understanding and utilization of modern technology. Commercially, 45 million metric tonnes of tomatoes are produced each year from 2.2 million hectares excluding the large amount grown in home gardens (Messiaen, 1992). In 2003,113 million metric tons of tomatoes were produced in the World and the US produced 13% of the total production (Eunkyang, 2005). In Nigeria, about 50,000 hectares are utilized for tomato production. Yearly production is approximately 600,000 tonnes with average yields per hectare of 12 tonnes (Erinle, 1989). Local demands have not been met from the local production and so considerable importation of tomato paste is still needed to augment local production (Okhuoya, 1995). The highest production occurs between October and February, during the coolest part of the year. There is little production between March and June due to high temperatures (Ibrahim *et al.*, 2000). The variations in yields between and within seasons make proper handling and preservation very vital for this profitable food item (Alamu *et al.*, 2002).

4.1 Properties of Fresh Tomato Fruits as Related to Prevention of Postharvest Losses

The properties of fresh tomato fruits, just like any other agricultural produce influence their quality during handling. Damages suffered by such produce are normally influenced by their properties. It is thus important to examine these properties, the knowledge of which could facilitate the provision of better handling methods that will reduce post-harvest losses. It has been observed that knowledge of the properties of food, and their responses to process conditions is pertinent to the preservation and shelf life of such produce (Nwanekezi and Ukagu, 1999). These properties of tomatoes include physical, mechanical, chemical, biological, biochemical and physiological properties.

The physical and mechanical properties of fresh tomato fruits are of interest when assessing the quality of the fruit. These properties include among others the size, shape, color, texture, density, firmness, stress, bioyield force, etc. The most important external quality of any fresh produce has been catalogued as size, shape, smell and appearance (Dewulf *et al.*, 1999). The size of fresh tomato fruits varies greatly. The diameter ranges from very small (< 3 cm), through small (3-5 cm), medium (5-8 cm), large (8-10) to very large (> 10 cm). Fruit sizes also vary among cultivars. The variations in sizes are important in the selection, design and construction of packaging containers that are used in the handling and distribution of tomato fruits.

The other physical property that is of importance is the color of the fresh produce. Color is the most important visual criterion of quality evaluation in tomatoes. The external color of tomato fruit is the result of both flesh and skin pigmentation. It is noted that fruit quality is first assessed by a striking appearance of the skin color (Reay, 1998). The color varies according to the cultivars. There are tomato genotypes which have pink-purple, orange, dark yellow, light yellow, yellow with pink end and other colors. The appearance also depends on the stage of ripening. As the tomato ripens it gradually become more red. This change has been arbitrarily subdivided into six stages as defined by U.S. Standard for Grades of Fresh Tomatoes (Lloyd and Lipton, 1983). These are:

(i) Green;
(ii) Breakers (not more than 10% of the surface is tannish-yellow, pink or red);
(iii) Turning (10 to 30% of the surface area has changed to tannish-yellow, pink or red);
(iv) Pink (between 30 and 60% of the surface shows pink or red);
(v) Light red (> 60% of the surface is pinkish-red, or red but not more than 90% is red) and;

vi) Red (more than 90% of the surface is red). During distribution, the color usually changes from the bright red to dull-red thus making the produce less attractive and this usually leads to low prices.

Another property of the fresh tomato fruit that is of great importance is the firmness of the fruit (Jan *et al.*, 1997). The skin toughness and the internal structural composition influence the behaviour of tomato fruits when subjected to loads (Batu, 1998). Others such as the biochemical, biological and physiological properties actually influence the reactions and changes that occur during the postharvest handling (Nwanekezie and Ukagu, 1999; Abboth *et al.,* 2002; Mohsenin, 1978; Altisent, 1991; Osagie, 1995; Freedland and Briggs, 1977; Egharevaba 1995b)

4.2 Postharvest Activities Associated with Tomato Fruits

Grower and central packinghouses are an integral part of post-harvest handling chain of fruits and vegetables in the industrialized countries. The basic operations in a packinghouse are cleaning, sorting, sizing, grading and packing. Depending on the kind of produce, additional activities such as, degreening, curing, washing, bunching, and precooling may also be included. These operations are essential preparatory steps to storage, transportation and subsequent marketing. They are carried out to ensure marketing of high quality produce and also to help in reducing post-harvest losses (Showalter, 1993). It is revealed that the keeping quality of fresh produce during storage, or transport is directly affected by the care taken during harvesting and field handling including these packing house operations (Osifo, 1995).

Unfortunately, most of these preparatory steps are lacking in most developing countries including Nigeria. In Nigeria, after harvest on the farm, the produce is usually taken to the collection points at the village markets where the fruits and vegetables are heaped on the ground under direct heat of the sun. The high temperature and heat build-up within the commodities, contamination, infestation, piercing and bruising lead to rapid deterioration as the heaps may remain for days in this state before transportation (Daramola and Okoye, 1998). The non-existence of these post harvest treatments in the current distribution systems for fruits and vegetables in Nigeria is greatly affecting the quality of the produce.

4.2.1 Tomato Packaging and Transportation and the Associated Postharvest Problems

It is generally asserted (Karen, 1991) that a good packaging material must meet the following requirements:

1. Must not contain chemicals, which could be injurious to the produce or toxic to consumers.
2. Holds adequate unit of the produce for efficient post-harvest handling.
3. Protect the product from damage (mechanical, physiological, pathological) during all post packaging handling operations including transportation, storage and marketing.
4. Adaptable to packing and stacking methods used and to appropriate packinghouse operations including precooling and chemical treatment (fungicides and insecticides).
5. Economical (cost effective) in relation to the unit value of the produce and the desired shelf life.

In Nigeria and many other less developed countries however, fresh fruits and vegetables are commonly packed in baskets made from palm fronds stem barks and bamboo, jute bags, fibre board paper and/or cardboard cartons and other improvised containers made of metal, plastic and wood that have been used for packaging of imported or locally manufactured goods (Karen, 1991; Oladapo, 1994; Idah *et al.*, 1996). These do not generally meet the above conditions. It has also been observed that the use of inappropriate packaging materials lead to additional costs on the part of the handlers (poor prices) because of the damages resulting from such packaging (Boligor and Lidasan, 1996).

Tomato transportation involves movement of fresh tomatoes from the farm-gate to its destination which could be the collection centre, intra state, interstate, national and international destinations including all the consumer distribution networks in between. Farm related transport needs are crucial because the farm produce must be moved fast to get them to their destinations before deterioration sets in (Adeoti, 1998). This farm related transport needs can be divided into two categories: on farm and off-farm movements.

The on-farm movements involve conveying materials from one point on the farm to another, generally characterized by small load over relatively short distances. The off-farm movements involves moving the farm produce from the farm first to collection centers or storage points in the villages, then to the markets within the states, between states within the country and between countries. Generally it involves material movements after the farm-gate.

The needs for these off-farm movements stems from the following:

1. The rural farmers are the major producers of crops and what they produce have to be marketed to the consumers who are mainly in the urban centers.
2. There is the need for even distribution of the produce between states and even between continents so as to promote trade and enhance economic development (Watts, 2002).

Transportation of tomatoes is mostly carried out via roads networks as the route in Nigeria and most of the mechanical damages results from the rough roads. Road irregularities are "discontinuities" or "unevenness" on the roads surfaces resulting from failure of the road under load. They include potholes, bumps and other profile elevations. Potholes are regarded as the greatest factor of pavement failure and they are "displacement inputs" factor to the vehicle wheels. They usually generate vertical "velocity" and "acceleration" inputs to the wheels, which cause vehicle ride vibration, with resonance and frequency; cause roll excitation and sometimes bring about loss of wheel contact with the road surfaces (Ogaga, 2000). Bumps on the other hand are "plateau" portions of undulations on the road surfaces. The bumps also create similar effects on the wheels of the vehicles just like the potholes though with less severity.

The fresh tomato fruit loaded inside the vehicle is affected by the vibrations which are generated by the irregularities of the road and this in turn causes damage to the produce (Singh and Singh, 1992; Jones *et al.*, 1991; Ogut *et al.*, 1999; Kra and Bani, 1988). It is thus believed that one important element in highway design is consistency, which is making every element of the pavement design to conform to the vehicle expectation and by avoiding abrupt and premature changes in the pavement (Ogaga, 2000).

It is also noted that a vehicle laden with fruits or vegetables traveling on a smooth road at constant speed may be considered to be in a vertical static equilibrium. The forces between the various system elements are constant and there is no transformation of energy. However, when the vehicle encounters discontinuity in the road surface, a bump for instance, some of the kinetic energy of the vehicle is dissipated in deforming the road, the tyres, suspension, chassis, package, cushioning and the produce (Jones *et al.*, 1991). Figure 1 depicts this arrangement. Damage to the produce is brought about by the direct dissipation of the energy in the produce through impact from the vehicle vibration. Road irregularities are therefore crucial in the investigation of the effects of road conditions on the vehicle and the packages of fresh produce it is conveying. Damage resulting from these conditions is a major cause of quality deterioration in fresh fruits and vegetables. The basic mechanisms involved seem to be impact experienced by the individual items of the produce as the vehicle traverse abrupt changes in the road profile. This is more severe when the suspension systems of the transport vehicles are either too soft or too hard. For a multi-layered energy absorbing loads such as horticultural produce, transfer of the

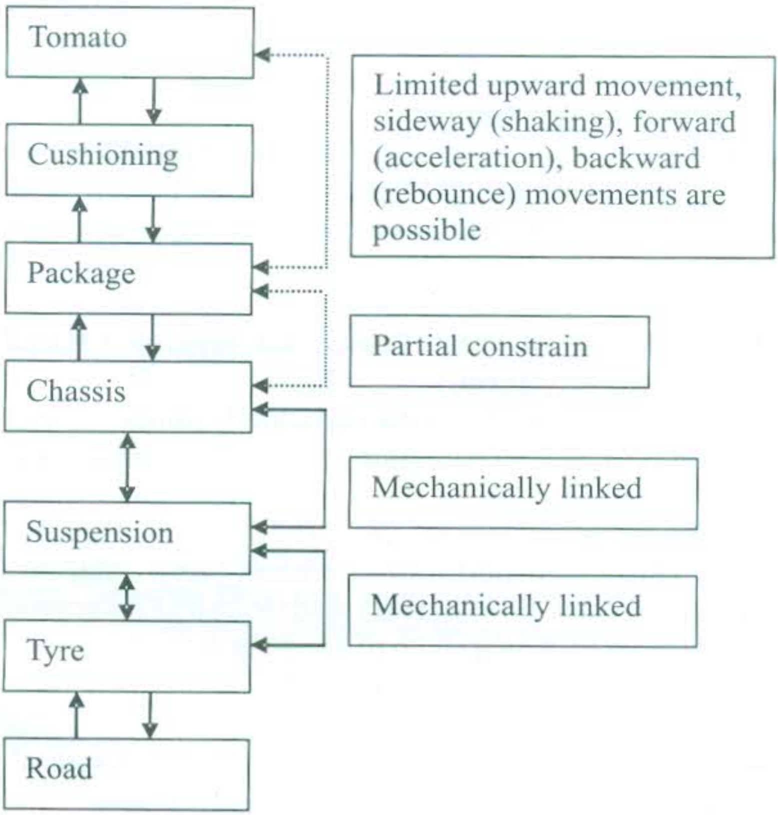


Fig 1: Elements and Couplings for the Road-Vehicle-Package System

energy (shock) generally from the vehicle to load determine the energy dissipated within the load, and hence the mechanical damage to the produce.

5.0 MY CONTRIBUTIONS

Mr. Chairman sir, I have been actively involved in the war against postharvest losses especially in fresh tomato fruits along with my supervisors, colleagues and my students over the past 25 years. Summaries of some of the researches carried out on postharvest processing, properties of fresh tomatoes, packaging, handling and transportation of fresh tomatoes and our findings are subsequently presented.

5.1 Studies in the Areas of Tomato Produce Properties and Handling Techniques

As can be noted from the above review, substantial postharvest losses in fresh fruits and vegetables occurred during handling. Efforts in curtailing these losses require thorough understanding of the factors involved.

5.1.1 Assessment of Fresh Fruits and Vegetable Handling Systems in Nigeria

In Nigeria, production of tomato, particularly Roma Vf variety in dry season is mainly by irrigation in the northern part, but the consumption is widespread throughout the country. Similarly, other fruits and vegetables are produced in different parts of the country. Thus, transportation becomes very vital in the distribution process. Post harvest distribution of fresh produce is characterized by a long chain of handling activities due to the distance between the supply areas and the demand centers.

Transportation and its associated problems therefore affect the quality and efficient distribution of the fresh produce. In this study, an appraisal of the current practices used in the transportation of fresh fruits and vegetables in Nigeria was conducted to identify the inherent problems involved (**Idah** *et al.*, 1999; **Idah** *et al.*, 2007). This is with the view to generate useful information necessary to curtail the losses. The Investigative Survey Research Approach (ISRA) was used, thus structured questionnaire were administered to the handlers and transporters in ten major markets across the country through personal interviews (Fig. 2).

Measurements of the dimensions and weights of some handling devices were also taken in addition to loss assessment in one of the markets.

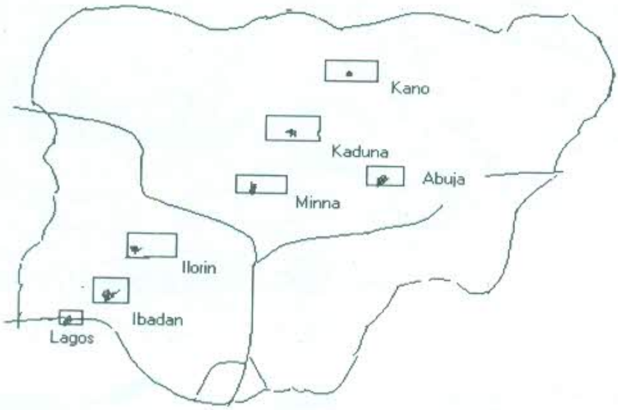


Fig. 2: Map of Nigeria showing the study areas

The results showed that the current system is bedeviled with a lot of problems. Virtually all the transporters interviewed do not own the vehicles they use. One major problem is the non-availability of the desired vehicles when needed, which usually caused delay, and subsequent decay of the product. In an in situ loss assessment in Ipata market in Ilorin, an average of 5 kg of fresh tomato fruits out of the 36 kg basket load were damaged. In other words, in a consignment of 7,500kg (lorry load) an average of 1,041.67 kg or 13.89 % of the fresh tomato fruits were bad (**Idah** *et al.*, 2007). The damage mainly consisted of bruised, rotten, compressed and water soaked fruits. In terms of monetary value, for an average price of N200.00 per kilogram, the losses due to damage is about N20,000.00 per lorry load. The packaging containers being used are unsuitable to the modern transport system. Highlights of some of the results obtained on the various packaging containers and the vehicles involved are shown in Plates 2-7 and Tables 3 and 4.

Plate 2: Orange fruits packed in jute bags and displayed in Kano (*Nngwa Huku*)

Plate 3: Tomato fruits in baskets at Ilorin in *Ipata* market

Plate 4: Baskets of tomato loaded inside a passenger bus about to be offloaded at Kaduna (*Mogadishu* market)

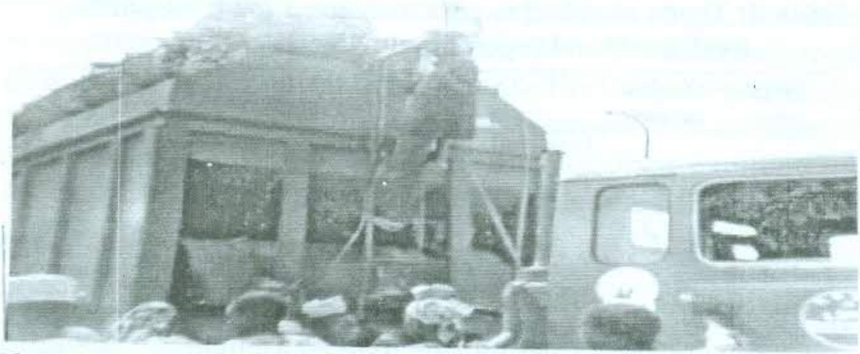


Plate 5: Baskets of fresh tomatoes tied outside a truck being off loaded at Ilorin (*Ipata* market)

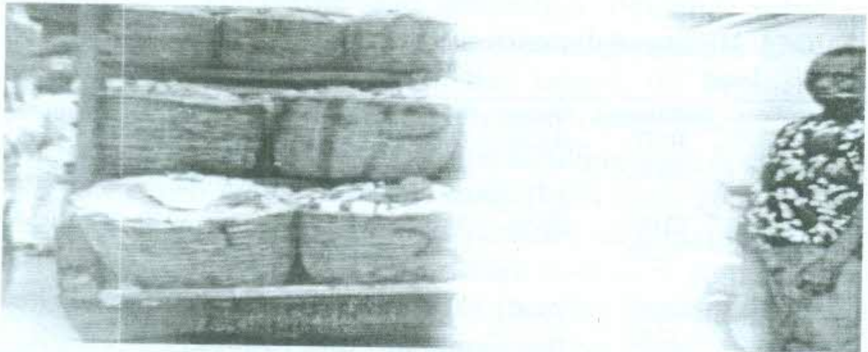


Plate 6: A Canter vehicle loaded with baskets of tomatoes in *Yankaba* market (Kano)

Plate 7: Canter vehicles waiting to be loaded in *Yankaba* market

Table 3: Types of vehicles currently used for transporting fresh fruits and vegetables in Nigeria

Vehicle types	Number of axles	Span			Capacity rating(kg)	Percentage users(%)
		Length(m)	Width(m)	Height(m)		
Mercedes 911 lorry	2	5-6	2-3	3-4	7500	50
Canter	2	5-6	2-3	3-4	4500	15
Fuel tanker	3	8-15	2-3	3-4	3000	10
Pick-up van	1	4-5	2-3	2-3	1000	8
Buses	1	4-5	2-3	2-3	400	2
Articulated truck	4	8-15	2-3	2-4	7500	15

Table 4: Measured dimensions of the baskets and weight at full load

Dimensions	Small(range)	Average	Medium(range)	Average	Large(range)	Average
Top diameter (cm)	40.97 - 50.61	46.32	50.96 -52.75	51.31	52.90 - 55.07	54.10
Bottom diameter (cm)	23.00 - 35.20	33.50	36.85 -39.60	37.50	39.90 - 42.90	40.10
Depth (cm)	23.00 - 27.00	26.50	27.50 -32.50	29.50	32.90 -35.5	33.70
Volume ($x 10^{-3}m^3$)	20.36 - 41.90	33.90	42.00 -52.61	46.10	52.85 - 59.15	55.15
Weight at full load (kg)	20.00 - 27.35	23.25	30.00 -35.00	32.00	35.50 - 37.00	36.18

The results of the study can be utilized to conceptualize appropriate handling devices that will minimize the current losses being encountered.

5.1.2 Determination of Engineering Properties of Some Fresh Tomato Cultivars Grown in Nigeria

Fresh fruits of tomato (Lycopersicon esculentum) are highly susceptible to mechanical injury during handling. The mechanical damage suffered by these produce is normally influenced by their engineering properties. There has been widespread interest in engineering properties of foodstuff, fresh or processed. The information is required by food researchers for various purposes such as quality assessment and evaluation, process design, operation and control of food plant, handling and transportation and design of packaging methods and materials, mass and energy balances among others.

The increasing importance of food materials together with the complexity of modern technology for their production, handling, storage, processing, preservation, quality evaluation, distribution, marketing and utilization demand a better knowledge of the physical and mechanical properties of these materials (Mohsenin, 1978). In this regard, the engineering properties of the fresh tomatoes as related to mechanical damage and losses during transportation and handling were determined and extensively assessed in this study (**Idah** *et al.*, 2006). Some engineering properties of three varieties of tomato cultivars (chico, roma and cherry) were determined from compression test. The fruits were at two stages (turning and fully ripe) of maturity and grouped into two (small and big) sizes. A standard compression testing machine, the Testometric Universal Testing Machine (UTM) was used to apply loads on the samples. The Properties determined were, force (load), energy absorbed, stress, Young modulus and deformation and results are shown in Table 5. The results show that the main effects of variety, stage of maturity and sizes of fruits on these properties were highly significant at 5% level of probability. The turning stage of maturity seems to have the greater capacity for taking elastic or recoverable deformation than the fully ripe samples. The results also show that the cherry variety is the weakest among the three varieties studied.

Table 5: Mean Values of the measured Engineering Properties of the fresh tomato fruits

Variety	Maturity Stage	Parameters						
		Load at yield(N)	Load at break(N)	Energy at Yield(J)	Energy at break(J)	Young Modulus (N/mm^2)	Deformation at yield(mm)	Deformation at break(mm)
Chico	Ripe	8.90	34.67	0.0122	0.2011	0.1070	3.38	11.97
	Turning	12.84	44.01	0.0211	0.3896	0.1482	3.24	1089
Roma	Ripe	10,66	40.20	0.0186	0.4109	0.1015	2.93	11.66
	Turning	14.98	66.90	0.0218	0.5080	0.1532	1.92	10.18
Cherry	Ripe	3.08	6.74	0.0021	0.0827	0.0968	4.40	16.97
	Turning	4.68	11.88	0.0050	0.1414	0.1373	3.50	15.49

The data obtained can be of great assistance in reducing mechanical damage to this produce especially during handling by selecting strong, appropriate variety and maturity for long distance distribution.

5.1.3 An Assessment of Impact Damage to Fresh Tomato Fruits

In this study, the effects of different impact surfaces and height of drops on bruise area and energy absorbed were investigated with the view to generate basic data/information that can be used in the design and management of handling and transport devices that will minimize mechanical damage to fruits (**Idah** *et al.*, 2007).

Five different impact surfaces namely, cardboard (A), wood (B), metal (C), Plastic (D) and Foam (E) were used on the platform of the equipment. Tomato fruits of two maturity stages, fully ripe (80-100% red) and turning (1-50% pink) and two mass groups (30 - 70 g as M1 and 1-30 g as M2). The fruits were dropped from different heights onto the different surfaces and the impact energy and bruise diameter were measured. The results (Fig. 3) show that impact damage measured in terms of bruise diameter is highly influenced by the impact surfaces.

The average bruise diameters obtained were between 25 mm and 38 mm from which the bruise areas were computed. Earlier studies graded degree of impact damage in relation to average bruise diameter as follows (Vurasvus and Ozguven, 2004): bruise diameter of less than 12 mm, the damage is classified as None; 12-19 mm: Trace damage; 19-25 mm: slight damage; 25-32 mm: medium damage and greater than 32 mm as severe damage. It can be seen from the results that the samples dropped onto the metal, wooden and plastic surfaces suffered severe damages. However, the metal surface seem to inflict the greatest impact damage on the fresh tomato fruits dropped on it than any other surface used in this study followed by the wooden material. The foam inflicted the least impact damage. It was noted that the ripe and bigger fruits are more susceptible to impact damage than the small and turning fruits. Fig. 4 shows the results of the effects of drop height, maturity stage and impact surfaces on the bruise area. The results show that samples of fruits dropped from height H1 (140 cm) on the metal surface suffered the greatest impact damage. Those dropped on wooden surface closely follow this. The impact energy on the fruit is greatly influenced by the drop height and the mass of fruits (Fig. 5). Fruits dropped from H1 (140 cm) absorbed the greatest energy indicating that they suffered the most impact damage. It will be recalled that in the course of handling and transportation of fresh fruits and vegetables in Nigeria, the handlers sometimes throw the packaged produce from heights as high as 3 m (lorry truck) on to the ground during offloading.

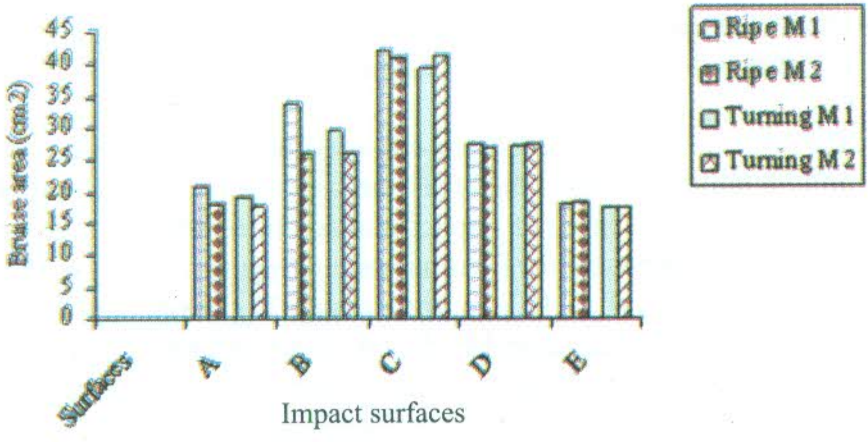


Figure 3: Effects of impact surfaces, maturity and mass on the bruise area on the fresh tomato fruits

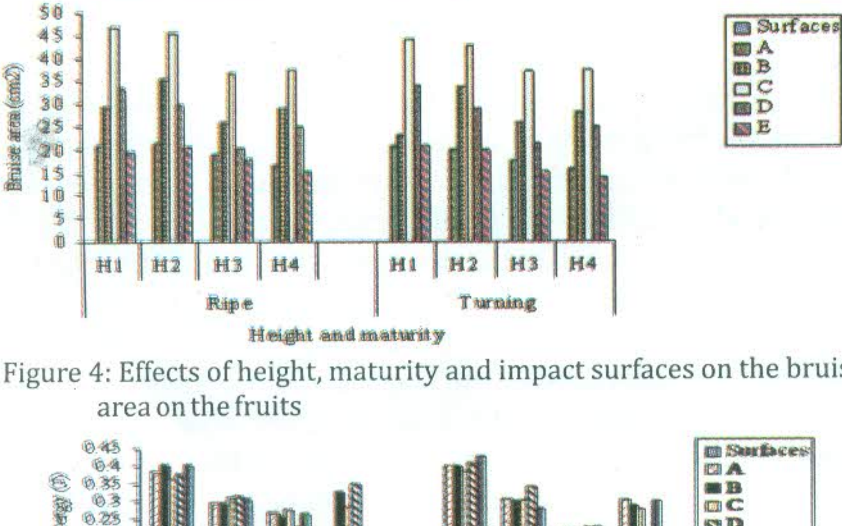


Figure 4: Effects of height, maturity and impact surfaces on the bruise area on the fruits

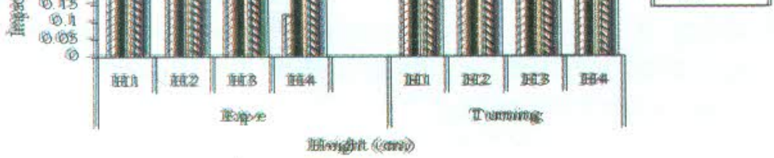


Figure 5: Effects of height of drop and impact surfaces on the impact energy on the fresh tomato fruits

5.1.4 A Study on Resonance Frequency of Nigerian Tomato Fruit as Related to Prevention of Damage during Transportation

The problem of damage during transportation can be studied from the context of vibration theory, based upon which, it is possible to reduce the damage. It has been observed that when the natural frequency (NF) of vibration of the fruit being transported coincides with the excitation frequency of the haulage vehicle then it leads to increase in acceleration that eventually culminates in produce damage (O'Brien *et al.,* 1965; Ogut *et al.,* 1999). It is therefore noted that the damage can be reduced if this condition is avoided by letting the NF of the containers of fruits to be away from the range of frequencies of excitation force while in transit (Ogut *et al.,* 1999). But there is little data on the NF of the varieties of tomato fruits grown in Nigeria. The knowledge of this property of the fruit can greatly assist in reducing losses that are currently being incurred during handling. This can be achieved by selecting appropriate traveling speed which will eliminate the conditions that will lead to resonance and subsequent damage of the fruits.

In this study, the effect of natural frequency (NF) of vibration of fresh tomato (Lycopersicon esculentum) fruits of Nigerian cultivars (Chico, roma and cherry) as it relate to preventing damage during transportation and handling was studied. The quality was determined at turning and fully ripe stages using compression test from which the modulus of elasticity of the fresh tomatoes was computed. The natural frequency was then determined using an established relationship as given in equation 1.

$$F_n = \frac{1}{4\lambda}\sqrt{\frac{Eg}{\rho}} \qquad 1$$

where, F_n = natural frequency (Hz), E = modulus of elasticity (Pa), ρ = density of fruit (kg/m^3), λ = depth of column of fruit (m), g = acceleration due to gravity (m/s^2).

The results (Table 6) show that the average natural frequency of vibration for fresh tomato fruit at turning stage of maturity were 17.6, 14.9 and 9.1Hz for Chico, Roma and Cherry varieties, respectively and were significantly different (p ¡ 0.05). At ripe maturity stage, the average values were 14.7, 14.2 and 13.2 Hz for Chico, Roma and Cherry varieties respectively (**Idah** *et al.*, 2009). The NF of Cherry variety is significantly (p ¡ 0.05) lower than those of Roma and Chico, while that of Roma was significantly (p ¡ 0.05) lower than Chico at turning stage of maturity. The practical utility of these data is in selecting proper traveling speed for vehicles used in hauling this fresh fruit to minimize mechanical damage. From Table 7 for instance the incidence of resonance can be avoided if the haulage vehicle speeds are selected outside the range that will produce frequencies close to those of the fruits.

It can be seen from the data that the excitation frequencies of the vehicle plying on these roads at speeds of 80 km/h and above are clearly within the range of the average frequencies of the fruits, hence the vehicle conveying these fruits on these roads under study should not exceed 60 km/h, if resonance is to be avoided.

Table 6: Natural frequency (Hz) of fresh tomatoes at turning and ripe stages of maturity and different sizes

Variety	M_1	M_2	M_3	M_4
		Turning stage		
Chico	19.3	19.4	17.7	14.1
Roma	15.1	14.9	12.4	17.2
Cherry	10.6	9.9	7.3	8.7
		Ripe Stage		
Chico	15.7	13.4	16.8	12.8
Roma	16.8	12.9	13.5	13.6
Cherry	11.9	15.5	14.4	11.1

Table 7: Excitation frequencies (Hz) of "Mercedes 911" lorry (truck) at different vehicle speed

Vehicle speed(km/h)	$W_1 = 2.84$	$W_1 = 2.00$	$W_1 = 1.33$
20	2.0	2.8	4.2
40	4.0	5.6	8.4
60	6.0	8.3	12.5
80	8.1	11.1	16.7
100	9.8	13.9	20.1
120	11.7	16.7	25.1

5.1.5 Simulated Transport Damage Study on Fresh Tomato (Lycopersicon esculentum) Fruits

In this study efforts were focused on simulating the factors of roads, vehicle and packaging systems and their effects on fresh tomato damage. Two packaging container types, the traditional basket woven from palm fronds (PM1) and plastic basket (PM2) were used to package the fresh tomato fruits. The developed vibration table (**Idah,** 2010) was used to simulate a typical road transportation condition in Nigeria under laboratory conditions. In this experiment, two packaging containers namely, the palm basket (traditional) and a plastic basket were used to study their effects on the mechanical damage of the fruits. The ASTM D4169-08 International Standard by Michel Magendans (Kipp, 2000) was adopted for the test.

Tomato fruit damage was determined based on only mechanical injury. Damage in terms of bruising was assessed by taking 50 samples of the fruits from top, middle and bottom of the containers after subjecting the fruits to vibration for the four hours period. The samples that displayed signs of bruising were sorted out and the dimensions of the bruised areas were measured. Control samples (unvibrated) were assessed alongside with the above to actually ascertain the effects of vibration. The samples were stored for 2 days during which the bruise damage and other forms of mechanical damage were assessed. The samples were weighed periodically during storage period to determine the weight loss in the stressed samples.

The results (Fig. 6) showed that in the traditional basket (PM1), 40%, 37.50% and 45% of the samples of tomato fruits taken from the top, middle and bottom of the basket respectively were severely bruised after 4 hours excitation which according to the ASTM D4169 truck, Assurance Level II stimulates an average distance of 2,100 km. With regards to the plastic basket (PM2), the corresponding values were 44.18%, 30.23% and 18.60% for the samples taken from the top, middle and bottom of the basket respectively after 4 hours of stressing. It was observed that most of the severely bruised fruits in the traditional basket were those in direct contact with wall and floor of the basket (**Idah** *et al.*, 2012). These are areas where friction between the fruits and surface of the packaging container was more. In the case of the plastic container, it was observed during the exercise that the magnitude of vibration at surface was greater as the fruits were moving freely and impacting on each other and this is responsible for higher percentage of damage at the top or surface of the packaged fruits. These results agree with other studies (Jones *et al.*, 1991; Ran *et al.*, 2007). Unlike the traditional basket, samples of the fruits at the bottom of the plastic container suffered the least bruises. The overall results indicate that samples of the fresh tomato fruits packaged in the traditional basket suffered more damage (40.83%) than those packaged in the plastic basket (30.98%).

After 24 hours of storage, the percentage of damaged fruits increased to 77.50%, 82.50% and 90% for samples from the top, middle and bottom positions respectively in fruits packaged in the traditional baskets (Fig. 7). For the samples in the plastic container, the values were 67.44%, 41.86% and 25.00% for those from top, middle and bottom positions respectively. It was observed that the samples of fruits that showed signs of bruises on the first day of the experiment became rotten or decayed.

Those that were not rotten showed signs of shrinkage and this led to decrease in weight as can be seen in Fig. 8. The results showed that the samples packaged in the traditional basket suffered greater weight losses than those packaged in the plastic container. The control sample (unvibrated) showed less reduction in weight during this same period of storage.

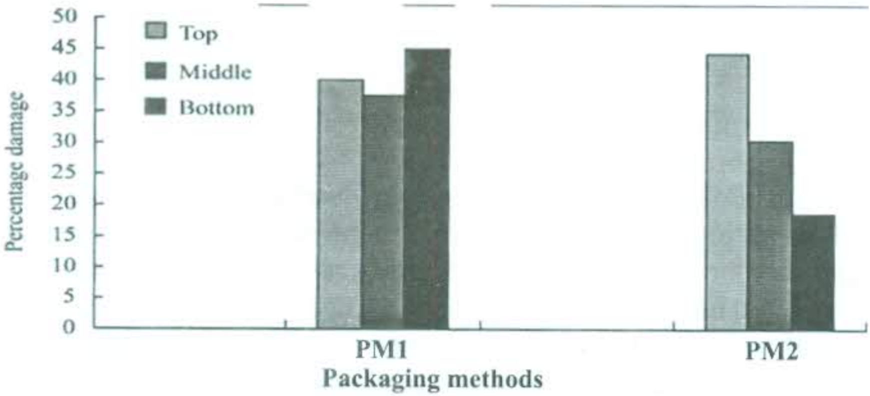


Fig. 6: Percentage damage of tomato fruits after four hours of stressing using two packaging containers

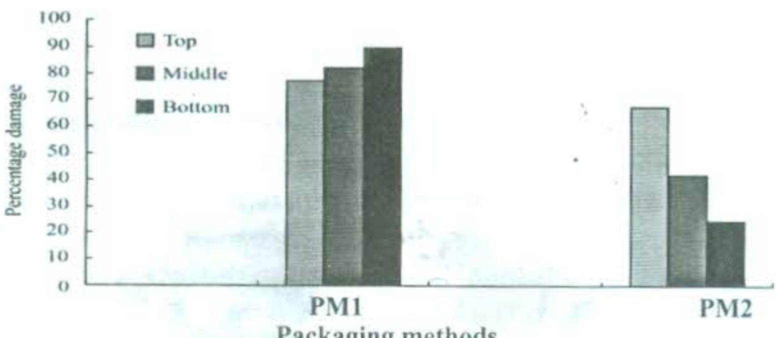


Fig. 7: Percentage damage to tomato fruits 24 hours after stressing for four hours using two packaging methods

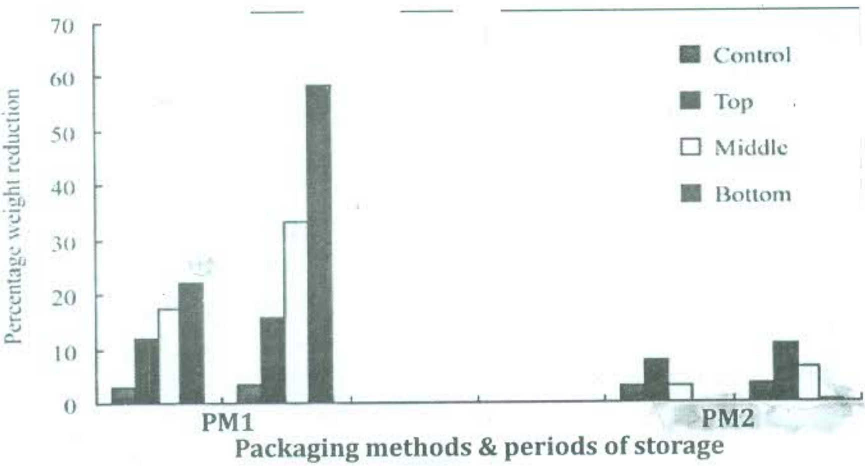


Fig. 8: Percentage weight loss in the fresh tomato fruits during the period of storage after vibration

The dimensions of the damaged (bruised areas) were assessed. The results of the assessment are presented in Table 8. The average bruise width of the damage areas in the samples packaged in the traditional basket was 24.36 mm and the average length was 36.67 mm. With regards to the samples packaged in the plastic basket, the average width of damage was 15.18 mm and that of length was 26.97 mm. The measured bruise dimensions were subjected to statistical analysis to ascertain whether the mean values of this damage sizes differ significantly between the samples from the two packaging materials and also the samples from the various depths in the package. The results also showed that the average dimensions of damage in the samples packaged in the traditional basket differed significantly ($P \leq 0.05$) from those packaged in the plastic basket. The average bruise dimensions obtained in this assessment for the samples packaged in the traditional basket fall into the category of severe damage according to the classification given by Vursavus and Ozguven (2004), while those of samples packaged in the plastic container fall within the medium category of damage.

Table 8. Characteristics of damaged fresh tomato fruits, mean values and standard deviation (SD, in Brackets) of the bruise sizes in damaged fruits from each depth

Packaging method	Position in the container	Damaged Fruits (%)	Mean width of bruises (mm)	Mean length of bruises (mm)	Overall mean bruise dimensions	
					Width (mm)	Length (mm)
Traditional	Top	40	23.30 (1.05)	34.80 (1.02)	24.36	36.67
Basket	Middle	37.50	24.52 (1.15)	36.40 (1.05)	(1.37)	(1.24)
(PM1)	Bottom	45.00	25.30 (1.39)	38.80 (1.39)		
Plastic	Top	44.18	18.70 (1.32)	28.60 (1.04)	15.18	26.97
Basket	Middle	30.23	13.85 (1.25)	26.80 (1.34)	(1.15)	(1.22)
(PM2)	Bottom	18.60	13.33 (1.19)	25.50 (1.52)		

Note: The mean values were calculated only on the damaged samples.

The essence of the simulated transport study in this research is to ascertain the effects of the road-vehicle-packaging system on the mechanical damage of the fresh tomato fruits during transportation. The assessment of the two packaging containers in this study is to investigate the possibility of improving on the packaging methods that will minimize the losses. Since the vehicles and the roads in the distribution system are already in place and cannot easily be influenced, the only available alternative is to improve on the packaging containers. The results of the assessment carried out here had revealed some positive indications in this regard. The traditional baskets recorded more severe mechanical damage in the fruits samples packaged in it than the plastic basket. Majority of the severely bruised samples in the traditional basket were those in contact with the wall and the floor due to its rough surfaces.

Currently, it is only the traditional baskets woven from the palm backs that are being used in the distribution of tomato fruits in Nigeria. However, no alternative containers have been tried along with the palm baskets. The results from this study showed that the plastic containers can perform better especially in reducing the incidences of mechanical damage during transportation resulting from the robbing of fruits on the walls of the containers.

Since the traditional baskets currently being used are in different sizes which form the basis of pricing the product (**Idah** *et al.*, 2007), the new plastic containers can be designed and fabricated in line with the traditional baskets shapes and sizes for easy acceptance and adaptation by the handlers and transporters. Unlike in the past when plastic industries were scarce in the country, several of these companies now exist in the country. Also, since the high cost of these containers are some of the reasons for their non-usage in the fresh fruits and vegetable distribution system (**Idah** *et al.*, 1999), adequate collaborative work can be embarked upon between the universities and the plastic companies in the country in this regard. Introduction of the plastic containers into the distribution system of the fresh tomato transportation in Nigeria will greatly enhance the delivery of high quality product to the consumers.

The results obtained from these investigations form a data bank which handlers, packaging containers and processing equipment designers and those involved in the management of post harvest distribution of fresh tomatoes can use to provide appropriate handling methods that will reduce losses in the distribution of fresh products in the country.

5.2 Studies in the Areas of Preservation Techniques for Fresh Tomato Fruit

5.2.1 Development of an Electric Dryer for Biomaterials

Drying is a major form of preserving and improving the storage quality of biomaterials which entails the process of reducing the moisture content of these materials. As more and more high moisture crops are produced and the desire to have all crops throughout the year, preservation methods takes an increased importance. Traditionally drying is achieved by putting the crops in the sun in the South East Asia, Africa and a host of third world countries. Mechanical and artificial drying methods are not common in these areas due to lack of appropriate drying technology for tropical conditions and comparatively high cost of procurement and installation of such technologies imported from overseas. In this study, an electric batch automatic dryer for biomaterials of high moisture content was developed (Yisa *et al.*, 1998). This is shown in Fig. 9. The developed dryer was used to dry fresh tomato, okra and fresh corn.

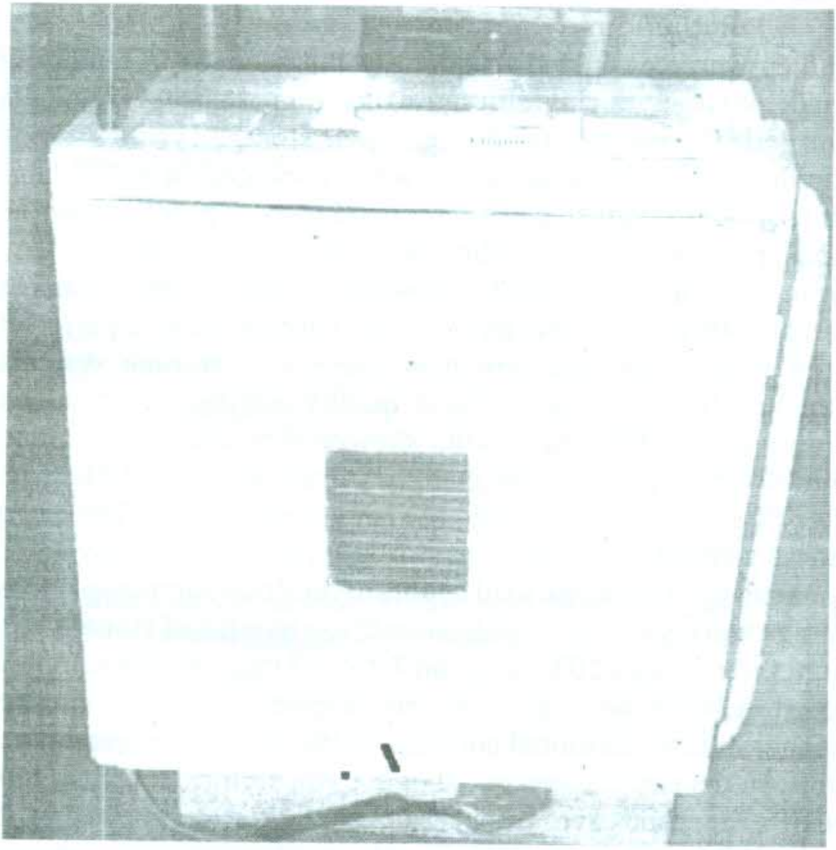


Fig. 9: An electric batch dryer

The results of the performance tests show that there was 32.31% weight loss after 70 minutes drying of fresh corn. Tomato fruit and okra lost 89.12% and 48.78% after 470 minutes and 240 minutes of drying respectively. Drying curves were established for corn, tomatoes and okra. The important contribution here is that the drying rate can be controlled unlike the traditional system which is dependent on the weather. The rate of drying is faster hence eliminating the usual delay and the associated contamination of the product.

5.2.2 Quality Changes in Dried Tomatoes Stored in Sealed Polythene and Open Storage Systems

Studies were conducted to quantify the changes in quality of dried tomatoes during storage using High Density Polythene Film (HDPF) and the traditional open storage systems. Some samples of the dried tomatoes were packaged in HDPF bags while similar quantities were in open bowls as practiced by the rural processors. Periodic assessment of some quality parameters, microbial loads, moisture content, colour, vitamins A and C, calcium and phosphorus were carried out for a period of three months to ascertain how these two storage systems influence the changes in these quality attributes (Idah and Aderibigbe, 2007). The results showed that the bacteria load counts of the dried samples prior to storage was 5.6 x 104 cfu/g. After three months of storage the counts were 0.76 x 104 cfu/g and 9.5 x 105 cfu/g for samples stored in HDPF and open systems respectively. The fungal load counts of the dried samples prior to storage were 3.6 x 103 cfu/g. After three months of storage, the counts were 0.54 x 103 cfu/g and 7.2 x 103 cfu/g for the samples stored in HDPF and open systems respectively (Table 9). The changes in the nutritional contents of the samples stored in the two systems can be seen in Table 10. The studies revealed that the HDPF method gave better results compared to the traditional method of storage in this assessment.

Table 9: Average bacteria and fungi load counts (cfu/g) in the stored dried tomatoes in open and sealed HDPF storage systems

Period of Storage(days)	Sealed HDPF system		Open Storage system	
	Bacteria loads	Fungi loads	Bacteria loads	Fungi loads
1	5.6×10^4	3.6×10^3	5.6×10^4	3.6×10^3
30	0.12×10^4	2.6×10^3	1.9×10^5	4.4×10^3
60	0.5×10^4	0.64×10^3	2.1×10^5	7.2×10^3
90	0.76×10^4	0.54×10^3	9.5×10^5	7.2×10^3

Table 10: Mean Values of the Parameters of Dried Tomato Stored in the Two Storage Systems

Parameters	Period of Storage (days)	Sealed HDPF	Percentage Change (%)	Open Storage	Percentage Change (%)
	1	134		134	
Vitamin A	30	124	7.5	118	11.9
Content	60	121.4	9.4	108	19.4
(µg/100g)	90	103.4	22.8	98	26.7
	Fresh sample 156µg/100g				
	1	5.21		5.21	
Vitamin C	30	4.99	4.2	4.11	21.1
Content	60	4.72	9.4	3.72	28.6
(mg/100g)	90	4.24	18.6	3.69	29.2
	Fresh Sample 16.25 mg/100g				
	1	9.12		9.12	
Calcium	30	8.97	1.6	8.23	9.5
Content	60	8.85	3.0	8.05	11.7
(mg/100g)	90	8.52	6.6	7.32	19.7
	Fresh Sample 7.21 mg/100g				
	1	16.12		16.12	
Phosphorus	30	15.56	3.5	13.24	17.9
Content	60	15.46	4.1	12.24	21.1
(mg/100g)	90	14.46	10.3	11.43	29.1
	Fresh sample 19.62 mg/100g				

5.2.3 Effects of Pre-drying Treatments, Duration and Drying Temperature on Some Nutritional values and Drying Rates of Tomato Fruit

Drying of fresh tomato fruits is being used by many local processors of tomato fruit and the consumption of dried tomato fruit is becoming more popular in developing countries including Nigeria, however, most of these dried products have poor quality especially the physical appearance such as colour. Apart from the physical appearance, the nutrients are also affected by the drying processes. It is in view of this that certain osmotic pre-treatment were carried out prior to drying to actually improve on these quality parameters (**Idah** and Obajemihi, 2014; **Idah** *et al.*, 2014). Ripe *roma Vf* tomato fruits were used for this experiment. Osmotic pre drying brix concentration of 40 °Bx and 60 °Bx were prepared from a sucrose solute. The total sample was divided into five (5) parts, each part weighing 300 g. The first part was treated with 40 °Bx at 1 h Osmotic time; Second part with 40 °Bx at 2 h osmotic time; the third part was 60 °Bx at 1h osmotic time; the fourth part was 60 °Bx at 2 h osmotic time and the fifth part was left untreated as the control and thereafter all the samples was dried on labeled trays. The results (Table 11) show that control samples have the highest content of vitamin C, ash and protein contents with average values of 37.97 mg/100 g, 4.941% and 20.39%respectively. The nutritional contents and colour of the dried tomato samples were preserved better at low drying temperature of 50°C than at higher temperatures. Samples pre-treated with brix concentration of 60 °Bx resulted in better nutritional contents and colour compared to those pre-treated with 40 °Bx. Some nutritional contents of tomato fruit such as vitamin C, protein and ash were preserved better by drying control samples than the treated samples. The nutritional contents and colour of samples pre-treated for 2 h osmotic time were better than those treated for 1 h. Drying of samples pre-treated with 60 °Bx for 2 h at a drying temperature of 50°C gave the best colour of dried tomato which is a major criterion either accepting or rejecting processed products by consumers.

The results of the effects of brix concentration, osmotic duration and drying temperatures on the rate of drying are as shown in Fig. 10. The drying rates of the samples pre-treated with different brix concentration, osmotic duration and drying temperature differed significantly ($p \leq 0.05$). It can be seen from Fig. 9 that samples with the slowest drying rate are those pre-treated at 60 °Brix and 2h with an average moisture removal of 25.2 g/h while those pre-treated at 40 °Brix ,1h has an average drying rate of 26.6 g/h. The control (untreated) samples have the fastest drying rates with an average moisture removal of 35.2 g/h. Generally, the rate of moisture removal is faster at higher temperatures than at lower temperatures. Samples subjected to 1 hour osmotic duration dry faster than those subjected for 2 hours. The rates of moisture removal decreased as the drying time increases for all the treatments (Figs. 11, 12 and 13). The importance of these results is that appropriate pre- drying treatment that will enhance the quality of the dried product especially colour has been established.

Table 11: Mean Values of the Nutritional and Colour Parameters of Tomato Fruit

Treatments		Soluble Solids (%)	Vitamin C (mg/100g)	Protein (%)	Ash (%)	Colour Grade(red)
40°Brix	50°C	31.80	27.96	14.70	3.08	2.57
1 h	60°C	30.57	25.39	14.40	2.35	0.23
	70°C	30.13	23.56	14.07	2.39	0.10
40°Brix	50°C	31.43	24.59	14.40	2.69	3.83
2 h	60°C	29.93	23.16	14.24	2.53	0.17
	70°C	29.67	21.73	13.98	2.35	0.17
60°Brix	50°C	32.53	25.24	14.91	2.51	3.21
1h	60°C	31.63	24.98	14.30	2.38	0.43
	70°C	29.57	22.52	14.01	2.34	0.17
60°Brix	50°C	30.83	21.75	14.69	2.89	3.77
2h	60°C	30.10	20.95	14.25	2.53	1.37
	70°C	29.97	20.83	13.80	2.42	0.10
Control	50°C	22.60	39.63	21.27	5.35	0.67
	60°C	21.83	37.99	20.73	4.89	0.10
	70°C	21.40	36.31	19.18	4.59	0.00

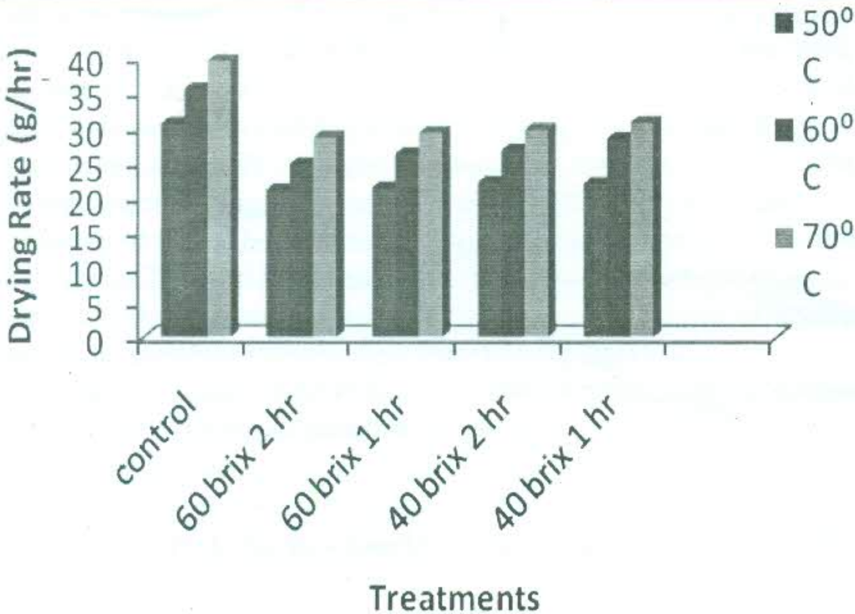
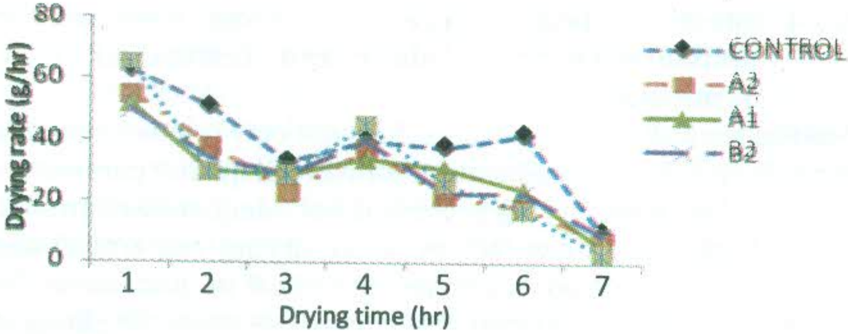


Fig. 10: Effect of Pre- drying Brix Concentration, Drying Temperature and Osmotic Duration on Drying Rate

From the results obtained and the analysis carried out, the following major conclusions can be drawn. Convective drying rate of tomato fruit increases with increase in drying temperature for both control and pre-drying treated samples. Pre-drying treatment is one important factor that affects the drying rate of tomato, the higher the degree of pre-drying brix concentration, the slower the convective rate of drying of the samples. Control samples have faster drying rates than pre-treated samples (Figs. 10, 11 and 12). Hence it is recommended that pre-drying treatment with low pre drying °Brix concentration, short osmotic duration and high drying temperature should be adopted to achieve faster drying rate, which saves time, money, energy and does not give room for microbial infestation.



A1 (60°Brix, 1h), A2 (60°Brix, 2h), B1(40°Brix, 1h), B2 (40°Brix, 2h)

Fig. 11: Drying Rate Versus Drying Time for different Samples pre-treatments at 70 °C

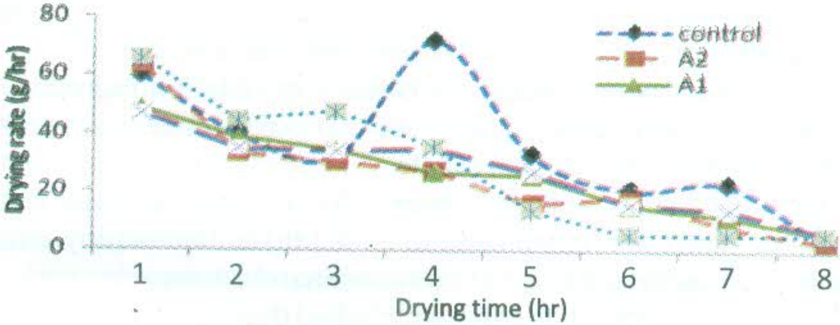


Fig. 12: Drying Rate Versus Drying Time for different Samples pre-treatments at 60 °C

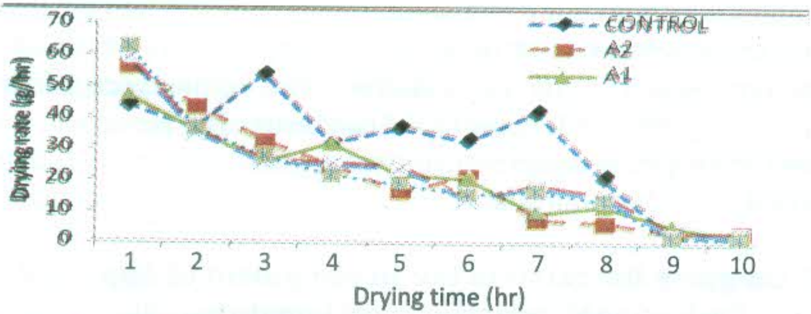


Fig. 13: Drying Rate Versus Drying Time for different Samples pre-treatments at 50 °C

5.2.4 Effects of Temperature and Drying Time on the Moisture Content, Colour and Texture of Dried Tomatoes

Studies have shown that drying does not only remove moisture from the produce, but also other nutritional quality parameters could be lost if the drying process is not adequately controlled (Ali and Sakr, 1981). Two factors namely drying temperature and drying time have been identified as critical in influencing the resultant quality of the dried products. In this study, the effects of drying temperature and drying time on the moisture content, colour and texture of the tomato were investigated with a view to establish appropriate drying temperature and time that will result in minimum loss of desired quality of the dried products (Idah and Omojiba, 2001). The data obtained from the drying using temperatures of 45, 55, 65 and 75oC and drying time of 2, 3, 5 and 7 hrs were analyzed statistically to obtain a regression model that was used to test the various temperature-time combinations. The results revealed that using a temperature of 65oC and drying time of 5 hours the moisture content was reduced from the original value of 16 % (db) to 3.69 % (db). This moisture content obtained at this combination is appropriate for good storage since it has been established that microbial growth can be prevented at moisture content less than 10 % (db). Similarly, the best colour and texture attributes of the dried samples which do not differ significantly (p ? 0.05 and p ? 0.01) from the original colour of the fresh samples were obtained at this temperature-time combination. The importance of this study is that the model developed can be used by researchers to select appropriate temperature-time combination to dry tomato to the desired keeping quality.

5.3 On-going Research in the Development of Appropriate Packaging Material for fresh tomato handling

Significant percentage of complaints received from tomato handlers and consumers are traced to packaging failure resulting from poor design or inappropriate selection and use. It is disheartening that tomatoes are still being packaged in the traditional baskets in Nigeria in this 21st century. Based on the researches conducted so far in the postharvest activities in fresh tomato fruits and in a bid to take the war to another level, an alternative packaging container is being developed. The container when produced will be used along with the traditional baskets currently in use to compare their performances in tomato transportation. The research is on-going.

6.0 CONCLUDING REMARKS AND RECOMMENDATIONS

Fruits and vegetables are important sources of vitamins and minerals which are essential in human diets. Research efforts to find solutions to Postharvest losses in fresh fruits and vegetables have been on-going since 1900s. Although tremendous progress have been made in understanding the properties of the produce, preservation techniques, handling and transportation techniques, appropriate techniques in reducing the losses is yet to be achieved. Increase in food production alone cannot necessarily ensure the needed food security if postharvest losses of the little that is produced are not reduced to the barest minimum. Since the bulk of the losses result from mechanical damage, adequate and appropriate handling devices that will minimize the incidences of mechanical damage to the fresh produce in transit has to be provided. In other words, minimizing losses during transport necessitates special attention to vehicles, equipment, infrastructure and handling. The efforts towards reduction in postharvest losses in fresh fruits and vegetables and in particular, fresh tomato fruit must be intensified. My research over the past twenty five years has focused on the aspect of processing the product to more stable forms in order to preserve, studying the basic parameters related to prevention of mechanical damage to the fresh produce during postharvest handling. In particular the study on the natural frequency of vibration of the tomato fruit as it relates to selection of vehicle speeds that will minimize resonant frequency and the attendant mechanical damage is very important in our situation in Nigeria. Similarly, working towards providing alternative packaging containers for fresh tomato packaging and transportation that will minimize the incidence of mechanical damage is very apt. The present effort of the Federal and state governments in rehabilitating the roads across the country is commendable because this will definitely reduce the incidences of vibration on vehicles emanating from the road irregularities.

Undoubtedly, the problem of postharvest losses in fruits and vegetables is on the increase and is actually affecting the trade in these perishable products both locally and internationally. In order to minimize this, the following are to be addressed:

1. There is the need to provide packing houses to serve as places for pre-shipment activities as practiced in developed countries at the farm gate where the fresh fruits and vegetables can be protected from the direct heat of the sun.

2. Packaging is a major item of expense in produce marketing especially in the developing countries where packaging industries are not well developed; government should make this a priority in its agricultural agenda especially by encouraging a synergy between researchers in the institutions and the industries.

3. Among the various types of packaging material that are available, natural and synthetic fibre sacks and bags as well as moulded plastic baskets and boxes seem to be more suitable and have greater promise for packaging

fresh fruits and vegetables for their transport to distant markets. Hence research into these materials should be intensified.

4. There is the need to assist the handlers of these fresh produce with appropriate transport vehicles to avoid delay that usually lead to produce deterioration in transit.

5. The present efforts towards roads rehabilitation by the government should be sustained to reduce the incidence of mechanical damage to fruits and vegetables resulting from vibration and impact during transportation.

6. Efforts should also be made towards designing and producing specialized transport vehicle(s) for fruits and vegetables transportation in the country.

7.0 ACKNOWLEDGEMENTS

Mr. Chairman sir, this aspect I must confess is really difficult for me because I have enjoyed great supports and encouragements from numerous individuals in the course of my journey through life and to appreciate everyone within this space of time in this lecture is an impossible task. I therefore wish all my well wishers whose names are not mentioned here to understand that they are all equally appreciated.

The Almighty God

First and foremost, I am highly grateful to God Almighty, the creator of Heaven and Earth for His divine guidance, blessing, protection, mercy and abundance grace that make it possible for me to stand before you this afternoon. I cannot thank Him enough but to continue to glorify and praise Him for His goodness to me.

My Teachers

Much appreciation goes to all my teachers from primary to the university level. You all provided the rudiments of education, the discipline, support and encouragement that actually created the enabling platform to acquire knowledge.

My Mentors/Supervisors

I sincerely wish to acknowledge the contributions of the following people to my academic development. His Excellency, Amb. Engr. Prof. M. G. Yisa (Major Supervisor) who did everything and made sure I return to the department after my service. Others are Profs. O. O. Morenikeji and O. Chukwu (Co-Supervisors); Profs. E. S. A. Ajisegiri (now of University of Agriculture, Abeokuta), S. Sadiku, Z. D. Osunde, O. O. Babatunde (late) and K. Oje (University of Ilorin), Engr. Dr. D. Adgidzi, Dr. S. Y. Bassi (one time HODs ABE) and late Dr. S. Adeoti (Unillorin). These people were great motivators and wonderful teachers and

friends combined who provided the necessary guidance and tutelage for me in the basic tenets of scientific research.

The University Management

My special thanks go to the present Administration of this great Institution (Federal University of Technology, Minna) under able leadership of the Vice-Chancellor, Prof. M. A. Akanji and his management team. I became a Professor under this team. I also thank you for finding me worthy to be appointed as Director and Chairman, Anti-Corruption and Transparency Unit (ACTU) of this great University.

I must also thank the former Vice-Chancellors from whose administrations I have also benefitted in one way or the other: Prof. J. O. Ndagi the pioneer VC who gave us "**Certificate in one hand and tool box in another**" a fulfillment of the promise he made during the very first matriculation ceremony of this great institution. Prof. S. O. Adeyemi employed me. I enjoyed my promotions during Prof. M. A. Daniya (AL to LII), Prof. Tukur Sa'ad (LI to SL) and Prof. M. S. Audu (SL to AP).

Colleagues at SEET

The School of Engineering and Engineering Technology (SEET) is a wonderful place to work going by spirit of team work being exhibited by the staff. I am highly indebted to the Dean and all the members of staff (academic and non-academics) of SEET for their love, support and care. In particular, I sincerely and most gratefully acknowledged the assistance of Engr. Dr. O. A. Olugboji and Engr. Dr. S. Abdulkareen in acquiring some of the instrument/equipment I used for my PhD research from oversea.

My colleagues/Staff of DABE

I am deeply indebted to my HOD, Engr. Dr. B. A. Adejumo, my colleagues and the entire staff of DABE for the cordial relationship that exist among us. It is truly DABE and others.

Colleagues in ABU, UAM

To all my colleagues in Department of Agricultural Engineering, Ahmadu Bello University, Zaria and University of Agriculture Makurdi, I say thank you for your encouragements and friendship.

My Students

I am indeed grateful to all my students at both undergraduate and postgraduate levels especially those who worked on the fresh tomato fruits. You kept me busy and have made this day possible through the contributions from your works.

ACTU Members

I sincerely thank the members of Anti- Corruption and Transparency Unit (ACTU) committee, FUT Minna for their cooperation in our collective efforts in educating the members of the University community on the dangers of corrupt practices and the need to stay clear of such vices.

My Special Friends

To my friends, Engr. Dr. Christopher K. Bala, Engr. Dr. A. B. Hassan, Engr. Christopher Ameh Adah, Engr. Dr. Vincent Ogwuagwu (late), Mr. Philip Adikwu Uleh, Mr. Gabriel Oodo, John Ogwuche, Joseph Idoko, Emmanuel Uleh, Mr. Sylvester Odeikwu, MacDickson Noah, Bar. Benjamin Adokwu, Mr. Matthew Ochigbo, Mr. Michael Agbenyi, Mr. Abah Francis, Mr. Adidu Igoche and Mr. Michael Aba, I say thank you all for the friendship and brotherliness we enjoyed together over these years.

I appreciate the friendship of my fellow pioneering students (**guinea pigs**) in the SEET, FUT Minna, Engrs. Edmond Chima Ike, Richard Dauda, Shehu Ahmed, Henry Egbuka, Robert Ogun, Kola Ademola, Charles Chukwuma and Engr. Dr. Baba-Ndaliman Mohammed. We started with **lanterns** and we all graduated with "**Certificate in one hand and Tool box in another**".

To my Spiritual Leaders, Very Rev. Frs. Gabriel Nelson Onuh, Leo Raphael and Augustine Fockchet and the entire members of St. Malachy's Chaplaincy, FUT Minna and St. Malachy's Catholic Church, Bosso, I say thank you all for your prayers.

Idoma General Development Community, Minna

My special thanks go to the President and all the members of Idoma General Development Community, Minna. I say a big thank you for your support and prayers over these years.

Idoma Forum, Minna

To the members of the Idoma Forum, Minna, and Idoma National Forum (INF), I appreciate and thank you all for your encouragement and support.

My Neighbours in Bosso Estate

My very sincere and deep appreciation goes to the residents of New Bosso Estate Extension for the cordial and friendly relationship being exhibited. I thank you all for the good neighborliness we have enjoyed to date.

My Late Parents

I am greatly indebted to my late parents, Pa Idah Umah and Mrs Elizabeth Onma Idah for their love and care. You sacrificed so much for me and ensured that I had a very decent, disciplined and God-fearing upbringing. May God Almighty continue to grant you eternal rest in His bosom.

My Nuclear and Extended Family

My late elder brother, Mr. Emmanuel Idah is greatly acknowledged for taking up the responsibility of paying my school fees and providing me with all the necessary things right from primary school to the university level. I can still remember vividly the very encouraging words you gave me in 1971 when you were about leaving the village for Lagos after your primary school. You told me that unless if I didn't want to study, you would ensure that I was educated to any level I wanted. You kept to your words and did exactly what you promised and on my part I made sure I did not disappoint you. How I wish you are here today physically to witness this occasion. May your gentle soul continue to rest in peace in the Lord's bosom. Amen. To Late Ms Christiana Oneh Idah and Mr. John Ejembi Idah your deaths in 2011 and 2015 respectively were painful but I thank God for your immense contributions to my life. Continue to rest in peace. To my brother Abbah Idah and my other sisters Mrs Jane Apeh, Mrs Helen Godwin and Mrs Julie Ignatius, I sincerely appreciate you all for being there for me.

My Uncle, Engr. Abel Oko Abbah, for the special interest you showed in advising me rightly when I was seeking admission to higher Institutions in the 80s, I sincerely thank you. I can still recall the pain you took in driving all the way from Makurdi in Benue State to Ogoja in Cross River State to deliver my JAMB admission letter to me at Federal School of Arts and Science, Ogoja in 1983. May God continue to strengthen you. To my other uncles, ASP Godwin Adah (Rtd), Inspector Livinus Umolo (Rtd) and Bar. Umolo Ugwa, Mr. Joseph Adah and Mr. Anthony Adah, I cannot thank you people enough for the roles you played at various points in my life. May God continue to lift you higher and higher. Amen.

To my in-laws, I say a big thank you to all of you for accepting me into your family. It has been wonderful relating with you people.

My special appreciation and gratitude goes to my children, Gabriel Sunday Idah, Christopher Ameh Idah, Blessing Aladi Idah, Joseph Eche Idah and Emmanuel Edache Idah (biological), Hycinth Abba Idah, John Idah and Christopher Inalegwu Idah (Chemical), I thank you for being sources of joy and blessings in the family.

To my dear wife "**Mummy**", Mrs. Theresa Onma Idah, you are really an epitome of love and humility. You have really demonstrated and kept on swallowing the "**Three Pills**" -**P**atience, **P**erseverance and **P**rayers that heal wounds and actually help in sustaining any marriage. I sincerely appreciate your support, selflessness, commitment and understanding and above all for tolerating my excesses and inadequacies all these years we have stayed together. May God continue to strengthen us. Amen.

The Seminar and Colloquium Committee

I thank the Chairman and members of the Seminar and Colloquium Committee for their efforts in making this a reality.

The Audience

I will not forget to say thank you to all of you seated here today to listen to me. If you were not here, to whom will this story be told? You are all wonderful.

Mr. Chairman Sir, that is the **Tomato Story** and the **Role** I have played so far in waging the war against **Postharvest losses** in order to **strengthen food security**.

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A BRIEF PROFILE OF THE INAUGURAL LECTURER

Peter Aba Idah was born on the 8th July, 1962 to the family of Late Pa Idah Umah and Late Mrs. Elizabeth Onma Idah in Ogbulo-Ekeh, Okpokwu Local Government Area (LGA) of Benue State.

He had his early education in the Roman Catholic Mission (RCM) now Local Government Education Authority (LGEA) Primary School, Ajide-Ekeh, Okpokwu Local Government of Benue State. Thereafter, he was admitted into Mount St. Michael's Secondary School, Aliade in Gwer Local Government Area of Benue State. In the school he served as the Time keeper and eventually became the Senior Prefect in 1981. He completed his secondary education in 1982 and obtained seven (7) credits in the West African Examinations Council (WAEC).

He was admitted into Federal University of Technology, Minna in 1984 and had his Bachelor of Engineering Degree (B.Eng) in Agricultural Engineering with Second Class Honours (Upper Division) in 1990. He proceeded for the National Youth Service Corps (NYSC) and served with the Directorate of Food, Roads and Rural Infrastructure (DFRRI) in Agaie Local Government Area in Niger State between 1990 and 1991.

Immediately after service, he joined the services of the Federal University of Technology, Minna as Assistant Lecturer (AL) in the Department of Agricultural Engineering in March, 1991. In 1992 he was admitted into the Department of Agricultural Engineering, University of Ilorin for his Master's degree programme which he completed in 1995. He enrolled for PhD degree programme in the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna and completed the programme in May 2010.

Among the awards received by him in his career are the following:

1. Best overall student 1986/87 session in School of Engineering and Engineering Technology, Federal University of Technology, Minna.
2. Certificate of Merit from NYSC Secretariat, Kwara State, 1990, for outstanding performance in platoon contests in camp.
3. Letter of Commendation for Excellent work from NYSC Secretariat, Niger State in 1991.

At the Federal University of Technology, Minna, he rose through the ranks and became a Professor of Agricultural and Bioresources Engineering in October, 2013. In Federal of Technology, Minna, Professor P. A. Idah has held a number of administrative positions including Head of Agricultural and Bioresources Engineering Department (2011-2013), Director and Chairman, Anti-Corruption and Transparency Unit (ACTU). He served in several committees in the University.

He is a member of several Professional bodies among which are Nigerian Institution of Agricultural Engineers (NIAE), Nigerian Society of Engineers (NSE), Council for the Regulation of Engineering in Nigeria (COREN) and American Society of Agricultural & Biological Engineers (ASABE). He is currently the Regional Chairman of Nigerian Institution of Agricultural Engineers (NIAE), North Central Region.

He has published many papers in his area in both National and International Journals and has contributed a chapter in a textbook. Professor P. A. Idah has supervised several undergraduate, PGD, M. Eng and PhD students and is still supervising scores. He has served as External Examiner for both undergraduate and postgraduate to several Institutions. He has assessed many candidates for promotion to professorial ranks at many Universities. He has served as reviewer to several National and International Journals.

Prof. P. A. Idah is happily married and blessed with five children.