FUNAAB
INAUGURAL LECTURE SERIES

FOOD PROCESSING FOR PROFIT: PANACEA FOR POST HARVEST LOSSES

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FUNAAB INAUGURAL LECTURE Series No. 46
Wednesday, 9th July, 2014

FUNAAB
INAUGURAL LECTURE SERIES

This 46th Inaugural Lecture was delivered under the Chairmanship

of

The Vice-Chancellor
Professor Olusola B. Oyewole
B.Sc. (Ife), M.Sc., Ph.D. (Ibadan)

Published 9th July, 2014

ISBN:

Series No. 46: Professor (Mrs.) F.O. Henshaw

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Preamble:

Except the Lord builds the house, they labour in vain, who build it, except the Lord keeps the city, the watchman wakes but in vain (Holy Bible, Psalm 127:1).

The opportunity to present an Inaugural Lecture is an obligation as well as a privilege. It is an obligation because after being appointed a Professor, an Inaugural Lecture is given in a formal event to mark the installation to the chair. It is one of Universities' traditions of "Gown meets Town" events. All professors therefore, are required to fulfil this obligation at some point in the course of their career. Similarly, it is a privilege because the contributions of the professors to the body of knowledge and scholarship are considered worthy of recognition and celebration. In addition, not all who are qualified are able to arrive at this juncture throughout their career and life time. On all accounts therefore, I am very grateful to God, who has given me grace to be alive to fulfil this obligation and to enjoy the privilege.
To God alone be the glory. Amen,

Three Inaugural Lectures have been delivered at various times from the Department of Food Science and Technology. These previous lectures addressed several aspects of Food Security. This is not surprising since the essence of our profession as Food Scientists/Technologists is to employ scientific and engineering principles in ensuring availability of nutritious, safe, convenient and sufficient food thereby advancing food security.

In my search for the focus of this inaugural lecture, I was guided primarily by the need to bring to fore another approach apart from increasing agricultural productivity, in remediation of food insecurity, which has continued to be a global challenge. In spite of improving agricultural productivity, the food security gap has not yet been closed, this brings a query on how much of what is produced actually get consumed? The United Nations set a world development agenda, the Millennium Development Goals (MDGs) (1990 – 2015). There are eight (8) of them, but the very first one has a component; to reduce poverty and hunger by 50% by the year 2015. At the national level, the Federal government of Nigeria launched the Agricultural Transformation Agenda in 2011, with the goal of increasing food supply by an additional 20 million metric tonnes of food and creating 3.5 million jobs along the agricultural value chain by the year 2015, which is just in another six (6) months. How near are we to achieving these targets, especially in the developing countries including Nigeria?

As a young girl growing up in Lagos, I still remember the images of enormous heaps of rotten fruits and vegetables at depots in Oyingbo market. Unfortunately, some four decades after, such scenarios are still rampant at several points along the Food supply chains in Nigeria as well as many other developing countries. The critical question requiring answers is how can harvest profits be preserved in order to increase food availability and accessibility, improve income generation and livelihood and have food secured populations in our communities and nations?

Vice-Chancellor Sir, distinguished audience, please permit me to share some thoughts based on the theories and practice of Food Science acquired over the last three decades in this **46th** in the series of FUNAAB Inaugural Lectures, the **fourth** from the Department of Food Science and Technology and the **second** from the College of Food Science and Human Ecology with the title: **Food Processing for Profit: Panacea for Post Harvest Losses**.

1.0 INTRODUCTION

Food is a fundamental need for human survival. Many definitions of food have been published, but the one I find most appropriate to the focus of this lecture is given by the FAO, which defined food as edible substance usually of plant or animal origin, consisting of carbohydrates, proteins, fats, minerals and vitamins which when ingested, assimilated through digestion, sustains life, generates energy and promote growth, maintenance and health of the body.

This definition gives us the salient functions that a substance must partly or wholly perform to qualify as food and also the requirement that food must arrive at the destination where it must be digested and assimilated before it can perform these functions. However, between production and consumption, there is a gap of events, actions, inactions and limitations which can either result in the safe arrival of the food at its functional terminus or in getting lost en route.

The biological nature of food materials (crops, livestock and fish) make them readily subject to deteriorative changes leading to spoilage and quality loss along the entire food production chain, (farm to fork or more precisely to mouth).

Food Spoilage may be classified into different types;

1. Microbial spoilage: deterioration due to activity of micro-organisms
2. Enzymatic spoilage: undesirable changes due to enzyme catalyzed reactions, different endogenous enzyme occur in foods as shown in Table 1
3. Chemical spoilage: undesirable changes due to non-enzyme catalyzed reactions between the components of food and its environment
4. Physical spoilage: undesirable changes in physical structure of the food.

Chemical and microbial spoilage are responsible for loss of 25% of primary agricultural and fishery products annually (Baird-Parker, 2000).

Thus, without efficient intervention strategies to prevent spoilage, food raw materials rapidly deteriorate and become unfit for consumption leading to shortage in food supply.

Table 1: Enzymes that cause food spoilage

Enzyme	Food	Spoilage action
Ascorbic acid oxidase	Vegetables	Destruction of vitamin C
Lipase	Cereals	Discoloration
	Milk	Hydrolytic rancidity
	Oils	Hydrolytic rancidity
Lipoxygenase	Vegetables	Destruction of vitamin A, off- flavour
Pectic enzyme	Citrus juices	Destruction of pectic substances
	Fruits	Excessive softening
Peroxidase	Fruits	Browning
Polyphenol oxidase	Fruits, vegetables	Browning, off-flavour, vitamin loss
Protease	eggs	Reduction of shelf life of fresh and dried eggs
	Crab, lobster	Over tenderization
	Flour	Reduction of gluten formation
Thiaminase	Meats ,fish	Destruction of thiamine

Source: Universalum, 2010

2.0 Post Harvest Losses and Food Security

Post-harvest food loss is defined as measurable qualitative and quantitative food loss along the supply chain from harvest till its consumption or other end-use (Hodges et al, 2011). The food security gap therefore is the difference between what is produced and what is consumed.

According to FAO (2013) on a global basis, annual food losses along the production chain is put at a whooping figure of 1.3 billion tonnes. The pattern of post-harvest losses vary in different parts of the globe based on the type of food commodities and stages in the production chain as shown in **Figures 1 and 2** respectively. Food losses in developed countries are lower in the middle stages of the supply chain because of better infrastructure and efficient processing and preservation facilities. These ensure the delivery of a large proportion of production to the consumption stage. Thus, food waste which is the loss of edible food due to human action, such as deliberate throwing away of food, failure to consume before the expiry date and taking portions of food beyond one's ability to consume, contribute majorly to food loss.

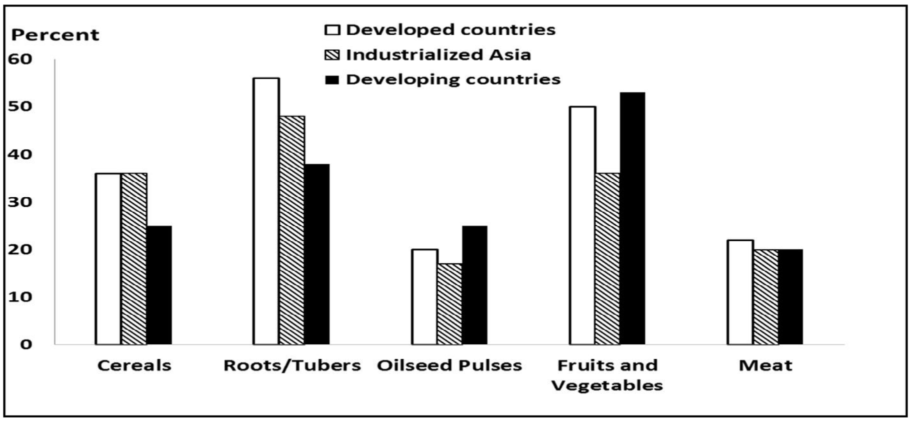


Figure 1: Percentage of food production loss for different food commodities across countries
Source: Aulakh and Regmi, 2013

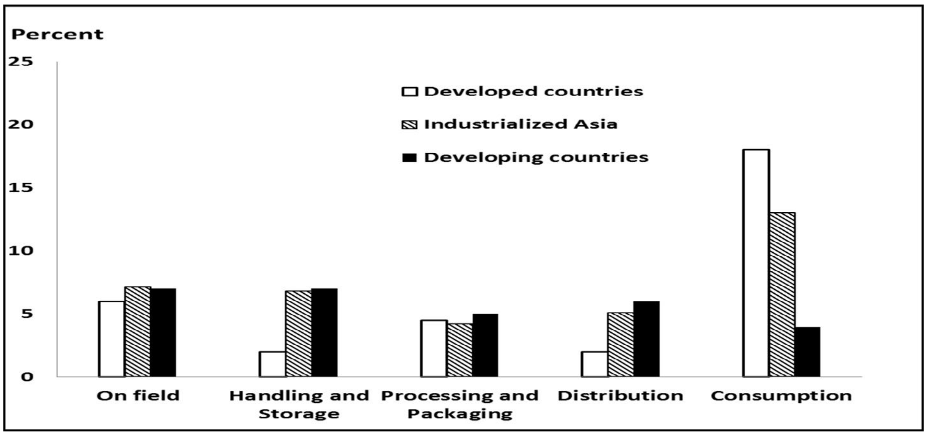


Figure 2: Percentage of food loss at different stages of Supply chain across countries.
Source: Aulakh and Regmi, 2013

Kantor *et al.(*1997), in their study of food losses in the USA reported losses of 30, 30, 15 and 30% for grain products, fresh fruits and vegetables, poultry and dairy products respectively, at the retail foodservice and consumption stages (Table 2).

In contrast, a large proportion of production ever get to the consumption stage in developing countries. Ineffective or inappropriate processing technologies, poor or non-existent infrastructure, poor post-harvest handling and lack of efficient value - addition chain are the major contributing factors to high food losses (Aworh, 2008). Post-harvest losses are a major contributing factor to global food insecurity.

Table 2: Food losses in the US food chain: products and locations

Commodity	Retail food loss (%)	Foodservice and consumer (%)
Grain products	2	30
Fruit, vegetables, fresh	2	30
Fruit, vegetables processed	1	15
Dairy products	2	30
Red meat, poultry, fish /seafood	1	15
Eggs	2	29
Dry beans, peas, lentils, tree nuts and peanuts	1	15
Fats and oils	1	32
Total	2	26

Source: Kantor *et al*. 1997

A hungry man is an angry man, is a saying that is well known. FAO (2013) gave an estimate of 842 million people in the world who do not have enough to eat and go to bed hungry each night, with a third of this in Africa. The anger of 842 million hungry people could constitute a huge threat to global peace and security. Over the past three decades, significant amount of resources have been allocated to increasing agricultural productivity and while 95% of research investments were focused on increasing production, only 5% was targeted to reduce post-harvest losses (Kader, 2005; Kader and Roller, 2004).

Increasing agricultural productivity is critical for ensuring global food security, but it is now doubtful if this approach on its own is sufficient. Agricultural productivity is currently being challenged by limited land, water and increased weather variability due to climate change. The report of Fox and Fimeche (2013) showed that current agricultural practices use 4.9 Gha (Global hectares or 4931 million hectares) out of the total 14.8 Gha (14894 million hectares) of land surface on earth. In addition, agricultural production uses 2.5 trillion cubic meters (M^3) of water per year and over 3% of total global energy consumption. Using the estimates for food losses at 30 – 50% of total production, this translates to wasting 1.47 – 1.96 Gha of arable land, 0.75 – 1.2 trillion M3 of water and 1 – 1.5% of global energy. As an average, 2.8 hectares (ha) per person is needed to provide food, energy and other input per life. But the ecological footprint, a measure of consumption level, in hectares of average productivity, is 9.5 ha in the USA, 8.05 in Denmark and 4.98 ha in the UK. The ecological foot print includes the space needed for production of crops, animals, fish etc, that is mostly the land used for agricultural production of food raw materials. Most parts of the globe are reported to have assessed their ecological footprint and have overshot it (Banati, 2009)

Rapid growth in world population is another challenge that will create more demand for food. The ever-increasing gap between population growth and food supply is considered the most serious threat to the survival of humanity. The world's population is expected to hit 10.5 billion by 2050 (FAO, 2011). This will raise food demand by 70% in the next 35 years. A large proportion of the projected population growth is from the least developing countries where there is already chronic food insecurity. Nigeria in particular, is expected to hit a population growth of 440 million by the year 2050, overrunning the figure for the USA, to become the third most populous country in the world, after China and India (Figure 3).

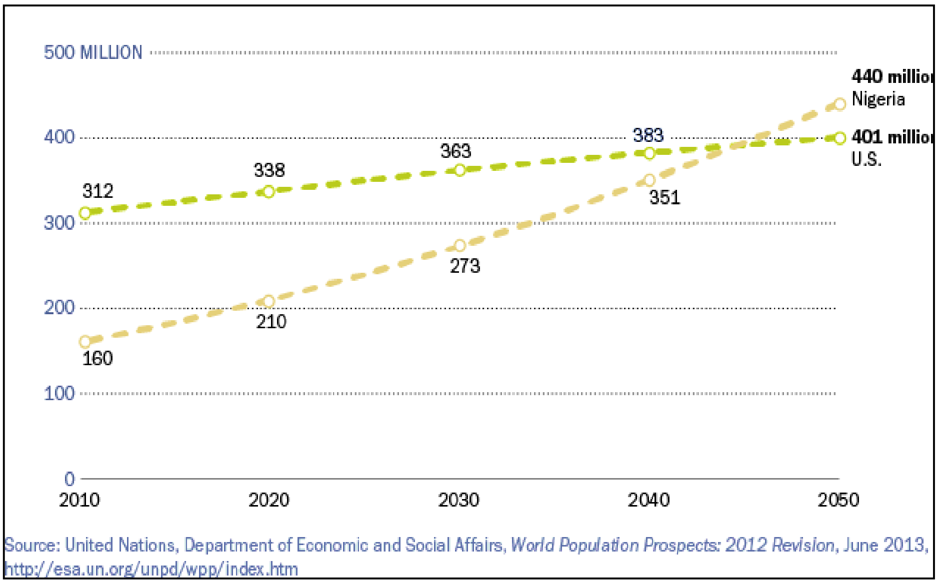


Figure 3: Estimated population from 2010 to 2050 in US and Nigeria
Source: UN, 2013

It is becoming apparent that the earth's capacity to meet the demand for production of raw materials of plant and animal origin has been overstretched. It is imperative to give more attention to **strategies to prevent and minimise post-harvest losses thereby increasing food availability and accessibility without increasing the use of land and other agricultural inputs.** In addition, food production and farming constitute significant proportion of typical incomes in sub-Saharan Africa (70%) and reducing food losses would have direct impact on increase incomes and livelihood Aulakh and Regmi (2013).

Therefore, improved post-harvest handling through processing and development of efficient value addition chain is an indispensable viable strategy which should receive more attention in order to advance global food security.

3.0 Food Processing

3.1 Historical Perspectives

Food Processing is generally defined as the application of scientific principles to the **preservation** and **transformation** of food materials (crop, livestock and fish) into affordable, safe and nutritious products and by-product. (Heldman and Hartel, 1997).

Historically, food processing is believed to be dated back to some 2 million years ago when an ancestral man discovered cooking, one of the earliest form of food processing (Wrangham, 2009). Other forms of food preservation such as drying, fermenting and preservation with salt are also dated to pre-scientific era. These early practices allowed communities to form and survive, with more stable food supply than the early stone age man who had to hunt and gather food regularly to survive. Much later in history, the domestication of plants and land cultivation became widespread and by the end of the last ice Age, humans have domesticated animals for food. The study of early civilization showed that throughout history, humans overcame hunger and disease, not only by harvesting food but also by processing it into more value-added products. In ancient Greece for example, bread, olive oil and wine were products of processing that transformed perishable unpalatable raw materials into safe, flavourful and enjoyable foods (Floros, 2004).

Major advances in food preservation accelerated with the development of canning, which proceeded from the investigation of Nicolas Appert in France in the early 19th century. Appert used heat to preserve food and sealed them in glass bottle to prevent re-contamination. Peter Durand in England introduced the concept of metal cans and was granted a patent in 1810 entitled "**preserving animal food, vegetable food and other perishable articles a long time from perishing or becoming useless"** (Thorne, 1986). The science underlying canning preservation was later discovered by Louis Pasteur in 1864, when he showed the lethal effect of heat on micro-organisms. Increase in scientific investigations, since this early period up to the 20th Century led to advances which resulted in expansion and refining of traditional processing and preservation and development of new ones (Table 3)

Table 3: A chronological classification of food processing and reservation

Old' Processes (since pre-history)	Current processes
Sundrying	Spray drying
Oven drying	Freeze drying
Smoking	Canning
Salting	Aseptic processing
Pickling	UHT pasteurization
Fermentation	UHT sterilization
Freezing	Extrusion cooking
	Irradiation
	Microwave heating
	Reverse osmosis
	Osmotic dehydration
	Modified atmosphere packaging
	Freezing or chilling

UHT - Ultra-High Temperature
Source: Henry, 1997

3.2 Objectives of Food Processing

Food processing usually serves multiple objectives. All food processes involves series of steps called unit operations, which must be followed in a specific sequence for any particular product. Thus, first of all food processing is a means of value addition. Processed foods are value added based on the premise that raw agricultural commodities are transformed into processed ones by use of labour and technology. Any raw material that has benefitted from any value addition through application of one form of technology or the other is referred to as a processed product, regardless of whether the amount of processing is minimal as for example washing and packaging or complex such as production of flour from grains or sugar from sugar cane juice. Modern food processing operations are conducted under controlled conditions to ensure efficient process and consistent product quality.

Therefore the clearly recognised objectives of food processing include the following:

3.2.1 Preservation: The most important reason for food processing is to extend the shelf life, that is the period from harvest or slaughter before quality loss and spoilage which can render the food unfit for human consumption. (Smith and Hui, 2004). When perishable raw food materials have longer shelf life, it will enhance availability of seasonal foods all year round. Preserved foods can also be distributed over long distances and retailers can stock them on the shelf for extended periods.

3.2.2 Safety: Food processing is crucial to removal of health hazards associated with foods. Many raw food materials contain harmful substances (natural toxins) as harvested, which must be removed before they are safe for consumption. For example Cassava roots *(Manihot spp.)* must be crushed, soaked and heated to eliminate hydrogen cyanide derived from cyanogenic glycosides, which are natural toxins in the roots, before it is safe for consumption. Heat processing operations such as pasteurization and cooking are significant in eliminating microbial pathogens.

3.2.3 Variety: Food processing ensures delivery of a wide variety of high quality products to consumers. By modifying the organoleptic attributes, such as texture, aroma, colour and taste of raw food and ingredients, a wide variety of foods are introduced into the food supply. Grains (maize, wheat, rice, beans etc.) for example can be processed into flour which serves as ingredient for making a variety of products (Fellows, 2000). The world acclaimed brand of breakfast cereals (Kellogs Brand) was created in 1860 by Dr. J. H. Kellogs. Today, many varieties of breakfast cereals are manufactured using process operations such as cooking, drying, toasting, flaking, puffing and extruding (Ensminger *et. al.,* 1994).

3.2.4 Convenience: Processed foods offer convenience by reducing preparation time and labour. Flour ingredient, frozen microwavable foods, instant noodles, beverage powder, ready-to-eat snack foods, packaged fruit juices are modern examples of convenience foods.

3.2.5 Nutrition, health and wellness: The ultimate function of food is to deliver nutrients necessary to meet the requirements for a healthy life. Processing can enhance the nutritional value of foods in a number of ways. For example inactivation and removal of anti-nutritional factors in many foods is necessary to improve bioavailability of essential nutrients. Heat inactivation of trypsin-inhibitor in protein rich legumes such as Soya beans improves the digestibility and utilization of the protein. Enrichment and fortification are also means by which processing can improve nutrient level in foods. Many foods are fortified with vitamins and minerals in response to defined nutritional needs of consumers. In the USA for example, salt is fortified with iodine, milk with vitamin D and grain products with thiamin, niacin, riboflavin and folic acid (Nestle, 2002), while in Nigeria, salt is fortified with iodine, sugar and vegetable oils are fortified with Vitamin A.

3.2.6 Sustainability: The goal of sustainability is to ensure that energy, water and other resources are used most efficiently and negative environmental impacts are minimized. Food processing ensures that resources expended to produce food raw materials are used most efficiently through conversion to a wide range of value added consumers products.

3.3 Food Preservation Processes

The rate of food spoilage after harvest or slaughter is influenced by a number of intrinsic and extrinsic factors. Intrinsic factors are the inherent properties of foods such as; moisture content, water activity, acidity, chemical components, oxidation -reduction potential and physical structure. All these vary among various foods (Table 4 and 5)

Table 4: Typical water contents of some foods

FOOD	WATER (%)
Cucumber	95 - 96
Tomatoes	93 - 95
Cabbage	90 - 92
Orange juice	86 - 88
Apples	85 - 87
Cow milk	86 - 87
Eggs, whole	74
Chicken, broiled	68 - 72
Hard cheese	30 - 50
White bread	34
Jams, preserves	30 - 35
Honey	15 - 23
Wheat	10 -13
Nuts	4 - 7
Dehydrated onions	4 - 5
Milk powder	3 - 4

Source: Berk , 2009

Table 5: Typical water activities (a_w) of selected foods

a_w range	Product examples
0.95 and above	Fresh fruits and vegetables, milk, meat, fish
0.90 - 0.95	Semi-hard cheeses, salted fish, bread
0.85 - 0.90	Hard cheese, Sausage, butter
0.80 - 0.85	Concentrated fruit juices, jelly, moist pet food
0.70 - 0.80	Jams and preserves, prunes, dry cheeses, legumes
0.50 - 0.70	Raisins, honey, grains
0.40 - 0.50	Almonds
0.20 - 0.40	Nonfat milk powder
< 0.20	Crackers, roasted ground coffee, sugar

Source: Berk, 2009

Extrinsic factors are environmental factors such as temperature, relative humidity, levels of carbon dioxide and oxygen, and levels and types of micro-organisms. The processes and methods employed in food preservation are targeted at controlling, eliminating and manipulating both intrinsic and extrinsic factors. Thus some of the main food preservation processes by which food spoilage are controlled are:

3.3.1 Thermal Processes:

3.3.1.1 Preservation by heat: Application of heat to increase temperature of raw foods is the most recognized and widely used approach to preservation of food. By increasing the temperature to appropriate levels and holding for appropriate time dependent on the nature of the food and the objective of the process, pathogenic or spoilage microorganisms are significantly decreased in number or eliminated. Thermal processes in food manufacturing are based on the same principles as in traditional cooking during food preparation. The impact of heat application on food components results in enhancement of the texture, colour and flavour of the food, while some modest losses of heat-sensitive nutrients also occur and constitute what is called thermal damage. Thorough knowledge of process optimization is required to minimise damaging effects of heat. Canning and Aseptic processing are examples of thermal processing which have made available many foods with extended shelf life.

Mild heat application such as blanching (usually accomplished at temperatures below 100^{o}C for 2-5 minutes, is aimed at inactivation of enzymes in foods that catalyze changes in flavour, colour and texture. Other benefits of blanching include removal of occluded air from food tissue to reduce oxidation, softening of plant tissue to facilitate packaging and inactivation of anti-nutritional factors such as enzyme inhibitors. Blanching is usually applied as a pre-process operation in canning, freezing and dehydration.

Pasteurization (named after Pasteur, who demonstrated the lethal effect of mild heating on microorganisms) is a heat treatment targeted at pathogenic microorganisms. However, pasteurized foods are not shelf stable, most pasteurized foods must be kept in refrigerated storage to extend shelf life. Pasteurized milk and beverages are classical examples.

3.3.1.2 Preservation by removal of heat (Refrigeration and Freezing). The activities of microorganisms and enzymes as well as rate of chemical reactions are depressed at low temperatures. In contrast to heat application, low temperature does not destroy enzymes and micro-organisms but it depresses their activities enough to prevent spoilage and extend the shelf life of most food products. Most fruits and vegetables can be maintained with minimal loss by low temperature preservation. However, for preservation to be effective, low temperature must be maintained (cold chain), all along the food supply chain. If the temperature is raised at any point before consumption, the preservation effect ceases. Freezing preservation, apart from lowering temperature also reduces water activity. The phase transition of part of the water in the food from liquid to solid ice results in drastic reduction of water activity and further depresses microbial and enzyme activities. The attraction for refrigeration and freezing is that the quality attributes of foods are maintained to compare favourably with the fresh counterparts (Mallet, 1993).

3.3.2 Preservation by removal of water (Dehydration)

Drying is one of the oldest form of food preservation and also the most widely utilized and most energy intensive (Saravacos, 1965). The removal of water from foods leads to reduced bulk (volume and weight), extended shelf life and convenient products which can be stored at ambient temperatures. Water removal is performed via evaporation, vaporization or sublimation (Whittaker, 1977). In addition to water removal, chemical reactions occur which lead to modification of food material structure and significant change in the dried products. The quality of dried foods is then closely linked to the method of drying and the dynamics of process control. Sun drying on trays, mats or platforms is the traditional method and is still widely used today especially in least developed and developing countries, because of lower energy and equipment cost. Modern mechanical dryers which include cabinet, bed, conveyor, vacuum, and spray dryers are also in use for various types of food.

3.3.3 Chemical preservation

Salting and smoking are based on the antimicrobial effects of salt and smoke chemicals (acids and alcohols). Application of heat with smoke also contributes to the control of spoilage and pathogenic bacteria. Many pathogens are also inhibited under acid conditions (low pH), hence the use of acids as preservatives. Use of acids as preservatives can be achieved by adjusting the pH of foods by addition of acids or biologically through fermentation processes.

3.3.4 Emerging novel processes

Increase awareness on the relationship of food and health, has created the demand for food preservation processes which retain the "naturalness" and still have high nutritive quality. These processes sometimes called minimal processing or non thermal processes are being explored to meet the demands of consumers for healthier and more natural processed foods. High pressure processing (pascalization), Ohmic heating and Active packaging are examples of emerging novel food preservation processes (Henry, 1997).

4.0 Research Contributions

4.1 Research Focus

A beneficial approach to increasing food availability is by creating a wide array of end-uses for food raw materials through product and process development. The major thrust of my research activities has been in the area of food processing and utilization, entailing functional characterization of food materials to determine diversified end-use applications in product formulation and process development. Significant contributions have also been made in upgrading indigenous food processing for improved process efficiency and product quality.

Food functionality involves study of properties, which are not nutritional and which affect utilization (Pour-El, 1981). These are physiochemical properties that give information on how a food ingredient or component will behave in a food system. Properties such as solubility, viscosity, water and fat binding, emulsification, foaming and gelation are generally considered in functional characterisation

(Hermansson, 1979). The lack or loss of functionality can lead to food rejection and income loss to the producer, processor or marketer. As an allegory, even in the life of an individual, state or nation, functionality is crucial, in order for any of these entities to perform and make the desired impact. The Yoruba adage which says *"E jawo ninu apon ti ko yo, E je ka da omi ila kana"* is very instructive on food functionality. The meaning here is that you need to discard an ingredient which when used did not behave to give the desired property. In this case the viscosity of soup made from "apon" (seed of *Irvinia gabonensis*) is a functional property and if it is lost, should be discarded and replaced with okra (fruit of *Hibiscus esculentus*), another ingredient that can deliver the desired viscosity in soup.

4.2 Bean / Cowpea Studies
4.2.1 Cooking Properties
Pulses including cowpeas, pigeon pea, bambara beans are

starchy legumes widely cultivated and consumed in Nigeria. Cowpea (*Vigna unguiculata)* in particular is a major pulse in which Nigeria is one of the largest producers. Apart from supply of carbohydrates (mainly starch) beans are very good sources of plant protein, vitamins, soluble and insoluble fibre. Many health benefits such as reduced risk of developing hypertension, obesity and coronary heart disease are attributed to consumption of beans.

Beans are prepared for consumption in several ways as shown in Figure 4, all of which require long preparation time and laborious operations. Consumption of beans is curtailed because of long cooking time needed to achieve the desired palatability and digestibility. Findings from a study to evaluate the cooking properties of different cowpea varieties, **Henshaw** and Sanni (1995) showed that cowpea varieties differed in their ease of cooking. Differences in physical and chemical properties, such as seed coat texture, ratio of chemical components, starch, amylose and protein, and rate of hydration were major contributing factors. Fast cooking varieties should be adopted for boiling while the varieties which had long cooking time could be screened for other end use other than boiling (Table 6, Table 7 and Figure 5).

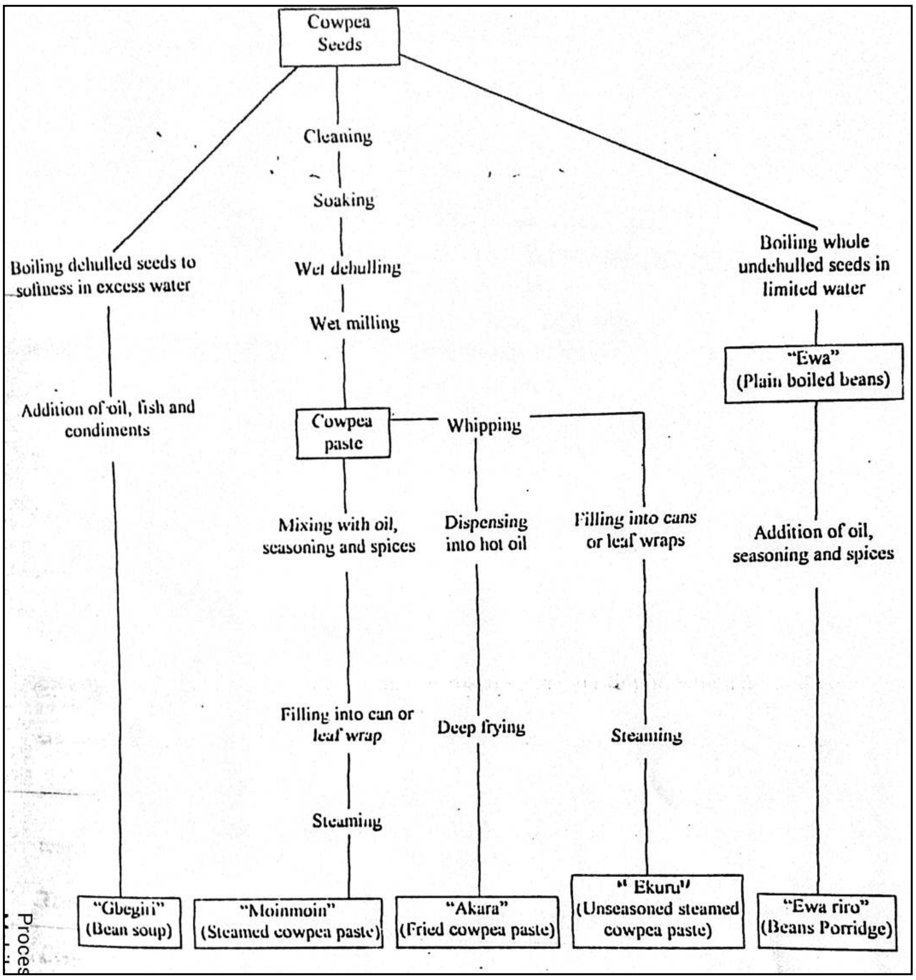


Figure 4: Flow chart for the preparation of some common cowpea foods in Nigeria.

Source: Henshaw, 2000

Table 6: Chemical Composition of Seven Cowpea Varieties

Variety	Moisture	Starch	Amylose	Protein	Starch Protein
IT84E-124	11.3	46.4	22.3	24.5	1.89
IT84S-2246	11.3	50.4	22.3	23.8	2.12
IT86D-715	10.8	52.7	28.5	22.3	1.85
IFE BROWN	11.5	44.1	22.0	22.4	1.96
TVX 3236	11.7	45.7	25.6	23.5	1.95
L 80	11.9	54.6	37.1	21.6	2.53
L 25	11.8	54.5	30.3	22.8	2.39
X	11.5	49.7	26.90	22.97	2.09
S.D	0.37	4.36	5.63	1.00	0.26
% C.V	3.25	9.33	20.93	4.39	12.44

X = mean
S.D. = Standard Deviation
C.V. = Coefficient of Variation
Source: Henshaw and Sanni, 1995

Table 7: Mean value of cooking time and Hydration indices of seven cowpea varieties

Variety	Cooking Time (Minute)	Hydration Index
IT84E-124	33.2	117.3
IT84S-2246	33.3	121.3
IT86D-715	48.3	129.6
IFE BROWN	35.0	111.3
TVX 3236	36.3	108.7
L 80	140.0	97.3
L 25	80.0	101
X	57.97	112.21
S.D	39.87	11.30
% C.V	68.78	10.07

X = mean

S.D. = Standard Deviation

C.V. = Coefficient of Variation

Source: Henshaw and Sanni, 1995

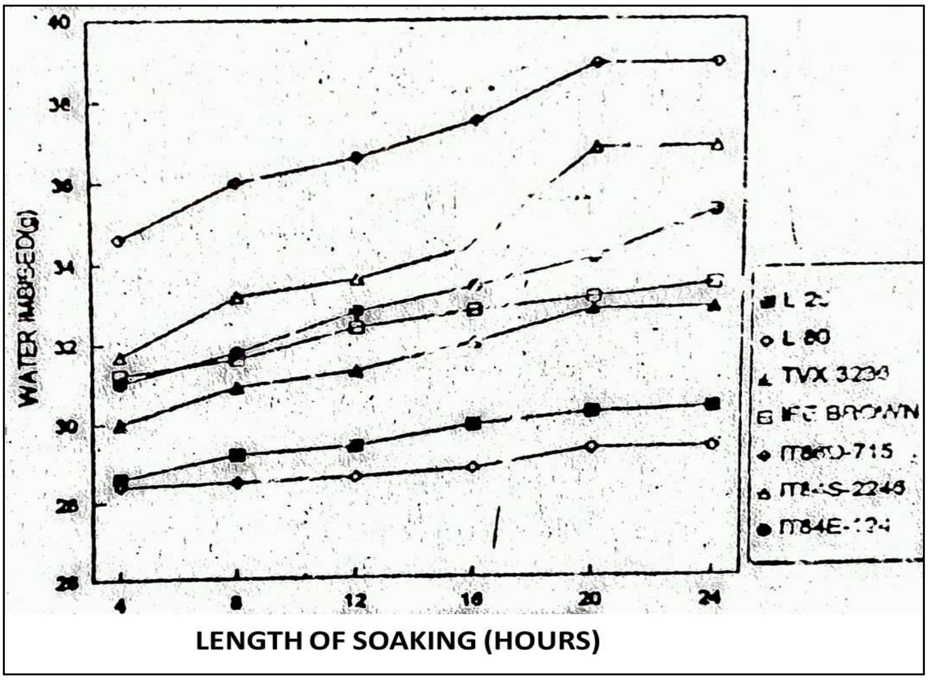


Figure 5: Water imbibition of different cowpea varieties during soaking for 24 hours

Source: Henshaw and Sanni, 1995

The study prompted other studies on cooking properties of another pulse pigeon pea (*Cajanus cajan)*. The objective was to look for means of shortening cooking time of this bean, which although similar to cowpea in composition, was not usually consumed as much as cowpeas because of the long cooking time, which has implication for energy cost. **Hen-**

shaw et al. (1999) studied the effect of pre-soaking and addition of trona on cooking properties of three varieties of pigeon pea.

Pre-soaking of beans decreased cooking time from 98-102 minutes to 77-79 minutes, confirming positive linear correlation of cooking time with hydration rate as shown in Table 8, Table 9 and Figure 6. Combining soaking with addition of trona did not lead to further reduction of cooking time. Pre-soaking alone was more effective in reducing cooking time than addition of trona without pre-soaking.

Table 8: Effect of addition of various level of trona on *cooking (minutes) of pigeon peas varieties

Variety	Level of Trona (%)					
	0	**0.03**	**0.06**	**0.10**	**0.13**	**0.16**
Giant Local	98.67[b]	96[d]	92.67[c]	89[ef]	85.33[g]	81[h]
	(1.15)	(1.00)	(1.15)	(1.00)	(1.52)	(1.00)
Market	101.66[a]	99[b]	96[bc]	90[ef]	83[g]	79.33[h]
	(2.00)	(1.00)	(1.00)	(1.00)	(1.52)	(1.00)
Local	98.33[b]	98[b]	96.33[bc]	95[d]	91[c]	88[f]
Dwarf	(1.52)	(1.00)	(0.57)	(1.00)	(1.00)	(1.00)

*Values in parenthesis are standard deviations of three determinations
Values bearing different superscript are significantly different ($p<0.05$)
Source: Henshaw et al., 1999

Table 9: Effect of combination of 24 hour soaking and 0.16% trona on *cooking time (minutes) of pigeon peas varieties

Variety	Soaking (Hours)	Time	Trona (%)		Trona 0.16% + 24 Hour Soaking
	0	24	0	0.16	
Giant	98.67[b]	79.33[d]	98.67[b]	81[d]	73.33[C]
Local	(1.15)	(0.87)	(1.15)	(1.00)	(2.33)
Market	101.66[a]	77[d]	101.66[a]	79.33[d]	67.67[f]
	(2.00)	(1.33)	(2.00)	(1.00)	(1.5)
Local	98.33[b]	78.67[d]	98.33[b]	88[c]	71[c]
Dwarf	(1.00)	(0.89)	(1.52)	(1.00)	(1.14)

Values in parenthesis are standard deviations of three determinations

Values bearing different superscript are significantly different ($p<0.05$)

Source: Henshaw *et al.*, 1999

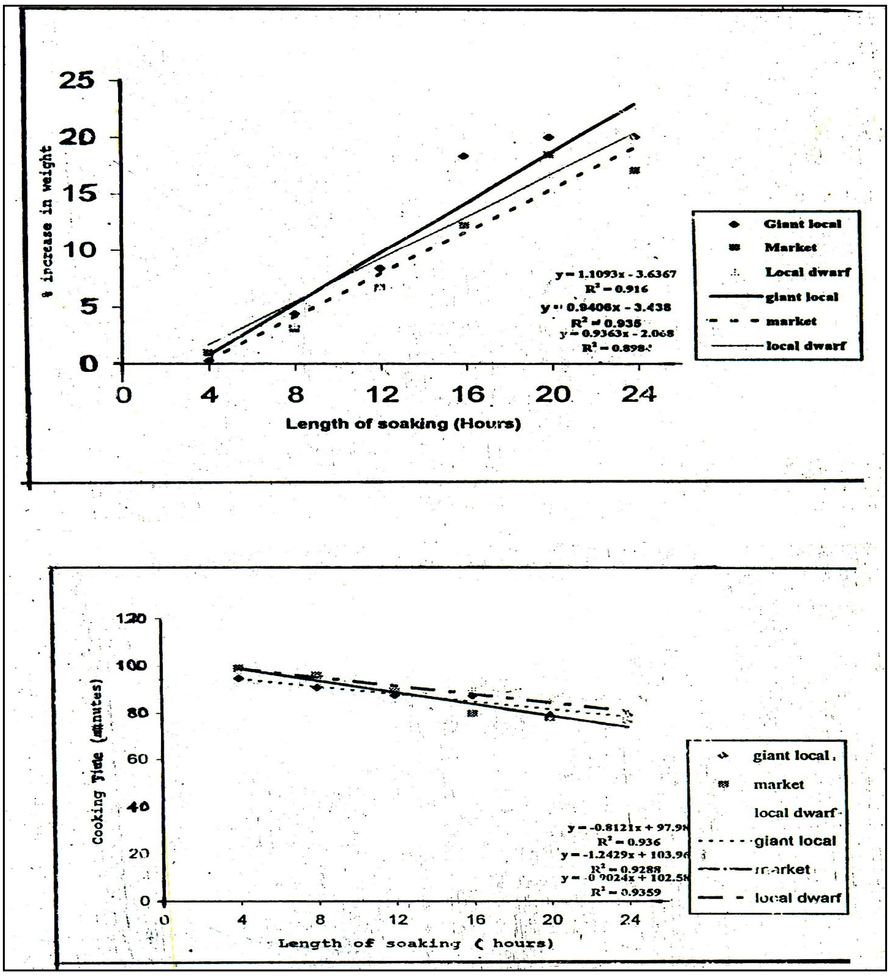


Figure 6: Effect of soaking on rate of water imbibition and cooking time of pigeon pea varieties

Source: Henshaw *et al.*, 1999

4.2.2 Bean Paste

Beans are also prepared into paste by a laborious process involving soaking, dehulling, grinding/wet milling to give paste. The paste is used to prepare popular West African foods akara (fried cowpea/bean paste) and moinmoin (steamed cowpea/bean paste). These foods are also commonly offered for sale as street vended foods. Cowpea paste prepared by vendors are usually left to stand at ambient conditions for several hours before it is prepared for consumption. This practice could pose public health hazards arising from use of soured paste due to microbial infiltration (Bulgarelli *et al.,* 1988) and also affect the functional properties.

The functional properties of cowpea paste frozen at different temperatures (-30^{0}C, -40^{0}C and -50^{0}C) were investigated. Freezing was fastest at -50^{0}C (Figures 7-9 and Table 10) and functional properties were best preserved in paste frozen at the same temperature. Frozen cowpea paste stored at -18^{0}C were still suitable for preparation of akara after 17 days of storage. A pre-process treatment involving a short heating (blanching) led to better preservation of functional properties which influenced textural and overall sensory quality of akara and moinmoin (**Henshaw** *et al.,* 2000; **Henshaw** *et al.,* 2003a). Although these studies established that cowpea paste could become a convenient frozen food ingredient, this is yet to be exploited in Nigeria because freezing preservation requires the availability of adequate and steady supply of electricity, a status yet to be reached in Nigeria. Hopefully, by the year 2020 there will be improvement.

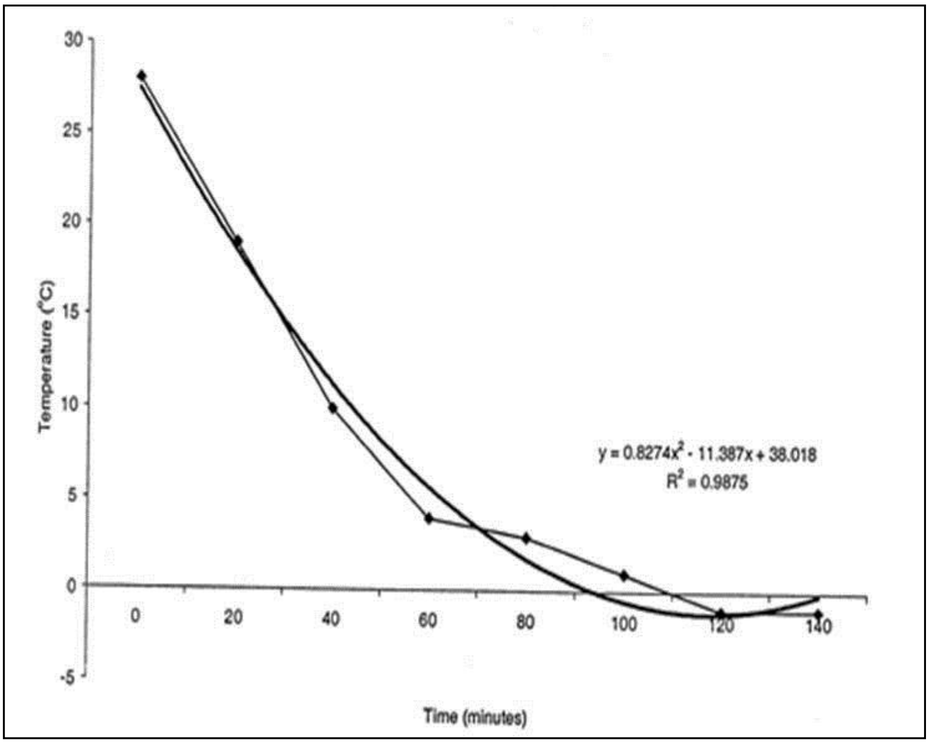


Figure 7: Freezing curve of cowpea paste at -30oC

Source: Henshaw *et al.,* 2003a

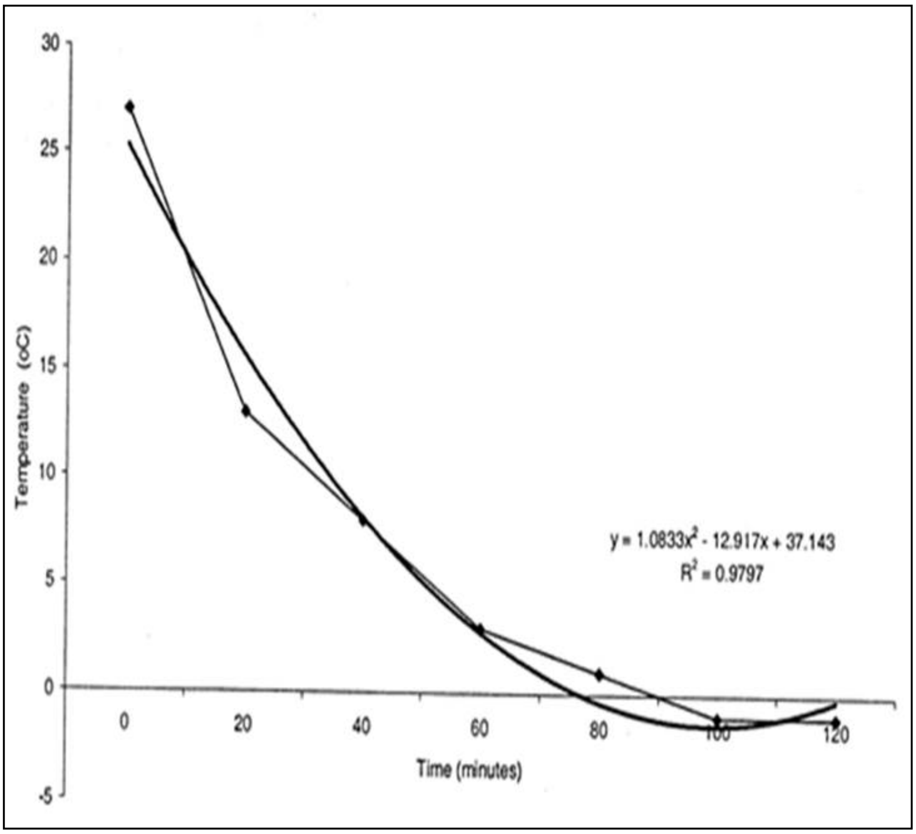


Figure 8: Freezing curve of cowpea paste at -40oC
Source: Henshaw *et al.,* 2003a

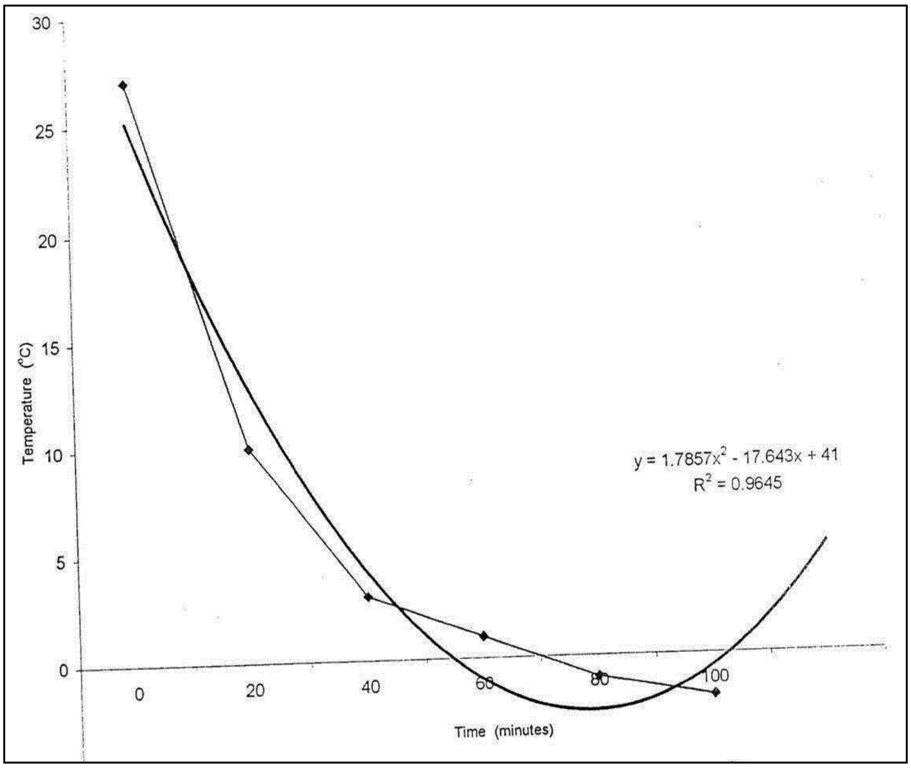


Figure 9: Freezing curve of cowpea paste at -50°C

Source: Henshaw *et al.,* 2003a

Table 10: Effects of freezing temperature on some functional properties of cowpea

Functional Properties*	Unfrozen paste	-30°C	-40°C	-50°C
Emulsion capacity (%)	50[a]	45.7[b]	46[b]	49[a]
Foaming capacity (ml/g)	6.2[a]	4.2[c]	4.2[c]	5.7[b]
Water absorption capacity (ml/g)	1.72[a]	2.42[c]	2.38[c]	1.9[b]
Oil absorption capacity (ml/g)	1.43[a]	1.61[a]	1.57[a]	1.47[a]
Gelatin capacity (%)	6[a]	10[b]	8[a]	6[a]
Pasting temperature (°C)	80[a]	78[b]	78[b]	78[b]
Hot paste viscosity (BU) at 95°C	490[a]	260[c]	270[c]	370[b]
Cooked paste viscosity (BU) on holding at 95°C	480a	170c	210b	180c
Setback viscosity (BU) on cooling at 50°C	540[a]	170[c]	200[b]	200[b]

BU= Barbender Units * Values bearing different alphabet in a row are significantly different at $p \leq 0.05$
Source: Henshaw *et al.*, 2003a

4.2.3 Bean / Cowpea Flour

Vice-Chancellor, Sir, taking cognisance of the fact that appropriate processing technologies need to be in tandem with the available infrastructural support for sustainability, several in-depth studies were carried out with the aim of replacing the starting ingredient for traditional cowpea products with a convenient shelf stable flour, which can be packaged and stored at ambient temperature without the need for electricity.

The major macromolecules in food (starch, protein and fat) are usually the determinants of many functional properties. Cowpeas are starch – protein seeds, unlike other legumes such as soya bean, which is an oil–protein seed, cowpeas contain very little fat. Therefore, the functionality of cowpea flour would logically be determined largely by the properties of its constituent starch and protein.

A number of studies to elucidate the behaviour of these components among many diverse varieties of cowpeas were conducted. The pasting properties of food ingredients are important determinants of functionality, since pasting involves changes which occur during heating of a suspension of starch and starch containing materials. The characteristics of the hot and cold paste affect many textural and sensory properties of end-products.

Pasting properties and swelling power of cowpea starch were significantly influenced by variety of beans. In a study of six different cowpea varieties, **Henshaw** and Adebowale (2004) showed that the hot paste viscosity at 95^{0}C accounted for 90% of variance in pasting viscosities (Table 11), while swelling power at 70^{0}C and 95^{0}C accounted for 89% of variance in swelling power (Table 12). The variation in starch functionality is indicative of varietal differences in possible end-use applications.

Henshaw and Lawal (1993) showed that the method of processing flour from cowpea affected the functionality in traditional foods such as akara and moinmoin. Three different processing methods gave flours with varied functionality (Figure 13; Table 12).

Table 11: Amylograph pasting properties of different varieties of cowpea starch

cowpea variety	PT (°C)	PVT (°C)	TVP (min)	PKU (BU)	HTPV (BU)	CKPV (BU)	SEBV (BU)
IT90K-	75	88	25	1277	1260	1240	2237
277-2	(1.3)	(2.0)	(2.1)	(5.8)	(10.0)	(10.0)	(5.8)
IT93K-	69	81	23	1407	1313	1220	2020
129-4	(1.9)	(1.3)	(1.0)	(11.5)	(11.5)	(20.0)	(20.0)
1T81D-	886	90	26	920	920	913	1780
994	(2.5)	(1.0)	(2.0)	(20.0)	(20.0)	(11.5)	(20.0)
IT95K-	668	73	18	1330	1320	1260	2550
1543	(0.3)	(1.5)	(2.0)	(10.0)	(20.0)	(20.0)	(10.0)
Oloyin	885	90	24	890	890	893	1913
	(0.5)	(0.2)	(1.0)	(10.0)	(10.0)	(5.8)	(11.5)
IT86D-	772	89	22	890	888	887	2493
7221	(1.3)	(0.3)	(2.0)	(8.7)	(5.8)	(2.9)	(11.5)

Source : Henshaw and Adebowale, 2004

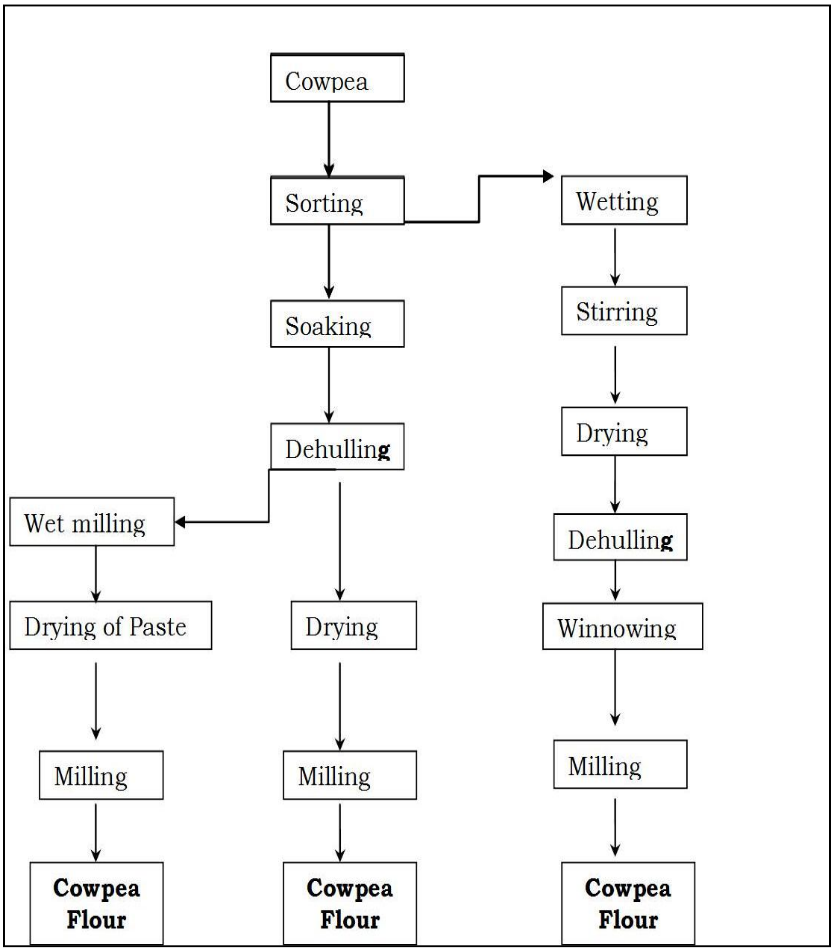


Figure 10: Production of dried paste cowpea flour (DPCF); manually dehulled cowpea flour (MDCP) and mechanically dehulled cowpea flour (MCDCF).
Source : Henshaw and Lawal, 1993

Table 12: Functional properties of cowpea flours

Functional property	DPCF	MDCF	MCDCF
Gelatin capacity (%)	16.00	15.00	18.00
Water absorption capacity (g/g)	3.00	3.00	3.00
Oil absorption capacity (g/g)	3.53	2.16	2.16
Foaming capacity (%)	25.00	30.00	33.00
Foaming stability after 15 mins (%)	0.00	96.67	100.00
Bulk density (g/cm^3)	0.86	0.67	0.73
Emulsifying capacity (ml/g protein)	32.01	17.69	17.41
Nitrogen solubility (%)	0.05	0.19	0.42

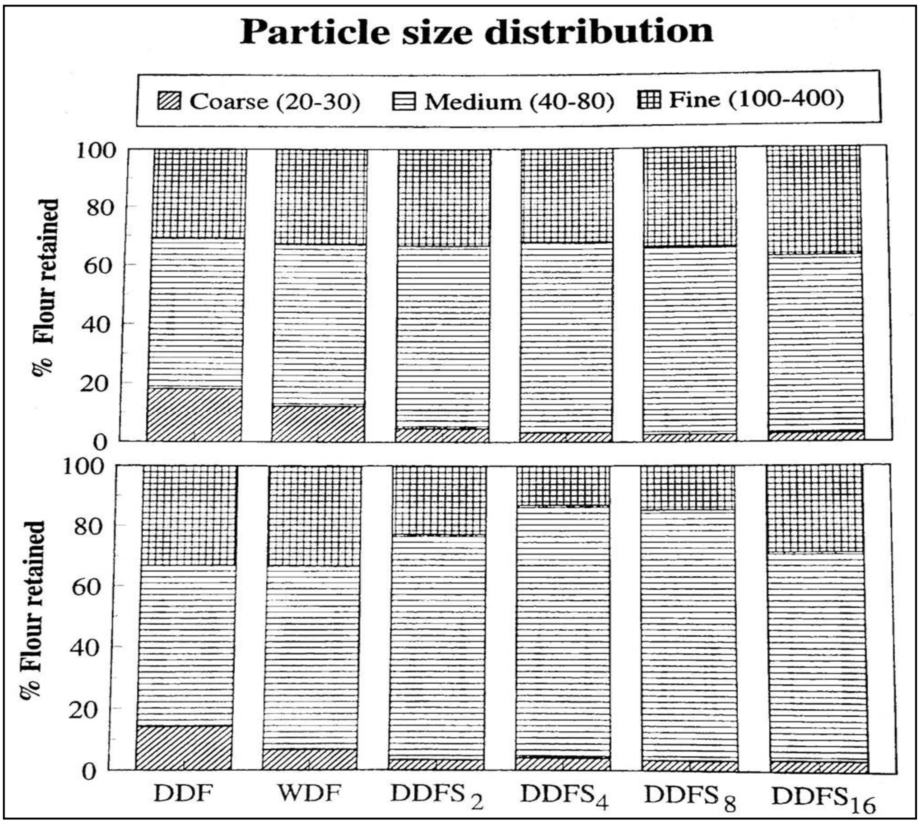
Source: Henshaw and Lawal, 1993

Based on the results obtained further studies were conducted. Twelve varieties of cowpea were processed into flour by two process methods involving dry and wet decortication and pre-soaking for different lengths of time. The functionality of flour was determined in terms of pasting properties, measured in a Brabender Viscoamylograph. Significant variation observed in pasting properties were affected by variety and processing method (Table 13); **Henshaw** *et al.* 1996. The method of decortication affected particle size distribution (Figure 11) of flour. Maximum hot paste viscosity and highest percentage of medium size particles (mesh 40 – 80) were obtained with flour produced from bean pre-soaked for 4 hours. The results showed that cowpea flour with at least 65% medium size particles exhibited best hydrothermal properties, leading to increased rate of moisture absorption and higher hot paste viscosity (**Henshaw** et al, 1996).

Table 13: Pasting properties of 12% cowpea flour slurries

Process[b]	Variety	HTPV[c]	CKPV[d]	STBV[e]	CLPV[f]	PCI[g]	PSER[h]	CPSR[i]	*Pasting* temp (°C)
DDF	Vita 5	117.5 cd	195 c	247.5 cdef	242.5 cde	1.66 bc	1.27 abc	0.98 a	79.6
	TVX 3236	140 bcd	232.5 bc	295 c	290 c	1.66 bc	1.27 abc	0.98 a	81.1
	California Blackeye 5	230 a	305 a	355 b	350 b	1.33 c	1.16 bcd	0.99 a	80.9
	White Acre	75 e	135 d	195 f	195 e	1.80 bc	1.44 a	1.00 a	80.6
	Mississippi Silver	245 a	310 a	412.5 a	420 a	1.27 c	1.33 ab	1.02 a	77.9
	Better Green Cream	110 de	202.5 bc	267.5 cd	267.5 cd	1.84 bc	1.32 ab	1.00 a	79.6
	Pinkeye Purple Hull	107.5 de	217.5 bc	255 cde	247.5 cde	2.02 ab	1.71 bcd	0.97 a	82.7
	Texas Cream 40	77.5e	200 c	217.5 def	210 de	2.58 a	1.09 cd	0.97 a	81.5
	White California Blackeye A	110 de	200 c	210 ef	200 e	1.83.bc	1.05 d	0.95 a	81.9
	White California Blackeye B	170 b	240 b	270 cd	260 cd	1.41 bc	1.13 cd	0.96 a	81.1
	IAR-339-1	157.5 b	227.5 bc	300 bc	290 c	1.44 bc	1.32 ab	0.97 a	80.3
	Ife Brown	150 bc	210 bc	260 cde	260 cd	1.40 c	1.24 bcd	1.00 a	79.6
WDF	Vita 5	122.5 de	215 cd	282.5 ef	265 ef	1.76 abc	1.31 abc	0.94 a	78.8
	TVX 3236	170 b	270 b	360 bc	340 cd	1.59 cde	1.33 abc	0.94 a	80
	California Blackeye 5	270 a	330 a	417.5 a	400 b	1.22 f	1.27 abc	0.96 a	80.3
	White Acre	100 e	190 d	275 ef	275 ef	1.90 ab	1.45 a	1.00 a	79.2
	Mississippi Silver	260 a	337.5 a	460 a	460 a	1.30 ef	1.36 ab	1.00a	79.2
	Better Green Cream	102.5 e	190 d	260 f	260 f	1.85 abc	1.37 ab	1.00 a	80.9
	Pinkeye Purple Hull	120 e	237.5 bc	345 bc	340 cd	1.98 a	1.45 a	0.99 a	82.2
	Texas Cream 40	172.5 b	277.5 b	332.5 bcd	320 cde	1.61 bcd	1.20 bc	0.96 a	80.3
	White California Blackeye A	130 cde	250 bc	280 ef	267.5ef	1.93 a	1.12 c	0.96 a	81.9
	White California Blackeye B	165 bc	257.5 bc	320 cde	302.5 def	1.56 cde	1.24 abc	0.95 a	80.3
	IAR-339-1	177.5 b	280 b	370 b	365 bc	1.58 cde	1.32 abc	0.99 a	78.4
	Ife Brown	157.5 bcd	220 cd	290 def	285 def	1.40 def	1.32 abc	0.98 a	79.2

Source: Henshaw *et al.*, 1996



DDF- Dry decorticated flour; WDF= Wet decorticated flour
$DDFS_2$, $DDFS_4$, $DDSF_8$, $DDSF_{16}$= Dry decorticated flour prepared from seeds pre-soaked for 2, 4, 8 or 16 hours.

Figure 11: Particle size distribution of flours prepared from Texas Cream 40 (top) cowpeas and California Blackeye 5 (bottom)

Source: Henshaw *et al.,* 1996

In another study by Henshaw et al, 2002, 28 varieties of cowpeas of Nigeria and USA origins were processed into flour by a method involving conditioning of seeds, dry dehulling and milling. The pasting properties were determined. The objective was to characterize the functionality of the 28 varieties of flour and to identify the properties which contribute most to differentiation. Findings showed significant varietal influence on pasting properties (Figure 12 and Table 14). The 28 varieties were classified into 3 groups by a statistical multivariate data reduction technique, canonical discriminant analysis (Zagrodzki *et al.,* 1995) as shown in Figure 13. The hot paste viscosity at 95^{0}C was the most discriminating paste viscosity and this confirmed previous findings by **Henshaw** et al., (1996). These results showed that cowpea varieties differed significantly in their functionality when processed into flour and that the hot paste viscosity is a useful index to determine functionality of cowpea flour and the most discriminating variable underlying variation.

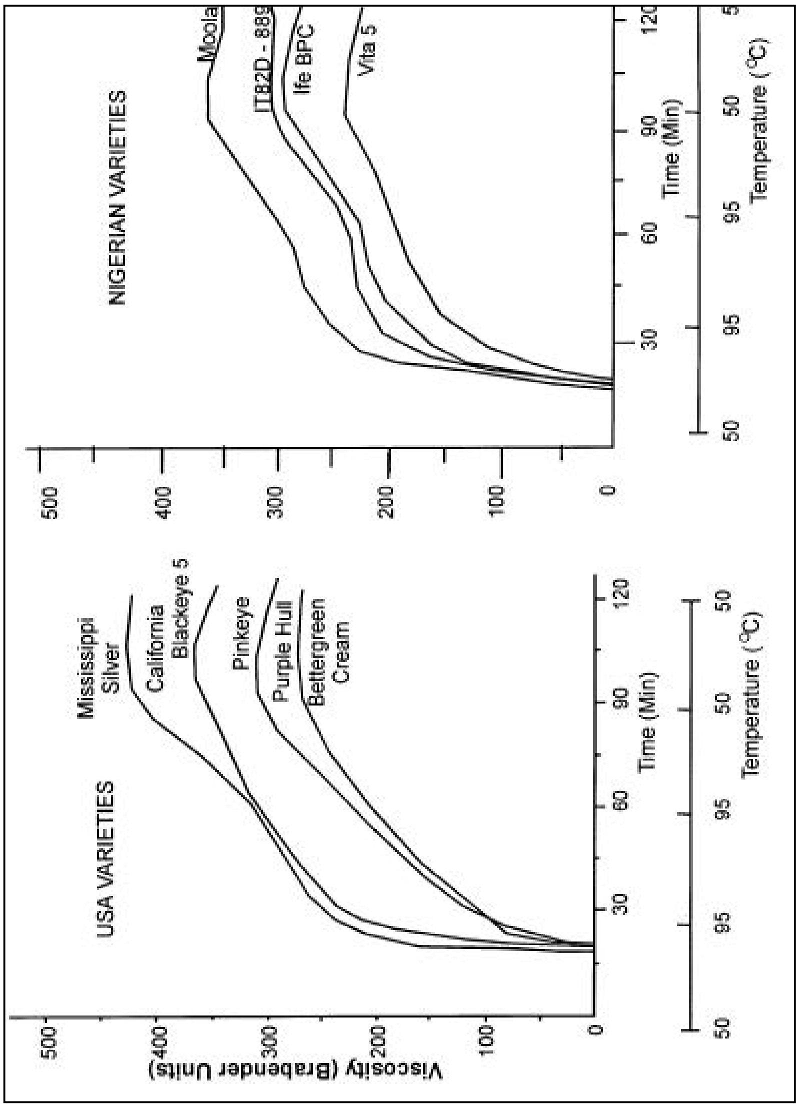


Figure 12: Typical Brabender amylogram patterns of cowpea flour.
Source: Henshaw *et al.*, 2002

Table 14: Pasting properties of selected varieties of cowpea flour[a]

S/N		Variety	HTPV	CKPV	STBV	CLPV	PTICI	HPCI	PSER	CPSR
1	A	Vita 5	117.5 de	1950b	247.5bde	242.5abc	79.6	0.66	1.27	0.98
2	B	TVX 3236	140.0dfg	232.5cde	295.0fgh	290.0cdefg	81.1	0.60	1.27	0.98
3	C	California Blackeye 5	230.0mm	305.0gh	355.0mijk	350.0ijk	80.9	0.75	1.16	0.99
4	D	White Acre	75.0a	135.0a	195.0a	195.0a	80.6	0.55	1.44	1.00
5	E	Mississippi Silver	245.0n	310.0h	412.5lmn	420.0i	79.9	0.79	1.33	1.02
6	F	Better Green Cream	110 .0cde	202.5bc	267.5def	267.5cdef	79.6	0.54	1.32	1.00
7	G	Pinkeye Purple Hull	107.5bcd	217.5bcd	255.0bcde	247.5bed	82.7	0.49	1.17	0.97
8	H	Texas Cream 40	77.5ab	200.0bc	217.5abc	210.0ab	81.5	0.30	1.09	0.97
9	I	White California Blackeye A	110cde	200.0bc	210.0ab	200.0ab	81.9	0.55	1.03	0.95
10	J	White California Blackeye B	170.0hijk	240.0def	270.0def	260.0cde	81.1	0.71	1.13	0.96
11	K	IAR-339-1	157.5fghi	227.5bcde	300.0efgh	290.0cdefg	80.3	0.69	1.32	0.97
12	L	Ife Brown	150.0fghi	210.0bed	260.0cde	260.0	79.6	0.71	1.24	1.00
13	M	TVX 1948-012T	127.5def	225.0bede	337.5hijk	355.0ik	80.0	0.57	1.30	1.05
14	N	IT81D-994	162.5ghij	310.0h	455.0h	450.0i	80.0	0.52	1.47	0.99
15	O	WHIPPOORWI	160.0ghij	240.0def	283.8defg	282.5cedfg	74.8	0.66	1.18	0.99
16	P	Ife BPC	195.0gl	235.0cde	297.0efgh	290.0cdefg	79.6	0.83	1.27	0.97
17	Q	IT86D-719	157.5fghi	257.5ef	337.5hijk	330.0hijk	78.5	0.67	1.31	0.97
18	R	IT850-3850-2	137.5defg	272.5ef	370.0kl	370.0k	78.5	0.50	1.33	1.00
19	S	Kanannado	235.0mn	227.5bede	280.0defg	280.0cdefg	80.0	10.03	1.23	1.00
20	T	IT88DM-363	205.0lm	302.5ghc	380.0klm	370.0k	79.2	0.67	1.25	0.97
21	U	Moola	240.0n	297.5gh	365.0jk	360.0jk	81.9	0.81	1.23	0.99
22	V	IT82D-889	165.0ghij	235.0cde	307.5fgh	305.0efgh	79.6	0.69	1.31	0.99
23	W	L-25	187.5jkl	215.0bed	310.0fghi	297.5efgh	79.6	0.87	1.44	0.96
24	X	IT82E-9	160.0ghij	220.0bed	312.5fghi	312.5fghi	80.0	0.73	1.42	1.00
25	Y	L-80	135.0defg	210.0bed	292.5defgh	292.5defg	79.6	0.64	1.39	1.00
26	Z	IT845-2246-4	140.0efgh	230.0bede	320.0gh	320.0ghij	81.3	0.60	1.39	1.00
27	1	IT86D-1010	172.5hijk	320.0h	425.0mn	425.01	79.6	0.54	1.33	1.00
28	2	Coronet	80.0abc	147.5a	210.0ab	205.10ab	83.0	0.54	1.42	0.98
		X	155.4	236.4	306.0	302.8	80.0	0.64	1.29	0.99
		S.D.	47.4	46.7	65.5	67.2	1.6	0.13	0.11	0.02

HTPV - Hot Paste Viscosity at 95°C; CKPV – Cooked Paste Viscosity after holding at 95°C for 30 mins; STBV –Set back Viscosity on cooking from 95 to 50°C; CLPV - Cooked Paste Viscosity after holding at 50°C for 30 mins; PT°C -Pasting Temperature: HPCI – Hot Paste Capacity Index; PSER - Paste Setback Ratio; CPSR - Cooled Paste Stability Ratio; BU - Brabender Units; X - Means; S.D. – Standard Deviation

Source: Henshaw *et al*., 2002

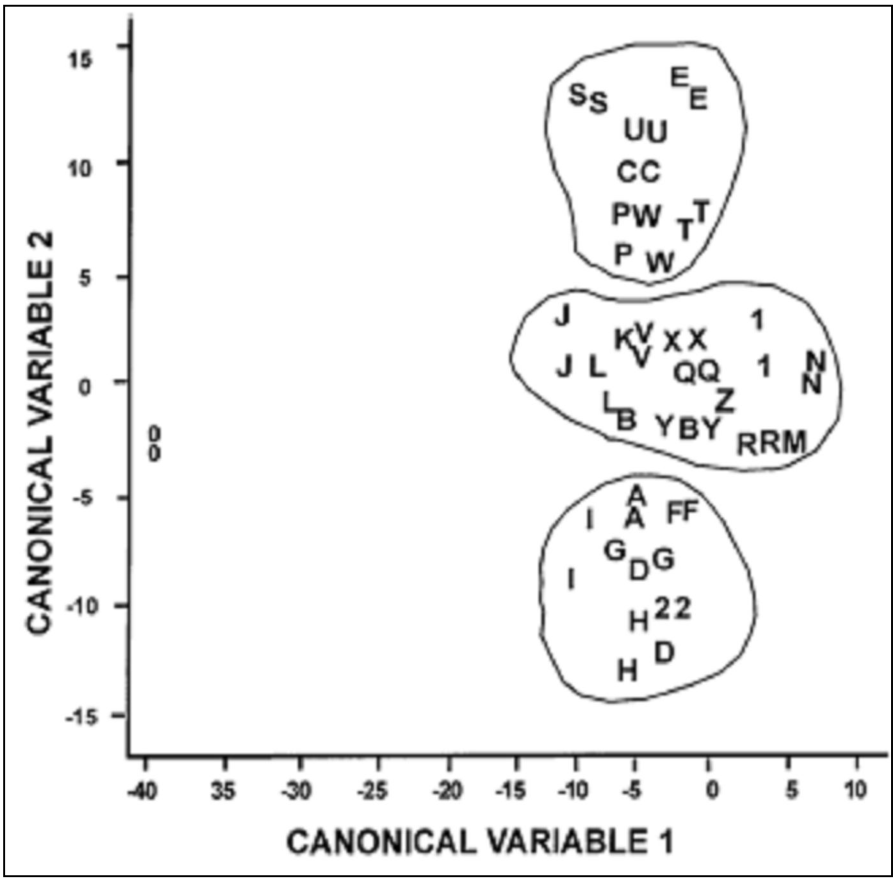
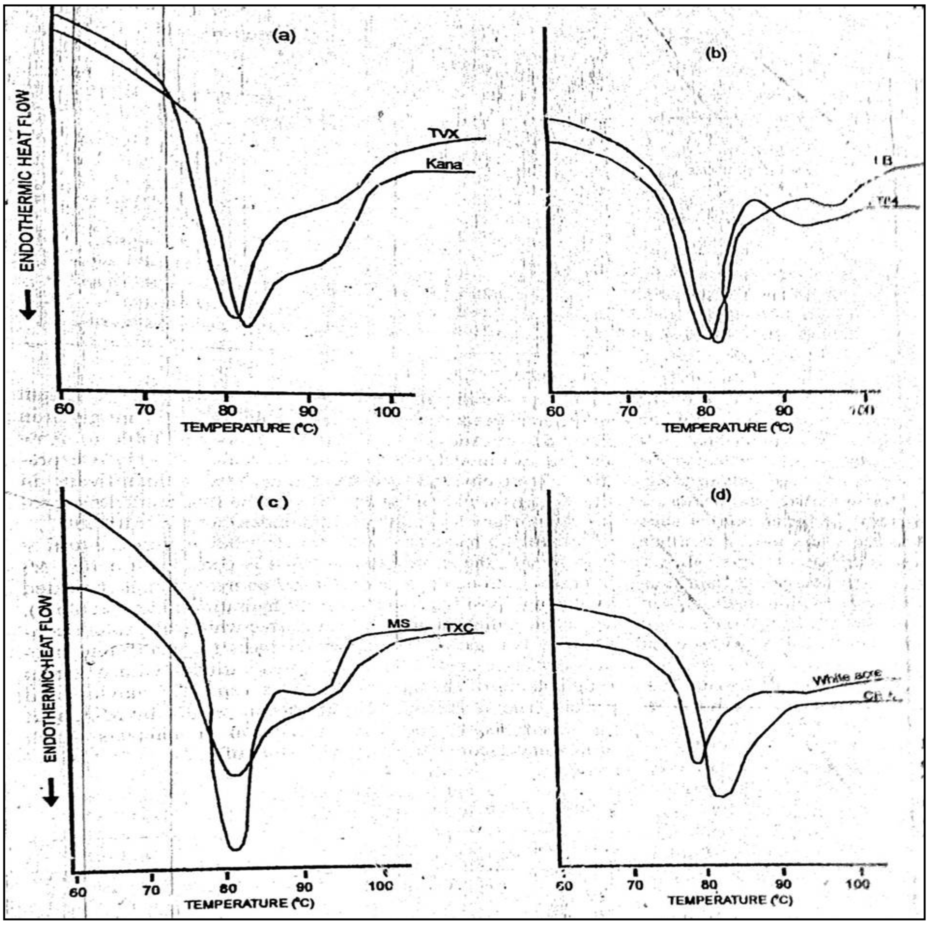


Figure 13: Plot of relationship between the 28 cowpea varieties
Letters represent varieties as listed in Table 14
Source: Henshaw *et al.,* 2002

Further studies to elucidate the inherent physicochemical basis for functional differences among cowpea varieties were needed. **Henshaw** *et al* (2003b) conducted another study on thermal properties of 12 varieties of cowpea flour using a differential scanning calorimeter (DSC). Thermal stability is an important determinant of functional properties. This is because structural parameters that influence functionality are altered chemically during application of heat. Thermal treatment of varying degree is a common operation during processing of foods. DSC is a thermo-analytical technique for monitoring changes in physical and chemical properties of materials as a function of temperature (Biliaderis, 1983). The change in state of a substance is accompanied by a change in energy level, which can be manifested by the absorption of heat (endothermic reaction) and liberation of heat (exothermic reaction). The measuring principle in DSC is to compare the rate of heat flow to a sample of interest and to an inert material which are heated and cooled at the same rate. Changes associated with absorption or evolution of heat in the sample cause a differential heat flow, which is recorded graphically as a thermogram. Thermal transitions among 12 varieties of cowpea flour were defined in terms of T_o (transition onset temperature), T_p (transition peak temperature) and ΔH (transition enthalpy). The thermograms obtained showed that most varieties of cowpea flour (Figure 14) exhibited single major endotherm transition occurring over a varied range of temperatures. Furthermore, there were significant differences in all the DSC parameters measured. The transition enthalpy (∆H) was the most discriminating parameter and accounted for 80% of the total variance. The chemical components of cowpea flour starch, amylose and protein were significant predictors of ∆H. Starch modification and protein denaturation were significant changes that occur during processing of cowpea to flour. The ratios or proportions of these macromolecules in different varieties have critical influence on functionality of cowpea flour as shown in Table 15 (**Henshaw** *et al.,* 2003b).



TVX (TVX3236), Kana (Kananedo), MS (Mississippi Silver), IB (Ife Brown) IT84 (IT84S-2246), TXC (Texas Cream 40), CB(CaliforniaBlackeye S)

Figure 14 : (a-d) DSC thermograms of selected varieties of cowpea flour.

Source: Henshaw, *et al.,* 2003b

Table 15: Chemical components and hydration indices of selected varieties of cowpea flour

Variety	Hydration Index	Starch	Amylose	Protein (%)	Total Soluble Sugar
Texas Cream	137.5	47.8	12.4	24.2	10.7
Ife Brown	110.5	52.5	15.2	22.4	9.2
Ife BPC	122.6	55.7	19.4	23.1	10.4
White California Blackeye A	130.9	58.5	20.6	24.9	10.7
White California Blackeye B	130.9	51.3	20.6	23.5	12.2
California Black-eye 5	122.7	54.3	21.7	22.9	10.7
TVX 3236	94.7	55.1	22.2	23.1	9.8
Kanannado	115.7	49.9	20.3	23.2	12.9
White Acre	114.6	55.8	18.1	24.9	11.4
Mississippi Silver	116.9	53.6	20.1	20.8	9.9
IT84S-2246-4	116.6	56.0	21.2	22.6	9.3
L-25	105.9	54.9	21.8	20.9	9.8

Source: Henshaw *et al.,* 2003b

Sensory properties are important determinants of consumer acceptance (McWatters, 1986; **Henshaw** *et al* (2000).

In a study to evaluate the acceptance of cowpea flour in akara and moinmoin, the sensory properties of these products prepared from flour and wet-milled paste (control) as starting ingredients were investigated. The results indicated that the differences in sensory attributes of akara ranged between 0.30 (no difference) to moderate differences while for moinmoin there were slight difference (0.10) to moderate difference. (Tables 16 and 17). The most discriminating sensory attributes for akara were crumb sponginess and lightness and crust softness, while those for moinmoin were mouthfeel and moistness (**Henshaw** *et al*., 2009). The results showed that cowpea flour appropriately processed can give the required organoleptic quality in these products that would ensure consumer acceptance.

Table 16 : Mean scores for the degree of difference from control for sensory properties of *akara* prepared from selected varieties of flour

Variety	Beany flavor	Color	Crust crisipiness	Crumb lightness	Crumb Non stickiness	Crust softness	Crumb sponginess	Taste
California Blackeye 5	1.8^{a}	0.59^{ab}	0.93^{a}	**1.4^{a}**	0.52^{a}	**0.88^{b}**	**1.5^{a}**	1.7^{a}
Mississippi Silver	2.4^{b}	0.59^{ab}	0.93^{a}	**1.7^{a}**	0.77^{ab}	**0.74^{a}**	**2.4^{b}**	2.0^{a}
Ife Brown	2.4^{b}	0.62^{ab}	1.5^{b}	2.7^{b}	0.88^{b}	1.2^{b}	2.5^{b}	1.9^{a}
TVX 3236	2.4^{b}	0.30^{a}	1.2^{ab}	2.5^{b}	1.0^{b}	0.92^{b}	3.1^{c}	2.4^{b}
White Acre	2.4^{b}	0.77^{b}	1.3^{a}	2.5^{b}	0.81^{ab}	1.4^{c}	2.6^{b}	2.5^{b}

Values in a column not bearing same letters are significantly different. $P<0.05$
Source: Henshaw *et al.,* 2009

Table 17 : Mean scores for the degree of difference from control for sensory properties of *moinmoin* prepared from selected varieties of flour

Variety	Beany flavor	Cohesiveness	Color	Moistness	Mouthfeel	Smoothness	Taste
California Blackeye 5	1.6^{a}	1.3^{a}	1.0^{a}	**2.1^{a}**	**2.1^{a}**	1.5^{ab}	1.7^{a}
Mississippi Silver	2.3^{b}	1.5^{a}	2.0^{b}	**1.6^{a}**	**2.0^{a}**	1.5^{ab}	2.4^{b}
Ife Brown	2.2^{b}	1.4^{a}	2.0^{b}	2.7^{b}	2.4^{b}	1.6^{a}	2.6^{b}
TVX 3236	2.6^{c}	2.3^{b}	2.1^{b}	2.7^{b}	3.4^{c}	2.4^{b}	2.6^{b}
White Acre	2.1^{a}	1.2^{a}	1.1^{a}	2.1^{a}	2.0^{a}	1.2^{a}	1.9^{a}

Source: Henshaw *et al.,* 2009

Vice-Chancellor Sir, based on the combination of data gathered from all the studies on functionality of cowpea flour, a patent was registered, Nigerian registered patent, **RP15148 Henshaw (2003)**. The patent described an appropriate process, selection criteria for variety of cowpea for processing to give flour with the required functionality as a convenient food ingredient, to facilitate the preparation of traditional cowpea products. These in-depth studies have contributed to making cowpea/bean flour a popular food ingredient, being produced by micro and small scale food processing enterprises in Nigeria and thereby increasing the consumption of nutritious cowpeas.

These studies were funded by the NUC – World Bank Academic Staff Development programme who supported my research visit to the University of Georgia, Experiment Station, Griffin, Georgia, USA, and Bean/Cowpea Collaborative Research Support programme (CRSP) Grant of the United States Agency for International Development (USAID).

4.3 Snack Foods

Snack foods are ready-to-eat and convenient stop gap usually consumed to achieve short-term satisfaction of hunger (Tettweiler, 1991). Indigenous snack foods, *robo*, *kulikuli* and *kokoro* prepared from melon seeds, groundnut and maize respectively as shown in Figure 15 were studied**.** The study examined the effect of packaging material and storage condition on the shelf life of the snack foods. Snack foods were packaged in polythene, glass bottles and paper and stored under conditions which simulated those available to retailers and consumers, ambient storage (30^0C – 31^0C), exposed to sunlight and in the dark (closed cupboard).

Development of off-flavour during storage was evaluated on a rating scale, from 1=none to 7= very strong off flavour. Mean scores for off-flavour development were used to calculate estimated shelf life according to the method described by Gacula (1975). *Kokoro, robo* and *kulikuli* packaged in polythene had longer shelf life when stored in the dark than when exposed to sunlight. *Kulikuli* had longest shelf life when packaged in glass bottles. The results are shown in Table 18. These snack foods because of high fat and low moisture content, are best packaged and stored away from light which can catalyse oxidative rancidity and off flavour development (**Henshaw** and Ihedioha, 1992).

In another study, the effect of soyabean supplementation on the chemical and sensory properties of *kokoro*, a maize-based indigenous snack, was investigated. *Kokoro* is a product of a cottage processing in the Imasayi-Iboro areas of Ogun State. It serves as a source of income generation for rural households in the areas. Two processing methods were examined; incorporation of soy flour to wet-milled maize and co-milling of soyabeans and maize. Soyabeans supplementation at levels of 20%, 30% and 40% increased the protein contents of *kokoro* from 7% in 100% maize *kokoro* to 8%, 14% and 17% in soy flour blends and 11%, 14% and 15%, respectively, for co-milling method. *Kokoro* developed a browner and more preferred brown colour with increase in soyabean content. Supplementation up to 20% had no apparent effect on flavour preference for *kokoro* produced by both methods. However, at 40% supplementation, flavour preference for *kokoro* produced by co-milling method was the highest (Figure 16). The co-milling method had a better potential for adoption in a lowly mechanized cottage industry as is the case for kokoro production (**Henshaw** and Craig, 1998).

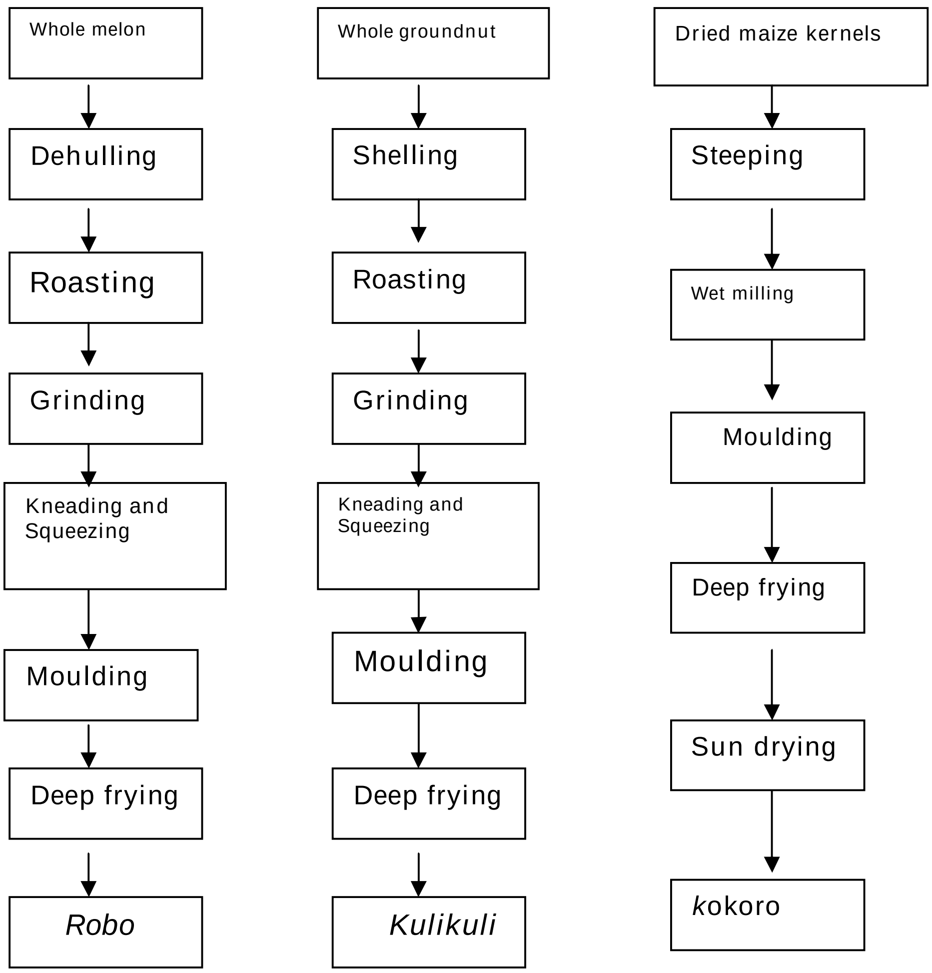


Figure 15: Flow charts for the production of *Robo, kulikuli* and *Kokoro*
Source: Henshaw and Ihedioha, 1992

Table 18 : Estimated shelf life of snack foods

Snack food	Packaging materials	Storage conditions	Estimate shelf-life (ESL) [days]	Range [days]
Kokoro	Paper	Dark	23	8– 38
Kokoro	Paper	A.S.	27	12– 42
Kokoro	Paper	Light	30	15– 55
Kokoro	Polythene	Dark	60	45– 75
Kokoro	Polythene	A.S.	33	18– 48
Kokoro	Polythene	Light	30	15– 45
Robo	Leaf	Dark	30	15– 45
Robo	Leaf	A.S.	23	8– 38
Robo	Leaf	Light	48	33– 63
Robo	Polythene	Dark	40	25– 55
Robo	Polythene	A. S.	33	18–148
Robo	Polythene	Light	23	8– 38
Kulikuli	Polythene	Dark	34	19– 49
Kulikuli	Polythene	A.S.	30	15– 48
Kulikuli	Polythene	Light	27	12– 42
Kulikuli	Glassbottle	Dark	150	135–165
Kulikuli	Glassbottle	A.S.	65	90– 80
Kulikuli	Glassbottle	Light	120	105–135

A.S. – Ambient storage

Source: Henshaw and Ihedioha, 1992

In another study, the effect of soyabean supplementation on the chemical and sensory properties of *kokoro*, a maize-based indigenous snack, was investigated. *Kokoro* is a product of a cottage processing in the Imasayi-Iboro areas of Ogun State. It serves as a source of income generation for rural households in the areas. Two processing methods were examined; incorporation of soy flour to wet-milled maize and co-milling of soyabeans and maize. Soyabeans supplementation at levels of 20%, 30% and 40% increased the protein contents of *kokoro* from 7% in 100% maize *kokoro* to 8%, 14% and 17% in soy flour blends and 11%, 14% and 15%, respectively, for co-milling method. *Kokoro* developed a browner and more preferred brown colour with increase in soyabean content. Supplementation up to 20% had no apparent effect on flavour preference for *kokoro* produced by both methods. However, at 40% supplementation, flavour preference for *kokoro* produced by co-milling method was the highest (Figure 16). The co-milling method had a better potential for adoption in a lowly mechanized cottage industry as is the case for kokoro production (**Henshaw** and Craig, 1998).

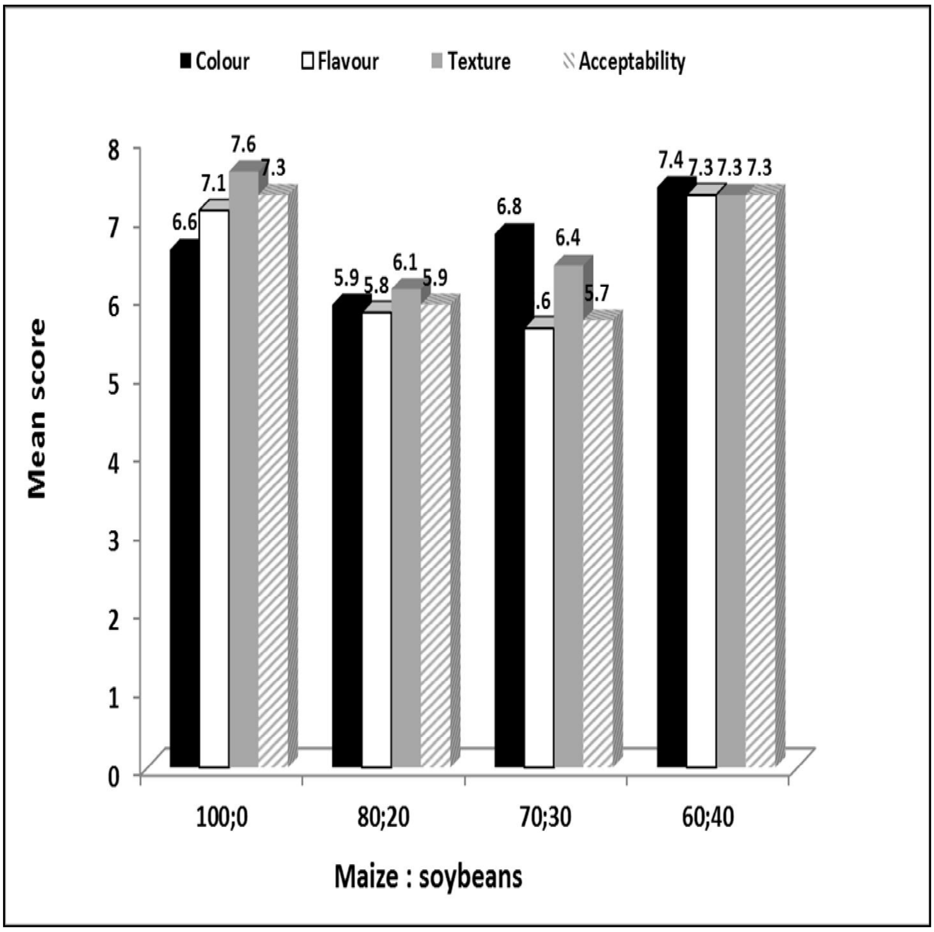


Figure 16: Mean scores for sensory attributes of maize and soy *kokoro* (Co milling method)

Source: Henshaw and Craig, 1998

More studies are on-going to further the development of healthy and nutritious snack foods from different local crops such as sweet potato, plantain, bananas and yam, which in spite of being produced in large quantities, remain grossly underutilized.

4.4 Cashew Nut Utilization

The cashew nut has high nutritional value, contains 40-57% oil, 21% protein contents (Fetuga et al., 1975). Cashew nuts are usually roasted and consumed as such or they are used in confectionery and as dessert nut. Compared to other sources of plant protein such as soyabean and peanut, the food potential of cashew nut are still under exploited. Studies to evaluate the production and functionality of cashew nut protein isolates and concentrates were conducted in order to promote diversified utilization in human foods. Functional properties of proteins are important in the development of new products which can attract consumer acceptance.

Protein isolates and concentrates were obtained from deffated cashew nut powder by two methods; alkaline extraction-isoelectric precipitation method (IP) and alkaline-extraction-methanol precipitation (MP). It was demonstrated that , cashew nut protein isolate (99.8%, protein content), and cashew nut protein concentrate of varying protein contents were obtained from the isoelectric precipitation method , while only protein concentrate was obtained from the methanol precipitation method. (Tables19and20) Ogunwolu *et al.*,

Table 19: Protein yield and content of cashew nut protein fractions produced by Alkaline Extraction – Isoelectric Precipitation (IP) Method

	Ext. Ratio	Ext. pH	Ppt pH	Protein Yield (%)	Protein Content (%)
CNPIP 1	1:5	7.0	3.5	57.83±2.06[f]	44.40±0.10[h]
CNPIP 2	1:5	7.0	4.5	60.60±0.30[e]	63.06±0.95[e]
CNPIP 3	1:5	9.0	3.5	69.30±0.30[d]	68.10±0.20[c]
CNPIP 4	1:5	9.0	4.5	79.50±0.50[c]	78.16±0.35[b]
CNPIP 5	1:10	7.0	3.5	48.20±0.35[g]	50.80±0.30[g]
CNPIP 6	1:10	7.0	4.5	59.10±0.10[f]	61.43±0.25[f]
CNPIP 7	1:10	9.0	3.5	90.60±0.10[b]	66.60±0.40[d]
CNPIP 8	1:10	9.0	4.5	98.90±0.00[a]	99.80±0.10[a]

NOTES: [a, b, c, d, e, f, g, h] means followed by the same alphabets on the same column are not significantly different at $p< 0.05$.
CNPIP: Cashew nut protein-isoelectric point precipitated.
EXT: Extraction
PpT: Precipitation.

Source : Ogunwolu *et al.*, 2010

Table 20: Protein yield and content of cashew nut proteins fractions produced by alkaline extraction-methanol precipita-

	Ext. Ratio	Ext. pH	Meth. Conc.(%)	Protein Yield (%)	Protein Content (%).
CNPMP 1	1:5	7.0	70.0	55.33 ± 0.15^{f}	70.30 ± 0.20^{de}
CNPMP 2	1:5	9.0	70.0	57.90 ± 0.20^{e}	72.30 ± 0.10^{cd}
CNPMP 3	1:10	7.0	70.0	59.33 ± 1.16^{d}	85.70 ± 0.10^{b}
CNPMP 4	1:10	9.0	70.0	88.20 ± 0.10^{a}	89.20 ± 0.10^{a}
CNPMP 5	1:5	7.0	80.0	58.53 ± 0.06^{e}	68.20 ± 0.20^{e}
CNPMP 6	1:5	9.0	80.0	61.70 ± 0.10^{c}	64.00 ± 0.10^{f}
CNPMP 7	1:10	7.0	80.0	52.10 ± 0.17^{g}	72.40 ± 0.10^{cd}
CNPMP 8	1:10	9.0	80.0	63.10 ± 0.17^{b}	74.56 ± 3.86^{cd}

NOTES: $^{a, b, c, d, e, f, g,}$ means followed by the same alphabetic on the column are not significantly different at $p<0.05$.
CNPMP: Cashew nut protein-methanol precipitated.
EXT: Extraction
Meth conc: Methanol concentration

Source: Ogunwolu *et al.*, 2010

Functional properties of cashew nut powder, protein isolate and concentrates were significantly different as given in Table 21. Processing of cashew nut into protein concentrate and isolate led to improved functionality. However, cashew nut protein isolate had higher water and oil absorption capacities, foam capacity and stability than the concentrates and powder, and had stability over a wide range of acidity. The effects of pH on the emlusion activity and stability (Figure17) showed minimum values at the iso electric pH (pH 4). The effect of pH on foam capacity and stability followed similar pattern (Figure18). The functional properties were comparable to those of peanut and soyabean proteins. The results established that protein isolates and concentrates of suitable functional properties could be produced from cashew nut as good source of protein ingredient in food systems (Ogunwolu *et al.,* 2009). Studies are ongoing to utilize cashew nut protein isolate in processing of meat analogue (Texturized vegetable protein).

Table 21: **Some functional properties of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC) and cashew nut protein isolate (CNPI) at their natural pH.**

Functional Properties	DCNP	CNPC	CNPI
WAC (ml/g)	0.81± 0.01[c]	1.74 ± 0.01[b]	2.20 ± 0.01[d]
OAC (ml/g)	2.05 ± 0.02[c]	3.32 ± 0.02[b]	4.42 ± 0.01[d]
EAI (%)	24.6 ± 0.02[d]	13.7 ± 0.02[b]	12.5 ± 0.01[c]
ESI (%)	128 ± 0.03[c]	153 ± 0.03[b]	447 ± 2.00[d]
FC (%)	14.0 ± 2.00[c]	40.0 ± 2.00[b]	45.0 ± 2.00[d]
FS (%)	8.00 ± 2.00[c]	40.0 ± 2.00[b]	55.0 ± 2.00[d]
Bulk Density	0.48 ± 0.02[a]	0.25 ± 0.01[b]	0.31± 0.01[c]
LGC (%)	6.50 ± 3.31[c]	10.0 ± 1.81[b]	13.5 ± 0.01[d]
SOL (%)	75.0 ± 2.00[b]	95.0 ± 1.00[d]	95.0 ± 1.00[d]

Notes: Means followed by the same alphabet on the column are not significantly different at $p < 0.05$.
WAC: Water Absorption Capacity; OAC: Oil Absorption Capacity; EAI: Emulsifying Activity Index; ESI: Emulsion Stability Index; FC: Foam Capacity; FS;
Foam Stability and LGC: Least Gelation Capacity and SOL: Solubility

Source: Ogunwolu *et al.,* 2009

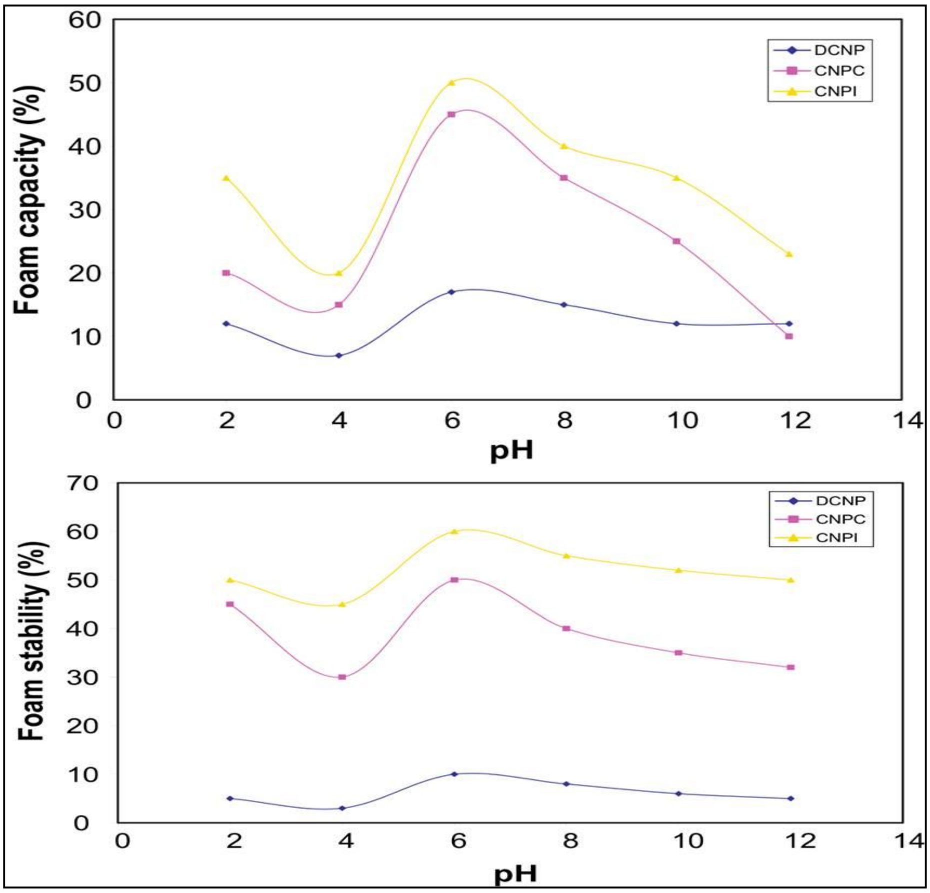


Figure17 :Effect of pH on foam capacity and stability of deffated cashew nut powder (DCNP), Cashew nut protein concentrate (CNPC) and Cashew nut protein isolate (CNPI)

Source: Ogunwolu *et al., 2009*

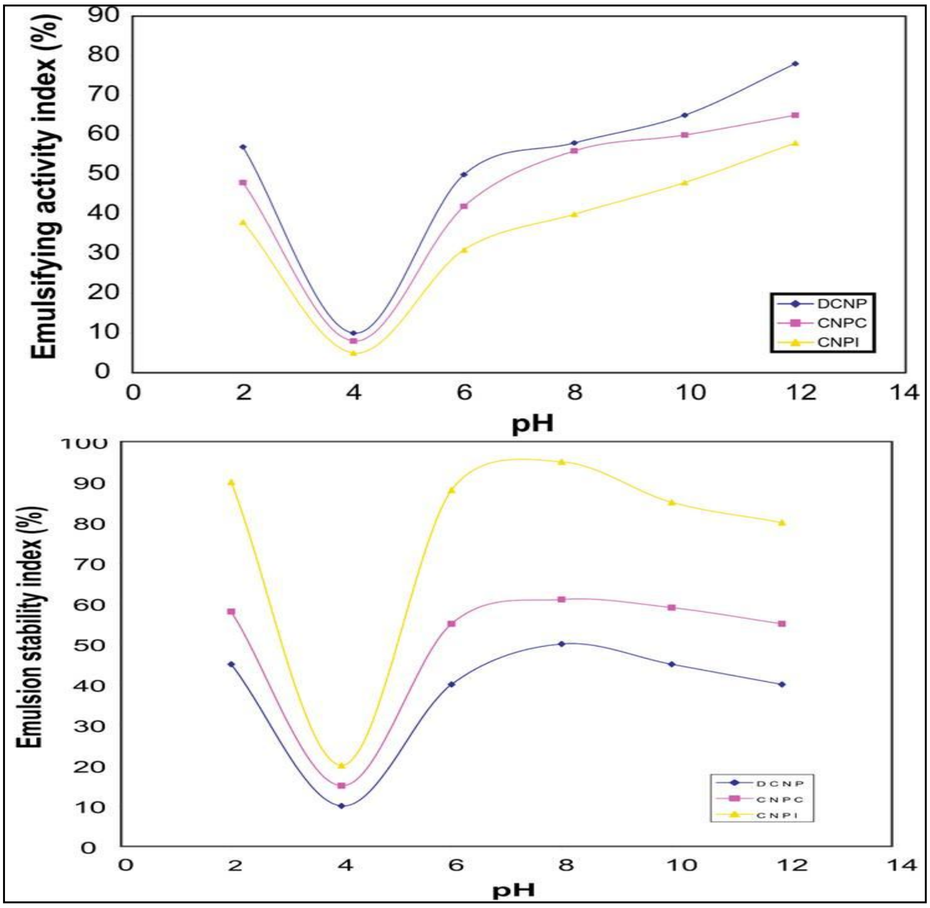


Figure18: Effect of pH on emulsifying activity index and stability of deffated cashew nut powder (DCNP), Cashew nut protein concentrate (CNPC) and Cashew nut protein isolate (CNPI)

Source: Ogunwolu *et al*., 2009

4.4 Yam Processing

Yams (*Dioscorea spp.)* are important root crops for many in sub-Saharan Africa. In some West African countries such as Nigeria, Benin and Ghana, yams are processed into dry yam tubers/slices which can be stored for longer than the raw yam tubers. Dry yam tubers/slices are processed by peeling yam tubers, slicing, parboiling in hot water for 1-3h at 40-60^{o}C), steeping for 24h and sun drying to give traditional product called *gbodo.*

The traditional dry yams/slices (*gbodo*) are usually milled to produce traditional flour (*elubo*), which is prepared by cooking in boiled water to give a viscous smooth paste called *amala*. *Amala* is consumed with soups which contain vegetables, fish, meat and spices. Studies to improve the quality of these traditional products were carried out. The effects of the processing variables such as yam variety, parboiling temperature and time on the quality of gbodo and products were investigated. Babajide *et al.,* (2006) showed that quality of dry yam slices were improved in terms of pasting properties, sensory and microbiological qualities by oven drying method better than traditional sun dried products (Tables 22 and 23).

Table 22: *Pasting properties of sun -dried yam of varied yam thickness, parboiling temperature and time

Sample size (cm)	Sample parboiled at: Temp.	Time.	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (min)	Pasting Temp. (0C)
	(°C)	(h)							
1->2	40°C	1	317.58^{ab}	274.75^{a}	42.83^{e}	422.00^{a}	147.25^{c}	5.35^{b}	61.90^{a}
		2	317.46^{ab}	278.17^{a}	39.29^{ef}	380.25^{b}	102.09^{de}	5.41^{b}	62.73^{a}
		3	311.92^{ab}	242.04^{ab}	69.88^{d}	365.83^{b}	123.79^{cd}	4.97^{b}	63.43^{a}
	50°C	1	242.75^{c}	214.75^{c}	28.00^{efg}	293.29^{d}	78.54^{efg}	5.80^{b}	61.93^{a}
		2	283.67^{b}	272.38^{a}	11.29^{fgh}	338.92^{c}	66.54^{g}	5.51^{b}	64.52^{a}
		3	280.42^{b}	211.29^{c}	69.13^{d}	326.71^{cd}	115.42^{cd}	5.13^{b}	63.35^{a}
	60°C	1	190.17^{d}	177.59^{d}	11.50^{fgh}	228.67^{f}	51.09^{gh}	8.99^{a}	62.40^{a}
		2	121.67^{e}	101.25^{fg}	8.63^{h}	138.08^{g}	36.34^{h}	8.96^{a}	64.13^{a}
		3	95.78^{f}	72.04^{g}	18.08^{fgh}	109.88^{h}	37.84^{h}	8.99^{a}	62.08^{a}
2->3	40°C	1	374.75^{a}	258.42^{ab}	116.34^{c}	388.67^{b}	130.25^{c}	4.56^{b}	62.90^{a}
		2	383.54^{a}	146.34^{e}	237.21^{a}	428.83^{a}	282.50^{a}	4.67^{b}	63.05^{a}
		3	352.46^{a}	183.33^{cd}	169.13^{b}	402.46^{ab}	219.13b	4.63^{b}	62.58^{a}
	50°C	1	338.04^{a}	232.5^{9b}	105.46^{c}	296.75^{d}	64.17^{g}	4.91^{b}	63.55^{a}
		2	327.21^{ab}	291.38^{a}	26.92efg	409.79^{ab}	118.42^{cd}	7.11^{ab}	62.63^{a}
		3	315.59^{ab}	278.08^{a}	34.50^{ef}	375.50^{b}	97.42^{de}	5.88^{b}	63.45^{a}
	60°C	1	270.04^{b}	250.79^{ab}	19.25^{fgh}	338.88^{c}	88.08^{ef}	5.23^{b}	63.10^{a}
		2	235.96^{c}	211.84^{c}	24.13^{efg}	297.17^{d}	85.33^{ef}	5.38^{b}	62.45^{a}
		3	269.55^{b}	192.92^{cd}	76.63^{cd}	349.21^{c}	156.30^{c}	4.43^{b}	63.03^{a}
3->5	40°C	1	321.84^{ab}	241.67^{ab}	80.17^{cd}	347.96^{c}	106.29^{de}	4.74^{b}	62.80^{a}
		2	317.00^{ab}	268.92^{ab}	46.08^{e}	433.33^{a}	164.42^{c}	5.18^{b}	63.70^{a}
		3	241.58^{c}	200.38^{c}	82.41^{cd}	302.29^{d}	101.92^{de}	5.12^{b}	63.26^{a}
	50°C	1	284.38^{b}	258.00^{ab}	22.17^{efg}	320.34^{cd}	62.34^{g}	9.00^{a}	64.48^{a}
		2	290.84^{b}	235.46^{b}	55.38^{de}	340.55^{c}	105.08^{de}	5.33^{b}	62.38^{a}
		3	283.71^{b}	288.71^{a}	55.00^{de}	384.08^{b}	155.38^{c}	5.02^{b}	63.40^{a}
	60°C	1	220.29^{cd}	177.17^{d}	34.63^{ef}	300.21^{d}	123.04^{cd}	9.00^{a}	62.93^{a}
		2	204.67^{d}	174.05^{d}	14.00^{fgh}	225.75^{f}	51.71^{gh}	8.99^{a}	62.93^{a}
		3	209.92^{d}	189.17^{cd}	20.75^{fgh}	249.71^{e}	60.54^{g}	7.62^{ab}	63.18^{a}

*Mean values in a column not followed by the same letter are significantly different at $p<0.05$

Source: Babajide *et al.,* 2006

Table 23:*Pasting properties of oven-dried yam of varied yam thickness, parboiling temperature and time

Sample size (cm)	Sample parboil led at: Temp. Time (°C)	(h)	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (min)	Pasting Temp. (0C)
1->2	0°C	1	327.17[ab]	274.21[a]	52.96[de]	402.30[b]	128.09[c]	5.43[b]	63.15[a]
		2	354.55[a]	298.80[a]	55.75[de]	444.29[a]	145.50[c]	5.20[b]	62.93[a]
		3	322.05[ab]	271.84[a]	43.38[e]	437.00[a]	165.17[c]	8.97[a]	62.58[a]
	50°C	1	308.21[ab]	270.13[a]	38.08[ef]	366.75[bc]	96.63[de]	4.73[b]	62.90[a]
		2	307.17[ab]	219.54[bc]	87.63[cd]	372.17[b]	152.63[c]	4.51[b]	64.15[a]
		3	325.17[ab]	266.42[ab]	58.75[de]	396.09[b]	129.67[c]	4.87[b]	63.50[a]
	60°C	1	218.25[cd]	198.00[c]	17.04[fgh]	255.46[e]	57.46[gh]	9.00[a]	61.93[a]
		2	198.13[d]	172.71[d]	10.88[fgh]	233.50[ef]	60.79[g]	9.00[a]	61.75[a]
		3	144.42[e]	131.00[e]	32.30[ef]	200.17[fg]	70.17[g]	9.00[a]	62.18[a]
2->3	40°C	1	383.46[a]	289.46[a]	94.00[c]	455.42[a]	165.96[c]	4.73[b]	63.05[a]
		2	386.54[a]	304.75[a]	81.79[cd]	466.92[a]	162.17[c]	4.99[b]	63.03[a]
		3	355.92[a]	250.29[ab]	66.13[d]	387.21[b]	136.92[c]	5.02[b]	62.73[a]
	50°C	1	300.33[ab]	221.13[bc]	79.21[cd]	316.08[cd]	94.96[de]	4.65[b]	63.23[a]
		2	355.68[a]	267.33[ab]	88.29[cd]	388.42[b]	121.09[cd]	4.89[b]	63.60[a]
		3	284.13[b]	225.46[bc]	58.67[de]	373.08[b]	147.63[c]	4.81[b]	63.38[a]
	60°C	1	263.96[b]	206.17[c]	57.79[de]	307.42[d]	101.25[de]	4.86[b]	62.65[a]
		2	264.58[b]	222.67[bc]	42.92[e]	334.96[c]	112.29[cd]	5.44[b]	62.33[a]
		3	248.13[bc]	197.13[c]	51.00[de]	309.00[d]	112.50[cd]	5.01[b]	63.15[a]
3->5	40°C	1	344.83[a]	247.17[ab]	101.00[c]	371.42[b]	123.58[cd]	4.28[b]	62.30[a]
		2	342.17[a]	241.17[ab]	97.00[c]	356.67[bc]	115.50[cd]	4.69[b]	63.10[a]
		3	317.50[ab]	248.00[ab]	69.50[d]	375.83[b]	127.83[c]	4.99[b]	63.00[a]
	50°C	1	254.88[bc]	190.17[cd]	64.71[d]	299.92[d]	109.75[de]	4.68[b]	63.00[a]
		2	247.34[bc]	209.54[c]	37.80[ef]	307.08[d]	97.54[de]	5.12[b]	62.35[a]
		3	274.50[b]	220.29[bc]	44.21[e]	312.71[d]	92.42[de]	5.25[b]	63.15[a]
	60°C	1	209.21[d]	176.42[d]	32.79[ef]	245.54[e]	69.13[g]	5.20[b]	64.35[a]
		2	205.13[d]	178.30[d]	19.21[fgh]	243.63[e]	65.59[g]	8.99[a]	62.35[a]
		3	202.63[d]	172.00[d]	12.33[fgh]	226.96[f]	54.96[gh]	8.99[a]	63.08[a]

*Mean values in a column not followed by the same letter are significantly different at $p<0.05$

Source: Babajide *et* al., 2006

In a related study the effects of yam variety on the pasting properties and sensory attributes of traditional dry yam and its products were investigated. Six varieties of white yam *Efuru*, *Abuja*, *Ise-Osi*, *Ijedo*, *Ewura* and *Mumuye*, were processed into dry yam slices. The effects of variety on viscogram patterns of dry yam flour are shown in Figure 19. The results further showed that other yam varieties such as *Ise osi*, *Efuru* and *Abuja* were suitable for dry yam processing in terms of sensory and pasting properties, which were not significantly different from those of *Ijedo*, the commonly used variety for traditional dry yam processing (Babajide *et al*., 2008).

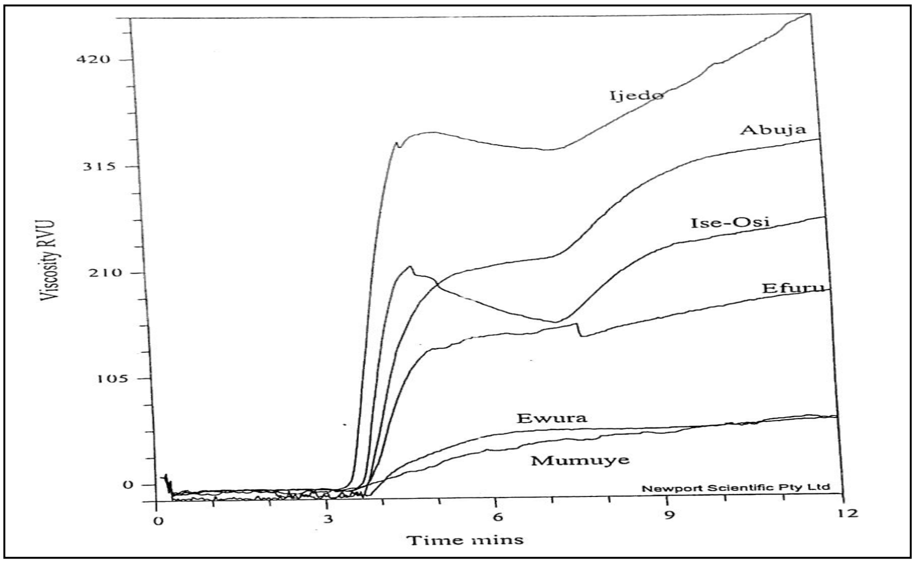


Figure 19: Effect of yam varieties on viscogram patterns of dry yams
SOURCE: Babajide *et al.,* 2008

Table 24: Pasting properties of dry yams made from different

Yam variety	Peak (RVU)	Trough (RVU)	Break (RVU)	Final (RVU)	Setback (RVU)
Efuru	206.0[b]	203.5[c]	3.5[b]	210.9[b]	7.4[d]
Ise-Osi	242.8[b]	158.6[c]	83.2[a]	279.7[b]	121.5[a]
Ijedo	358.0[a]	319.2[a]	38.8[a]	378.2[a]	78.9[b]
Ewura	57.2[c]	57.9[d]	−1.3[b]	75.4[c]	17.5[c]
Mumuye	35.5[d]	38.5[d]	−2.9[b]	55.5[c]	1.0[d]
Abuja	241.3[b]	260.3[b]	−19.1[c]	346.9[a]	85.6[b]

* Mean values of the same superscript letters in a column are not significantly different at $P > 0.05$.
RVU, rapid viscosity unit.

Source: Babajide *et al*., 2008

Studies to further expand utilization of yam beyond traditional processing, explored the use of thermo extrusion processing of yam and legume flour blends. Thermo extrusion processing is an important technique for modification and manufacture of a wide variety of novel foods and food blends.

Expanded snack foods, ready-to-eat cereals and texturized vegetable proteins are manufactured by the high temperature short time cooking, during thermo extrusion. The physical properties and sensory properties of extruded products are generally influenced by a number of process and ingredient variables. These factors include extruder type, screw configuration, feed moisture, temperature profile of the barrel section, screw speed and type of raw material and ingredients. The elevated pressure and high temperature applied during extrusion processing also result in alteration of chemical properties of extruded products, thereby modifying functional properties (Iwe and Ngoddy, 2000).

The effects of extrusion condition on the physiochemical properties of blends of yam and Bambara nut flours were investigated. White yam grits (750µm) and Bambara nut flour (500µm) in a ratio of 4:1 (yam:Bambara) were processed by extrusion cooking. The extrusion parameters were varied; screw speed (50 – 70 rpm), feed moisture (12.5 – 17.5%) and barrel temperature (130 – 150^{o}C). Results showed that expanded products which are nutritious and safe could be manufactured from yam and Bambara blends. This potential can be exploited to promote industrial utilization of yams. (Oluwole *et al.,* 2013).

4.5 Contribution to Capacity Building

Vice Chancellor Sir, in my three decades in Academia and all spent here at FUNAAB, I have been privileged to have been trained and mentored until I blossomed to maturity. I am very grateful to God who has allowed me also to train and mentor several others. Therefore, I cannot omit from this address the contributions to the development of the Food Science and Technology Profession in Nigeria and in particular to the Department of Food Science and Technology here at FUNAAB through human capital development. As one of the pioneer academic staff (indeed the longest serving academic staff in the Department). I have contributed to the training of 8 out of the current 12 academic staff of our Department, and also a number of others in other Departments in the College of Food Science and Human Ecology. All these have also blossomed into distinguished Scholars and academics, and some are already at the Professorial cadre. There are also several other mentees, some of whom are present here today who are distinguished scholars, practitioners of the Food Science profession in various places across the nation and indeed the globe. I believe the job of a Professor remains yet uncompleted without proof of having reproduced himself or herself with professional offspring.

I have also been privileged to contribute to building capacity of upcoming female academics. It is not a subject of debate that cultural and society norms have some “stereotypes” of what is expected of the female gender. In addition, the natural role of childbearing and family care borne by women constitute extra hurdles they have to manage together with career development. However, this is not to present a convenient excuse but rather to highlight the need for gender inclusiveness. Therefore, based on personal experience, by word and deed, I have encouraged their career development and promotion of work - family harmony and balance. I have also been privileged to participate in structured Career development Programme as two-time mentor of the African Women in Agricultural Research and Development (AWARD). I am happy to say that as Dean of the College of Food Science and Human Ecology, since June 2010 till date, more female scholars have been appointed and those on ground have become more visible and given opportunity to use their competencies fully. A good number who were appointed as Heads of Departments, have performed and are performing excellently to the joy of those who support gender equity and mainstreaming, and of course to the consternation of those who hold the view that belonging to the female gender should automatically be reckoned as having inferior cerebral capacity. However, Vice Chancellor Sir, I am happy to tell this audience that under the current administration and indeed previous ones, FUNAAB is fully gender compliant and will continue to remain so. Amen.

5.0 RECOMMENDATIONS

5.1 Ensuring Efficient Post-Harvest System in Nigeria

One of the major contributing factors to high post-harvest losses as observed earlier is the lack of processing avenues and absence of value addition chain. This means that the farm outputs will have to reach the markets without any form of processing, and almost 50% do not arrive in good quality, especially highly perishables such as fruits and vegetables. In order to ensure an efficient post-harvest system, the following recommendations are proposed.

5.1.1 Commodity Value Addition Chain (CVAC). The food processing sector in Nigeria is dominated by large multinationals, whose parent companies are based in foreign countries. They process large tonnage of raw materials into a variety of consumer goods. However, most of their raw materials and ingredients are imported, only a small fraction are sourced locally. There is need to promote expanded utilization of our food raw materials by establishing CVAC. This will require a strengthening of Producer-Processor-Market linkages on community basis. Each community/local government should have value added products (intermediate and fully processed products) from outputs of their agricultural production. This approach will lead to setting up of several SMEs in food processing, with the attendant gains of job creation, reduction in rural-urban migration, improved incomes and livelihoods in many communities.

5.1.2 Ministry of Food Processing.

Today's problems cannot be solved at the same level of consciousness that created them (**Albert Einstein**)

There is enough indication that another agency of government, apart from the ministry of Agriculture, needs to be established to coordinate all aspects of post-harvest technology (storage, processing and preservation). This gap and neglect of several years will partly explain why Nigeria, in spite of abundant resources and potentials, is the largest importer of food in the world. In the same way that funds are provided and mechanisms are put in place to facilitate inputs (improved seeds, fertiliser, loans, etc) into agricultural production, the ministry of Food processing should have mandate to facilitate the availability of required inputs to provide processing facilities for value addition in various communities. It will be really laudable if Mr President can launch a POST HARVEST TECHNOLOGY TRANSFORMATION AGENDA, as an essential compliment to the AGRICULTURAL TRANSFORMATION AGENDA. There is no doubt that with an efficient Post-Harvest system and improvement of enabling infrastructure (roads, transportation and electricity), Nigeria has the capacity to feed herself and have surplus to sell to the world and become a net exporter of food.

5.2 National Research Agenda and Funding

There is a need for Nigeria to have Food Research Agenda that will be pursued with better funding than is presently done. A well articulated and funded research agenda will deliver the necessary capacities for knowledge–based development. Universities and research Institutes should be designated as centres of excellence in food process and product development to provide technical support on improved processing methods, food safety and quality including traceability. Funds must be allocated to address critical gaps in food raw material utilization.

5.3 Changing food habits and choices

Nigerians are the only people in the world who consume large quantities of food commodities, which they neither have agro-ecological conditions to grow nor the technological capacities to process. I tried to imagine why for instance Europeans stick to their food staples based on wheat, potato, peas, fruits and vegetables. I wonder why they do not set up industries worth multimillion dollars to process large quantities of imported raw materials, such as yams, cassava, plantain, cowpeas, as we have done for wheat? What is Nigeria's capacity to produce enough wheat to meet the industries already on ground? In order to ensure sustainable food security and economic growth, a nation must love to eat what it grows or grow what it loves to eat. There is urgent need to revive consumption of locally grown foods and also process and export to other cultures. After all, some smart foreign companies have succeeded in adding consumption of noodles into our food basket. Some 20 years ago noodles were not part of what we eat, but the story is different today.

6.0 CONCLUSIONS

Post-harvest losses of agricultural commodities mean that production resources such as land, water, energy, fertilisers and labour are wasted, which ultimately means reduction in profits to the producers/farmers. The major contributing factors to high post-harvest losses in developing countries including Nigeria are; poor post-harvest handling, inefficient or non-existent value addition chain, inadequate infrastructure such as good roads, transportation channels, and lack of adequate and regular supply of electricity.

It is not enough to merely increase agricultural production, equal provisions and efforts are required to ensure that what is produced get consumed and utilized. In order to guarantee sustainable food security therefore, post-harvest losses must be attacked by developing an integrated post-harvest system that incorporates processing and preservation. This will lead not only to enhanced incomes and **profit** for producers but also to better accessibility and affordability, accruing as **profit** for consumers.

7.0 ACKNOWLEDGEMENTS

I acknowledge first and foremost the almighty God and Father of my Lord and Saviour Jesus Christ, for the story of my life and His grace that has brought me thus far. I give praise to Him for allowing me to see this day and I wish to thank Him for all the people He blessed me with, who have been major or even minor actors in my story.

MY PARENTS: The two wonderful faces of my parents are missing here today, Sir (Chief) Olapade Ajileye Osunkiyesi and Lady (Chief) Mrs. Victoria Ebun Osunkiyesi, both of blessed memory. They were wonderful parents who loved me and nurtured me throughout their entire life. Though they are absent today, I am however grateful that the two of them were alive when I was appointed a Professor in 2008. The critical values of hard work, integrity, discipline and sound character which they taught me by word and deed are key components which contributed to the success story of today. I am grateful for the period of their sojourn here on earth and their memories are precious and live on after them.

I appreciate the love and support of my brother, Engineer Oluwambe Osunkiyesi and his wife Isioma, and my nephew, Oluwafikunmi. God bless you all.

My aunt and her husband, Sir and Lady F. M. Olisa, I appreci-

ate your support and care for me and my family.

The Sabosun family of Odigbo Kingdom, Odigbo, Ondo State. I thank you for your support, even after the demise of my father, for standing as true kinsmen. I appreciate the support of my uncle leading others here today to represent the family.

ALL MY TEACHERS: My school teachers, at the primary level, St. Judes Primary School, Ebute-Meta, Lagos and my secondary school teachers at Queen's School, Apata-ganga, Ibadan. Many of them may have passed on, but I cannot forget the dedication and discipline of my primary and Secondary school teachers in the early 1960s and part of the middle 1970s when I went through these stages of my education. They laboured to train and gave their best to give a total all-round education including moral training. The fear of the class teacher was the beginning of wisdom in those days. I remember today their contributions to my story and express my appreciation.

My academic mentors – at Obafemi Awolowo University, Ile-Ife, where I obtained my first degree and at the University of Strathclyde, Glasgow, where I obtained my M.Sc degree. The late Professor John Hawthorn and others too many to name who taught me the foundations of Food Science. My academic mentors at the University of Ibadan, Ibadan where I obtained my Ph.D degree; Professor O. Oguntunde (of blessed memory), Professor O. Olorunda, Dr. G. E. A Ossai, Professor C.O. Aworh, and my supervisor, Professor J.O. Akingbala. At FUNAAB; Professor E. B. Oguntona, gave me opportunity with his grant from IDRC of a research visit to Cotonou, Benin Republic in 1991. Professor P. A. Okuneye, who was Dean of the College of Agricultural Production and Technology (CAP&T) in 1987, when I got married. Professor Olugbenga Ogunmoyela from whom I learnt the rudiments of University teaching, Professor S.O. Awonorin, who mentored me in a lot of administrative skills as Head of Department and for his support and academic leadership in the college. I appreciate all these distinguished scholars and many others for their support and various contributions to my story.

MY EMPLOYER: In August 1983, I responded to an advertisement I saw in a UK News Journal for appointment of Lecturers for a new University in Nigeria. I had just completed my M.Sc programme and was planning to come back home. My application letter led to a call for job interview, which I attended at National Universities Commission (NUC) office at 180 Tottenham Court road, London in August 1983. The Vice-Chancellor, Professor Chimere Ikoku (of blessed memory) chaired the panel of interviewers. I was given the job and assumed duty as an Assistant Lecture and one of the pioneer staff of the Federal University of Technology Abeokuta, (FUTAB) in December 1983.

I have been in this Institution through all its metamorphosis until maturity. I want to thank God that I also came in at the egg stage and grew with the Institution and metamorphosed into adulthood. I arrived in Abeokuta as a single lady, alone, but today, I am blessed with generations in two camps; biological and professional. I can say like Jacob …… *"I crossed this Jordan with only my staff and now I have become two camps" (Holy Bible, Gen. 32:10b.).* To God be the glory.

I appreciate the current Vice Chancellor, Prof. Olusola Bamdele Oyewole for giving me the privilege to present my Inaugural Lecture, because without his approval, I cannot be here to tell my story. I appreciate his drive for continued excellence and his visionary leadership for FUNAAB to be a world class Institution. I wish him a very successful tenure in office.

I wish to place on record the great contributions of the foundation Vice Chancellor of FUNAAB, Prof. Nuredeen Olorun-Nimbe Adedipe to what this University has become today. On a personal note, I want to appreciate him for his contributions to my career development as a University teacher and researcher. I appreciate the various and significant contributions of all other previous Vice Chancellors of this University;

Professor Julius A. Okojie, Professor Israel F. Adu, Professor Ishola Adamson and the immediate past Vice Chancellor, Professor Oluwafemi Olaiya Balogun, during whose tenure, I was appointed Professor and Dean. I learnt a lot from his exemplary and visionary leadership. I worked with all these highly distinguished scholars and all have made significant contributions to my story of today. I appreciate all of them very sincerely.

ACADEMIC and PROFESSIONAL COLLEAGUES

I am grateful for the support and cordial relationship with all colleagues here at FUNAAB, too many to be listed because I have more friends than enemies. I appreciate all my professional colleagues from other Universities as well as our professional body, the Nigerian Institute of Food Science and Technology.

COLFHEC TEAM - GREAT TEAM

COLFHEC is the number One College of FUNAAB, not only because it is the Vice chancellor's college, but also for being the pacesetters in academic excellence and scholarship.

I appreciate all members of COLFHEC (Academic and Non teaching staff), especially for their confidence in my ability and electing me Dean for two terms. I appreciate the opportunity given to me to lead a great team. It has been a wonderful experience. COLFHEC was established in 2009 and was nurtured under the leadership of an acting Dean, Professor S. O. Awonorin, before I assumed the position of Dean in 2010.

We have set good traditions of healthy collaboration and relationship. We have a model that others have commended and are ready to emulate. I want to appreciate a very dependable, loyal and highly committed Deputy Dean, Dr W.A.O. Afolabi, whose immense contributions and support have facilitated the smooth administration of the College in the last four years. COLFHEC is a great team and we must keep moving in that direction and reject the unhealthy culture of bitterness, rancour and clamouring, but we must continue on the path of professional collaboration for the growth and wellbeing of individuals and development of the College and University. I thank all Heads of Departments who have served and are serving during my tenure in office. Prof. L. O. Sanni, Dr. M. A. Idowu, Dr. Tolu Eni-Olorunda, Dr. (Mrs) S. A. Sanni, Prof. Olusegun Atanda, Dr. (Mrs) A.M. Omemu, Dr. (Mrs) J.M. Babajide, Dr. T.A. Shittu, and Dr. (Mrs) A. Amubode . I appreciate your cooperation and support. I thank all College Committee chairmen and members, chairman COCER, Dr. O. Obadina, Sport coordinators; Dr. T.A. Shittu and Dr. O. P. Sobukola, all College representatives in different University committees, my College protocol coordinator, Dr Abdulrazaq Adebowale. I appreciate all past and present College officers and other administrative staff; Mrs Dawodu, Mrs Elemo and Mrs Enikuomehin, Mrs Adeosun and Mr Adebiyi and the College driver Mr Peter Oyebola. I thank you all for your various contributions and support.

MY FRIENDS: These are the people who love you the way you are, they are always there at high and low times, who offer prayers and even fast when necessary. Mrs. Bola Akintunde, Dr. Moyo Alimi, Mrs R.O. Ogunjimi, Dr. (Mrs) F. A. O. George, Mrs Lara Itabiyi, Rev (Mrs) Toyin Adeyemo, Dr. . (Mrs) Ibiyemi Olayiwola, Prof. (Mrs) A. Uzomah, Mrs Desola Akin-Alade. I thank you for your support and friendship over the years.

CHURCH FAMILIES: I want to appreciate all the brethren of the different fellowships and church where I and my family have enjoyed, over many years support and true Christian love. The Abeokuta Scripture Union fellowship, The Full Gospel Business Men's Fellowship, The Foursquare Gospel Church, Onikolobo zone. I appreciate the support of my Senior pastor and his amiable wife, Rev. and Pastor (Mrs) S.A. Adedina. I am grateful for the spiritual support of Rev and Rev. (Mrs) R.O. Owoade, of the Disciples Gospel Mission, Abeokuta. I appreciate the love and support of Pastor and Mrs Oye Ositelu. I thank God for all these wonderful brethren and many others not listed here.

MENTEES: I want to appreciate all my past and present students and mentees. It is the joy of knowing and seeing that one is adding value to others that gives the greatest fulfilment. I am especially grateful for your contributions to this Inaugural Lecture. I must make special mention of Dr. (Mrs) A. M. Omemu for her contributions in the processing of the manuscript. God bless you all.

HENSHAW FAMILY: I am grateful to all members of the Henshaw Family of Ikot Effangha and Henshaw town, Calabar Cross River state for accepting me without any reservation since I joined the family by marriage . I appreciate the love and support of my parents in law. I thank them for making me feel at home in spite of belonging to another tribe. I appreciate the support of our only surviving parent, grandpa, Mr I.G.D. Henshaw who is ably represented here today. God bless you all.

MY CHILDREN: I thank God for all of you, Utibe Tejumoluwa, Offiong (junior) Bolutife, Immanuel Ifeoluwa and Daniel Adeoluwa. You are all special and I thank you for your love and for making our home joyful and giving us reasons to be proud and thankful as your parents. The Lord will continue to guide you to fulfil your destinies in Him. God bless you for your cooperation and support.

MY HUSBAND AND BEST FRIEND: I want to appreciate the role of my husband and best friend, Mr Offiong Inameti Henshaw, as a major actor in my story today. In the last twenty seven years, he has been a friend, brother, faithful companion and loving husband. His support has been unwavering and consistent, through thick and thin, in bad and good times, we have been there together. Without his support and encouragement the road to building my career would have been extremely difficult to travel. I thank God for his life and appreciate him always.

Finally, Vice chancellor Sir, distinguished ladies and gentlemen, let me **THANK YOU ALL** for leaving many other important things to be here to honour me today. I pray that God will bless and honour and you, and make all the beautiful colours of your life to come forth, in Jesus mighty name. Amen.
Except the Lord builds the house, they labour in vain, who build it, except the Lord keeps the city, the watchman wakes but in vain (Holy Bible, Psalm 127:1).

The Lord has done all these things because it is by HIS grace and mercies that we are who we are. Therefore my song today is:
"All the Glory must be to the LORD
For He is worthy of my praise

No man on earth should give glory to himself
All the Glory must be to the LORD."

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