LADOKE AKINTOLA
UNIVERSITY OF TECHNOLOGY
OGBOMOSO, NIGERIA

19th INAUGURAL Lecture

My World of CEREALS

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ISAAC ADEBAYO ADEYEMI
Professor of Food Science & Technology

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OF TECHNOLOGY
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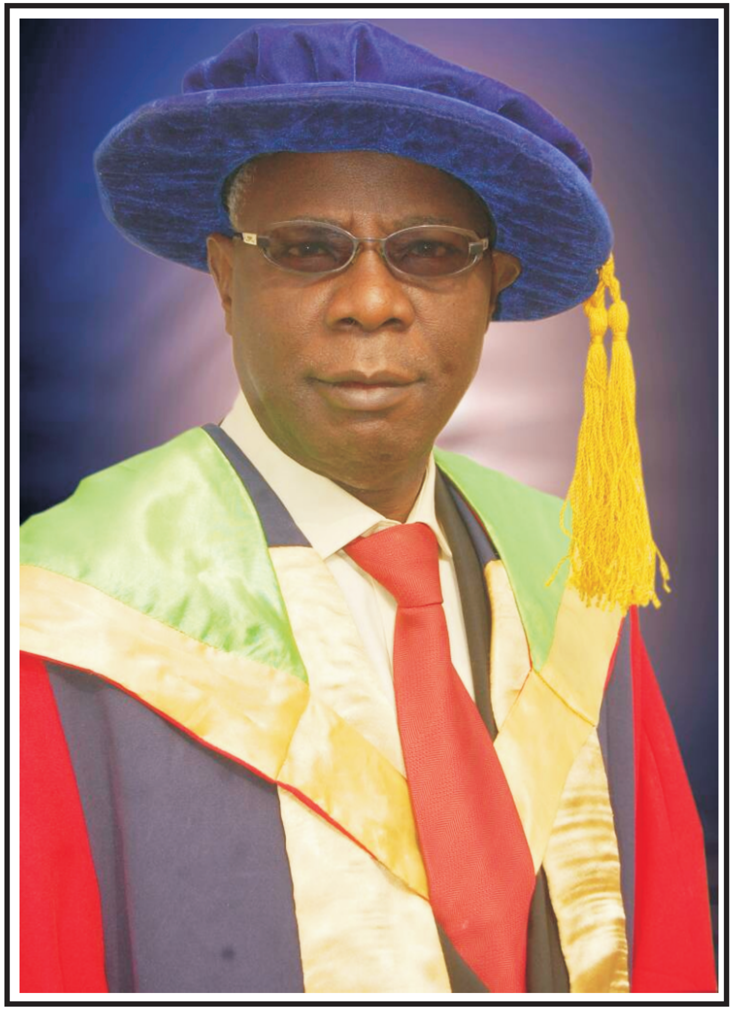

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1.0. INTRODUCTION

As a student of Agriculture with specialization in Agricultural Biochemistry and Nutrition at the University of Ibadan (1969 - 1972), I had little exposure to the emerging field of - Food Science and Technology specialization in Nigeria then. However, as students in the department of Animal Science, we were exposed to some aspects of basic food processing, meat and milk processing. These aroused my interest and some of my colleagues in Food Science and Technology. By the time we were graduating in June 1972, the University of Ibadan in her Faculty of Technology had commenced the Food Technology option. As at that time, the closest to this was the Food Science and Applied Nutrition Unit (now Department of Human Nutrition) in the College of Medicine where I did a one year programme in Human Nutrition which further exposed me to more basic courses in nutrition, food science/technology, nutritional biochemistry, among others.

The one year programme gave me the opportunity of coming in contact and to work closely with two of my academic mentors, Professor (Mrs.) Bola Osifo, an international figure in nutritional biochemistry, and Professor Edward Banigo, who had just returned from the University of Leeds then where he did his Ph.D. in Food Science with his research on Ogi under the supervision of Dr. H. G. Muller (of blessed memory). He, i.e. Professor Banigo, eventually became the Vice-Chancellor of Rivers State University of Science and Technology (RUST), Port-Harcourt. I had the opportunity of carrying out my dissertation on Ogi processing under his supervision. The dissertation was titled: ***"A Comparative Study of the Commercial Practice of Traditional Ogi Manufacture Using High Lysine Corn (HLC) and Normal Corn".***

This exposure fully aroused my interest in cereal processing. After the Diploma Programme, I secured a job in the Unit as a Research Assistant, a position I retained for one year (1973 - 1974). I worked closely with Professor (Mrs.) Bola Osifo, who played a real mentorship role and almost diverted me into Nutritional Biochemistry for my Ph.D. work. I wangled my way through with the convincing evidence of my interest in Food Science with option in cereal chemistry and processing.

In 1974, I was a recipient of the Nigerian Federal Government Scholarship Award for my Ph.D. in Food Science at the University of Leeds, England under the supervision of Dr. H. G. Muller at the recommendation of Professor (then Dr.) Banigo, whom Dr. Muller held in high esteem being amongst his first set of Ph.D. students and probably his first student at that level. This marked my foray into the field of cereal science and technology.

1.1. Commencement of Active Research

In the course of my application to the University of Leeds, as the convention was, and still is, the submission of a research proposal. I, therefore, submitted a research proposal on composite flour which was the focus for developing and developed countries with the encouragement of the Food and Agriculture Organization (FAO). To my dismay, the proposal was rejected outright by Dr. Muller who then gave me two options to pick one. Either I work on ogi (a continuation of Professor Banigo's work) or the Zeleny Sedimentation Test, a rapid wheat flour quality evaluation. I preferred the latter.

1.2. Scope of the Inaugural Lecture

At the take-off of the University, Oyo State University of Technology (OSUTECH) (now Ladoke Akintola University of Technology - LAUTECH), Ogbomoso in 1990, I was among the first four Professors formally appointed having attained the position of Reader (Associate Professor) at the Obafemi Awolowo University (OAU), Ile - Ife in 1990. My Ph.D. research work placed me in the right position on getting to the then University of Ife, Ile-Ife, in 1978, as I found in place a well-equipped cereal laboratory and bakery. These were donated by the Dutch Government and managed for a couple of years by two Dutch Scientists - Wouderman and Nout. The laboratory was one of the best cereal laboratories in Nigeria. The facilities in the cereal laboratory and complimentary facilities in the Department, especially the food processing laboratory, and other functional facilities in the Department of Chemical Engineering, enabled me to plan active research activities in cereal processing. These involved my undergraduate and postgraduate (mainly at Masters level) students. I had access to the laboratories in OAU after my movement to LAUTECH in 1991. This enabled me to continue with my publications in the field of cereal processing until around 2003 with three chapters in a book, thirty-five journal articles and over ten papers in Conference Proceedings.

Therefore, for the purpose of this lecture, I have refrained from considering my publications after 2004 which consisted of works in other areas of Food Science and Technology or non - cereal commodities. These post 2004 publications, I believe, will form contents of inaugural lectures of my thirteen Ph.D. graduates with nine (9) and four (4) from the Ladoke Akintola University of Technology, Ogbomoso and the Federal University of Technology, Akure, respectively. A case in point is that of Professor Michael Oluwafisayo Ologunde who gave the first inaugural lecture in the Department of Food Science and Engineering and the 16th in the University (LAUTECH) on Thursday, July 14th, 2016 titled: **"From Infancy to Adulthood: A nexus for Healthy, Safe, Nutritious and Wholesome Food".**

There is time for everything in life and, therefore, I consider this lecture as fulfilling all righteousness from the academic perspectives. Very soon, God willing, I would be presenting my valedictory lecture which would address in full my academic career within the Nigerian education landscape. I hereby present my research inputs in the world of cereals between 1978 and 2004 and relate these to current developments in the field, globally and nationally.

1.3 CEREALS: DEFINITION, CLASSIFICATION AND IMPORTANCE TO MAN

A cereal is any grass, i.e. gramineae family that is cultivated for the edible components of its grain. Botanically, it is a type of fruit called a caryopsis which is composed of the endosperm, germ and bran (Figure 1). The word cereal is derived from Ceres, the Roman goddess of harvest and agriculture (Wikipedia). Cereal grains are grown in greater quantities and provide more food energy worldwide than any other type of crop. In their natural form, as in whole grain, cereals are a rich source of vitamins, minerals, carbohydrates, fats, oils, and protein.

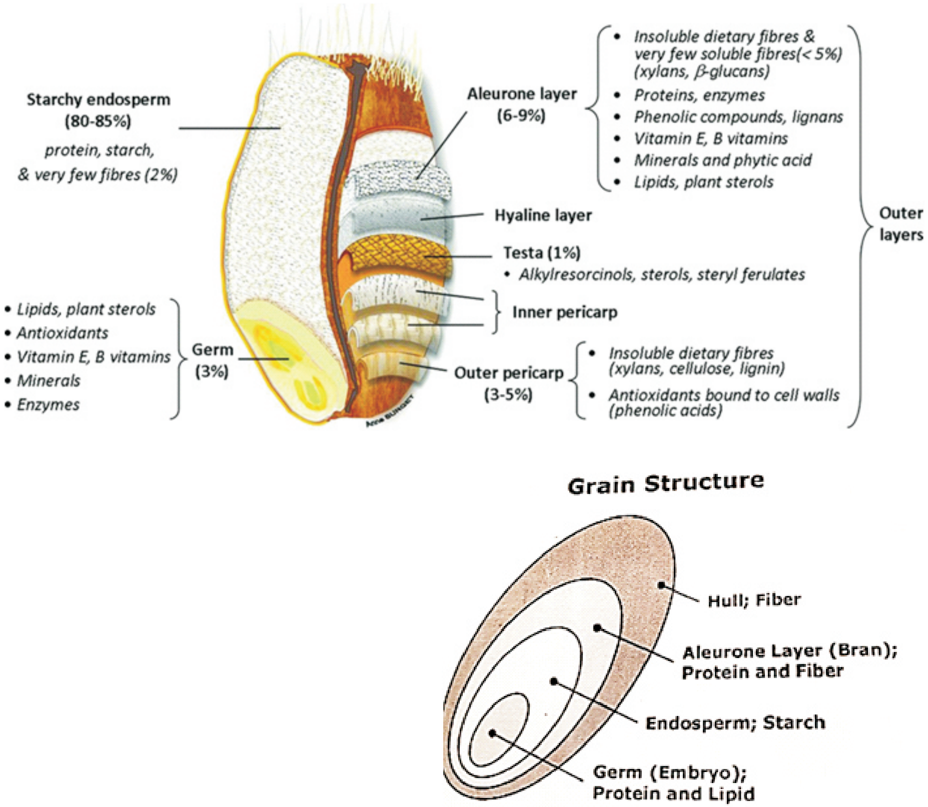


Figure 1: Structure of a Cereal Grain

(Source: https://www.researchgate.net/figure/284181419_fig1_ Figure-1-Wheat-grain-structure-Adapted-from-Surget-Barron-2005 -and-Brouns-etal)

Cereals are classified broadly into two main groups. i.e. tropical and temperate. Tropical cereals include maize (corn), rice, sorghum, millet and teff, the smallest grain widely grown in Ethiopia. Temperate cereals are mainly wheat, barley, oat, rye and triticale (a man-made cereal, a cross between wheat and rye).

Cereals, globally, serve as food, feed and industrial raw materials. They are processed into various products depending on the level of technology and the specific cereal. Some of the products from cereals include baked goods, breakfast cereals, fermented products such as ogi, flour - based products such as noodles, pasta, alcoholic and non-alcoholic drinks, snacks, etc. The nutritional benefits of cereals are as indicated in Plate 1.

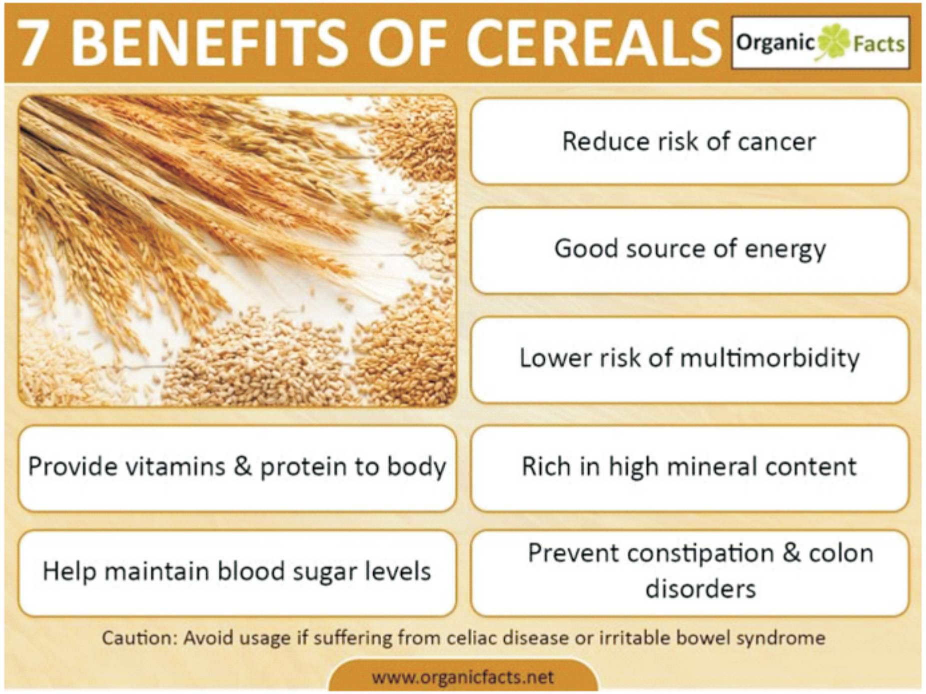


Plate 1: Health benefits of cereals
(Source: https://www.organicfacts.net/health-benefits/cereal)

The brewing industry relies mainly on barley, maize and or sorghum. Industrial products, especially from maize, include starches (modified and native), syrup and its bye products, such as alcohol.

That cereals are excellent sources of various food and industrial products are exemplified with the industrial potentials of maize (Figure 2).

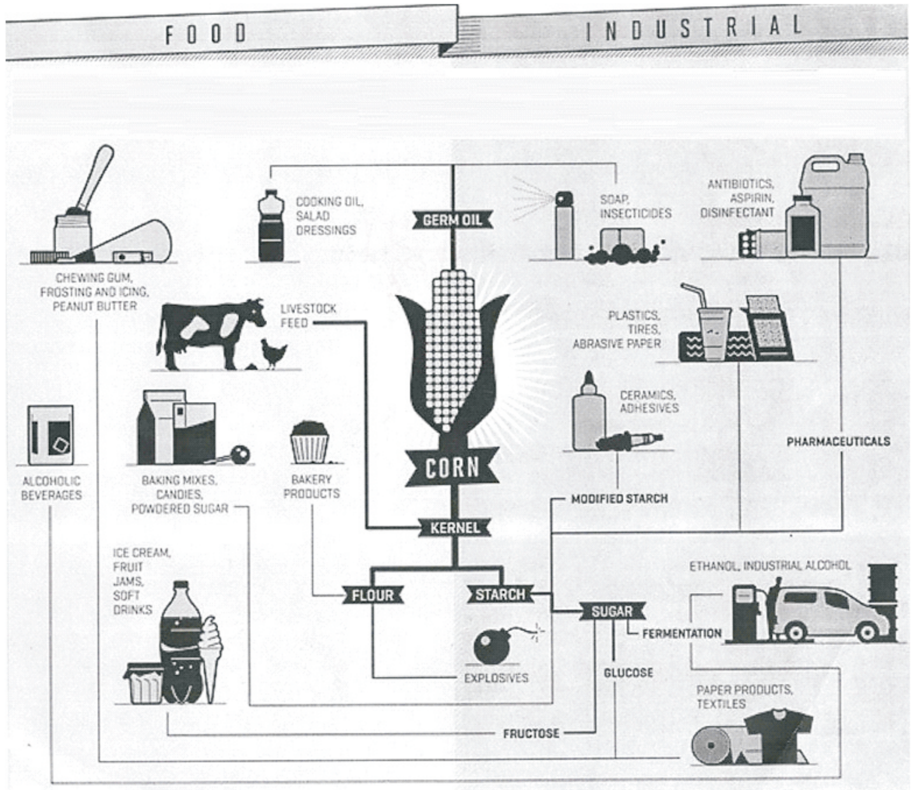


Figure 2: Food and Industrial Potentials of Maize

1.4 My Research Trust

My research trust and contributions as reflected in my publications are presented under the following sub-headings:

i. wheat quality evaluation and composite flour;
ii. maize quality, ogi and agidi manufacture;
iii. enhanced utilization of fruits;
iv. complimentary/weaning food manufacture;
v. kunun zaki; and
vi. rice quality and processing.

2.0 ZELENY SEDIMENTATION TEST, WHEAT PROTEIN FIBRILS AND THE CONCEPT OF FLOUR QUALITY

My Ph.D. thesis titled ***"A Study of the Zeleny Sedimentation Test"*** investigated the mechanism of the Zeleny test for wheat flour quality evaluation. The test was developed by Lawrence Zeleny (1947) in an attempt to find a rapid, simple and accurate test to evaluate bread making quality of flour.

2.1 The Zeleny Test

The standard Zeleny test is based on the modification by Pinckney *et al.* (1957) which involves shaking 3.2 g of flour with 50 ml of distilled water containing some bromophenol blue in a 100 ml measuring cylinder ("reagent A"). Then, 25 ml of an aqueous solution of lactic acid containing some isopropanol is added ("reagent" B). This mixture is now shaken and allowed to settle. After 5 min., the sedimentation volume is read in milliliters (ml). This is referred to as the Zeleny value. Strong flour gives a high Zeleny value of about 50 ml, while weak flour gives about 20 ml (Plate 2).Value could range from about 3 ml for very weak wheat and up to 70 ml for very strong wheat.

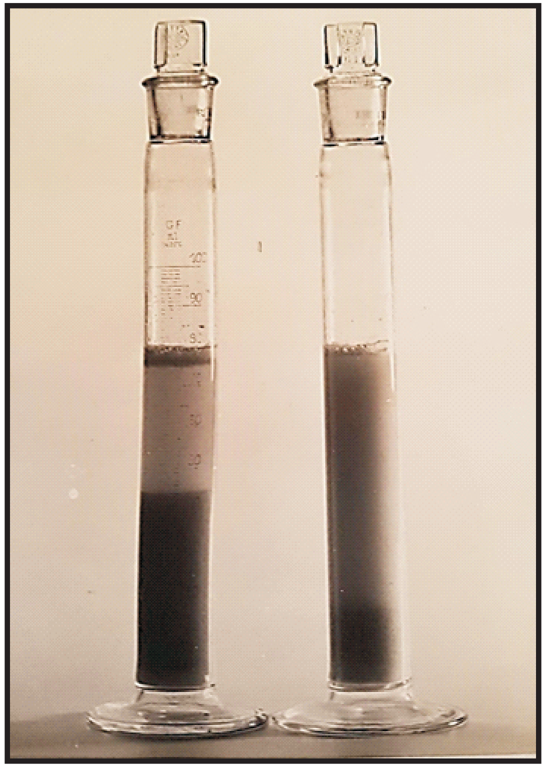


Plate 2: Zeleny test on strong flour (left) and weak flour (right)

2.2 The Mechanism of the Zeleny Test:

2.2.1 Swelling of gluten and flocculation theories

An attempt was made in 1947 to explain the mechanism of the test on the basis of gluten swelling in acid since previous reports had indicated that there was a difference in the swelling characteristics of strong and weak flour glutens in dilute acids (Wood, 1907-1908; Upson and Calvin, 1915; Sharp and Gortner, 1923).

Cawley *et al.* (1961) drew attention to the starch component and suggested that the test depended on an interaction between starch and gluten. They observed that starch alone gave little sediment and the amount of starch present had little effect on either rate of settling or the Zeleny value. Kitterman and Barmore (1969) found 60 - 80% of the total protein dissolved in the reagent while less than 40% of the total protein was insoluble and exhibited swelling properties.

Subsequent study by Frazier *et al*. (1969) showed that the Zeleny value was largely due to flocculation of flour particles and not primarily to gluten swelling. It was established that flour particles settled independently in reagent A, although a few aggregates were present while in a combination of reagents A and B, the particles aggregated into large flocs with the large cell clusters showing the greatest degree of flocculation.

2.3 Protein Fibrils, Zeleny Test and Flocculation Theory

Bernardin and Kasarda (1973) discovered that when a drop of water was placed directly upon a thin wheat endosperm section, an explosive reaction occurred with the wheat kernel transferring the entire contents of endosperm cells to the aqueous phase whenever the cell wall was broken. Simultaneously, fibrils of protein streamed rapidly into the surrounding solution. Fibril formation was very rapid requiring less than 0.05 s. These initial fibrils quickly developed into a linked network as more streamed from the cell with starch granules adhering to the surface of the fibrils. The network formation of the protein fibrils was found to be restricted by high flour concentration or any physical obstruction such as covering the flour particles on the slide with a cover slip. Once formed, the fibrils were very slow to dissolve in water and would persist for several hours. Triticale and rye formed fewer fibrils than wheat, while no tendency to fibril formation was observed in endosperm sections of maize, rice or barley.

The exploratory study on the involvement of protein fibrils in the flocculation mechanism of the Zeleny test was carried out by Muller and Bernardin (1975) who observed that protein fibrils produced when flour particles were irrigated with reagent A or B on a microscope slide or isolated from the floc were responsible for bridging.

2.3.1 Protein fibrils and the mechanism of the Zeleny sedimentation test

In the quantitative estimation of fibrillar particles in water on a microscope slide (Plates 3 and 4) and from the Zeleny floc (Plate 5). Adeyemi and Muller (1975) showed that sedimentation value and, hence, bread baking performance of the flour was:

i. inversely proportional to the number of fibrillar particles apparent in water; and
ii. directly proportional to the number of fibrillar particles in the floc.

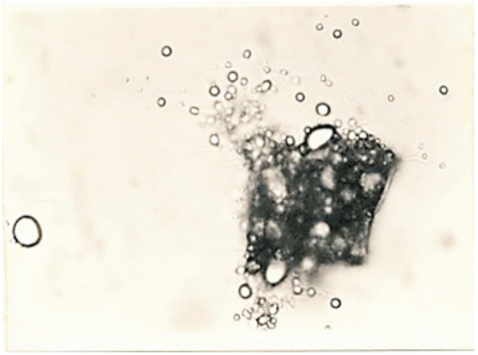


Plate 3: Fibrillar particle from irrigated flour particles on a microscope slide (Adeyemi, 1978)

Plate 4: Electronmicrograph of protein fibrils (Adeyemi, 1978)

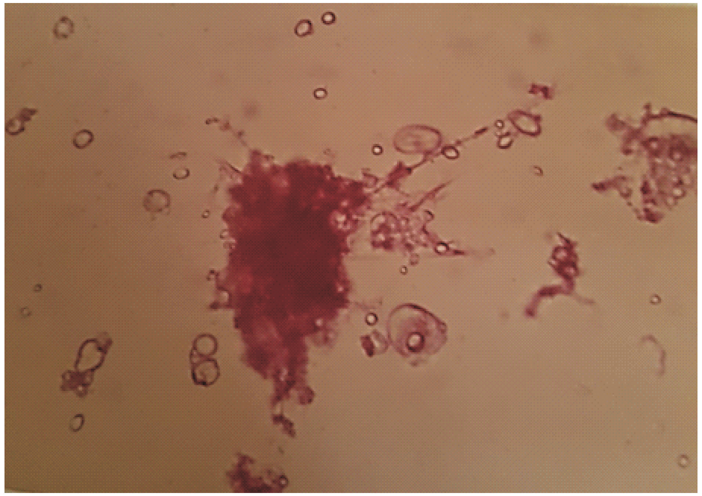


Plate 5: Fibrillar particle isolated from the Zeleny floc

The fact that the sedimentation value was directly proportional to the percentage of fibrillar particles in the floc appeared to bear out the observation of Muller and Bernardin (1975) that floc formation was due to fibrillar interaction. It is, of course, unknown whether fibril composition or interaction is the same in Zeleny floc as in water. Further observations showed that Zeleny reagent B caused extensive rupture of flour endosperm cells resulting in a significant increase in the number of fibrillar particles.

The percentage of apparently broken cells and that of the fibrillar particles approximately doubled. This further confirmed the importance of fibril interaction in the Zeleny test. Furthermore, it is interesting to note that not all cells are ruptured (Plates 6a and b). One would imagine that if a sedimentation liquid could be used which ruptured all endosperm cells, the test would be more reproducible and the effect of milling prior to the test would presumably lose its importance.

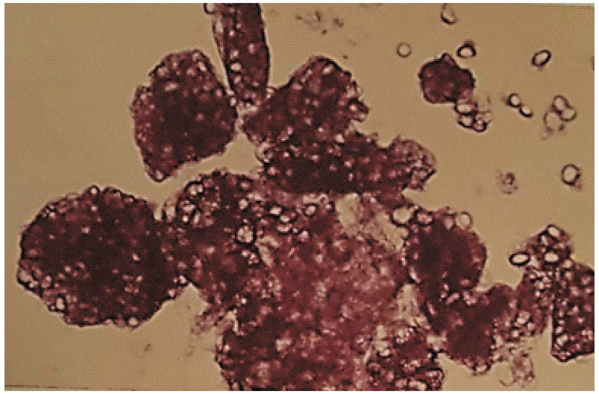


Plate 6a: Flour particles irrigated with Zeleny reagent A on a slide

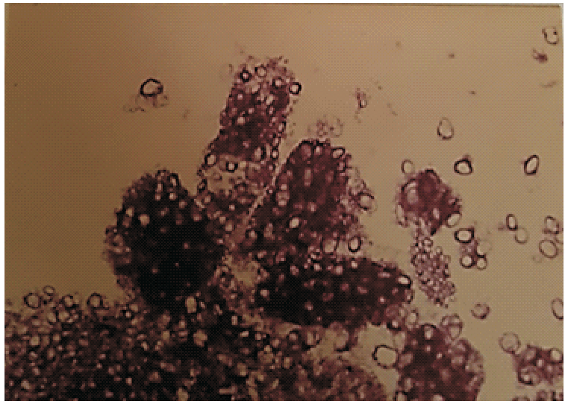
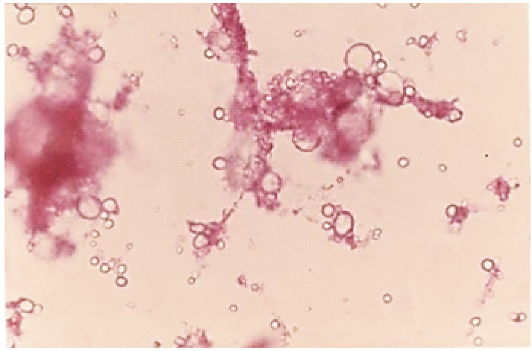


Plate 6b: Flour particles irrigation with Zeleny reagent B

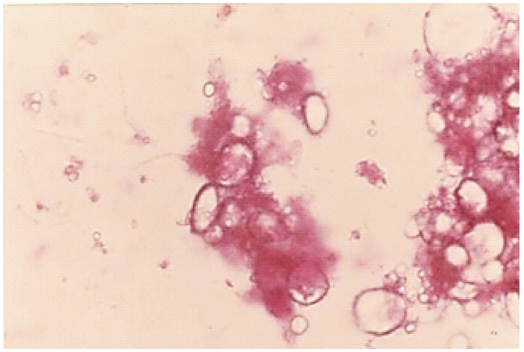
2.3.2 Protein fibrils, disulphide cleaving reagents and Zeleny test

The Zeleny test performed with disulphide cleaving reagents (sodium sulphite, L-cysteine, 2-mercaptoethanol, thioglycolic acid or reduced glutathione) in reagent A showed a decrease in the sediment value with increasing concentration of each of the cleaving reagents. Furthermore, a decrease in the sediment volume was accompanied by an increase in the weight of flour particles suspended in the supernatant due to a breakdown of the floc. The greatest weight of particles recovered from the supernatant occurred in the presence of sulphite, which was consistent with the finding that this reagent had the most pronounced effect in reducing sediment volume (Adeyemi, 1978).

Quantitative estimation of the percentage of fibrillar particles at the end of the Zeleny test performed with two different concentrations of mercaptoethanol in reagent A showed a reduction in the sediment volume and fibrillar particles in the floc. Furthermore, the fibril structure was adversely affected by the cleaving reagent (Plates 7a & b).



(a)



(b)

Plates 7 a & b: Fibrillar particles isolated from the sediment after a Zeleny test performed with 0.025% sodium sulphite in reagent A

These, along with other studies, are evidences that flocculation mechanism of the Zeleny test was due to fibrillar interactions and the flour endosperm particles.

2.3.3 Protein fibrils and Zeleny sedimentation test: recent developments

Studies as reviewed above were conducted and published prior to 1980. Subsequent studies by Evers *et al.* (1990) found an inverse relationship between particle concentration and the proportion of particles producing fibrils. This is a further confirmation of our findings that the ease of fibril formation depends on flour concentration which would also affect objective estimation of fibrils (Adeyemi and Muller, 1979). However, the workers did not find any evidence for the involvement of spontaneously formed fibrils in the floc formation in sedimentation tests for flour quality (Evers *et al.*, 1990).

One of the drawbacks of the Zeleny sedimentation test is lack of reproducibility due to the type of mill or milling technique and the manual steps involved in the procedure. Meanwhile, there is currently a commercialized set up that comprises of a mill and an instrument, the Sedimat and shaker (Plate 8) which ensures consistency and accuracy of the test.

Plate 8: Brabender laboratory mill, sedimat and shaker
(Source: http://www.cwbrabender.com/Sedimat-new)

Zeleny test, which has remained one of the simple and cheap methods of wheat quality evaluation, has been adopted in most countries for commercial and grading purposes (Indian Standard1993; Hruskova and Famera, 2003; ISO, 2017). Furthermore, Reeves *et al.* (1979) have demonstrated the potential of the test for predicting the malting quality of barley based on the flocculation mechanism of the test.

3.0 COMPOSITE FLOUR TECHNOLOGY AND BAKED GOODS

3.1 Composite Flour and Its Perspectives in the Baking Industry

Composite flour can be defined as a mixture of non - wheat flours, with or without addition of wheat flour. Composite flour could therefore be one with 100% non - wheat flour or that containing 60 - 70% wheat flour. The non - wheat flour sources are mainly roots and tubers, non - wheat cereals (maize, rice, sorghum and millet) and cereal - like grains (e.g. amaranth). A protein fortifier is the incorporation of soy flour or any other high protein legume or oil seed.

Baking of bread from a combination of two or more flours dates back to the Biblical period: ***"Also take for yourself wheat, barley, beans, lentils, millet and spelt; put them into one vessel and make bread of them for yourself .... During the numbers of days that you lie on your side, three hundred and ninety days, you shall eat it" (Ezekiel 4:9).***

Internationally, it is the FAO that championed research, in the early sixties, on composite flour development and utilization. The major objective of the intervention was to reduce wheat import bills of developing countries by stimulating local production and processing of non - wheat flour(s) to be incorporated into wheat flour (FAO, 1973).

I will at this stage highlight my input to composite flour technology before evaluating the progress of composite flour technology in Nigeria.

3.2 Composite Flour Technology: My Contributions

I gained better insight into composite flour technology at the Institute of Cereals, Flour and Bread, Wageningen, The Netherlands where, for three months, I was on the Dutch fellowship. The Institute happens to be one of the world's leading research institutes on wheat, baked goods and composite flour technology. I have investigated, with my students and other researchers, the use of non - wheat flours such as cocoyam flour, maize flour, amaranth flour and, cassava flour and starch in baked products.

3.2.1 Cocoyam flour and starch for biscuit and cake manufacture

In our initial study on composite flour, the potentials of cocoyam flour and starch were evaluated for biscuit and cake making (Adeyemi and Omolayo, 1984). Biscuits were prepared using sheeting and depositing (pipping) methods. Biscuit samples prepared by the sheeting method were made from either 100% biscuit flour or mixture of wheat flour and 20%, 40%, 60% and 80% cocoyam flour. Biscuits from 100% cocoyam or cassava starch were made by use of the depositing method. For cake making, the sugar - fat batter method was used with either cocoyam flour or starch. Except for the flour mixture with 80% substitution, the height and diameter of all samples containing cocoyam flour compared well with that baked from 100% wheat flour, which was the reference sample.

Penetrometer readings showed that all samples containing cocoyam flour were softer than the reference sample, the values being 0.28 mm/sec and 0.15 mm/sec for 40% substitution and reference samples, respectively. Result from the taste panel evaluation showed that acceptable biscuit could be produced with up to 60% cocoyam flour substitution without much adverse effect on the overall quality and acceptability of the product. Previous workers have reported the manufacture of acceptable biscuits with up to 55% flour substitution with either barley, millet, corn or sorghum flour (Tsen, 1976; Badi and Hoseney, 1976, 1978).

Acceptability of cocoyam biscuit and cake
Our findings showed that a higher percentage of the panelists liked biscuit made from cassava starch than that made from cocoyam starch. However, more than 70% of the panelists found "cocoyam biscuit" acceptable, while only 23% did not like the product. It was inferred from the questionnaire that about 50% of the panelists would buy the "cocoyam biscuit" if offered for sale. Furthermore, about 90% of the latter group would still buy the product if they knew that it contained cocoyam starch, though most of them were not used to eating cocoyam. That biscuits could be produced from 100% cassava starch had been demonstrated by earlier workers (Kim and DeRuiter, 1969; Adeyemi, 1980), depending on the method of manufacture.

Statistical analysis ($p<0.05$) of taste panel results of cake samples showed that 20% cocoyam starch substitution was significantly superior to the other samples, while 0%, 40% and 60% starch substitutions were within the acceptable range. While sample from 80% cocoyam starch substitution was found unacceptable, only the sample with 20% substitution was acceptable of all the cocoyam flour substitutions.

Cake samples prepared from 40% and 60% cocoyam flour substitutions were scored low by the panelists for textural quality. This could be due to the particle size of the flour which was more granular than that of starch. It would appear therefore that to produce acceptable cake, a further reduction in the particle size of cocoyam flour would be necessary. This may be achieved by the use of roller mills. The results obtained showed that acceptable cakes could be produced using between 20% and 60% cocoyam flour or starch. The results are comparable to those of other workers who used banana flour, wheat or cassava starch (Rodriguez - Soza *et al.,* 1977; Dubois, 1959). It was observed in the course of the study that cocoyam starch retards staling of cake.

3.2.2 Amaranth flour in baked products
The investigations on amaranth *(Amaranthus cruentus L.*) included an evaluation of the milling, chemical composition and utilization of the resultant flours for baking purposes (Adeyemi *et al.,* 1992, 1994). For the purpose of this lecture, quality and staling rate of bread and cake samples containing amaranth flour are discussed.

Staling rate studies indicated that staling was much faster in composite bread samples than that baked from 100% wheat flour (Figure 3). It is apparent that wheat - amaranth mix had identical staling properties to those of wheat - corn or wheat - cassava starch (mixes). The magnitude of the changes in freshness value depends on the type of non - wheat flour, which could be related to its respective retrogradation result. There was a reduction in specific volume of bread with the addition of 30% amaranth flour. Reductions in quality factors of

composite bread are consistent with values reported in literature, especially with wheat flour substitutions above 10% level (Sanchez - Marroquin *et al*., 1985; DeRuiter, 1978).

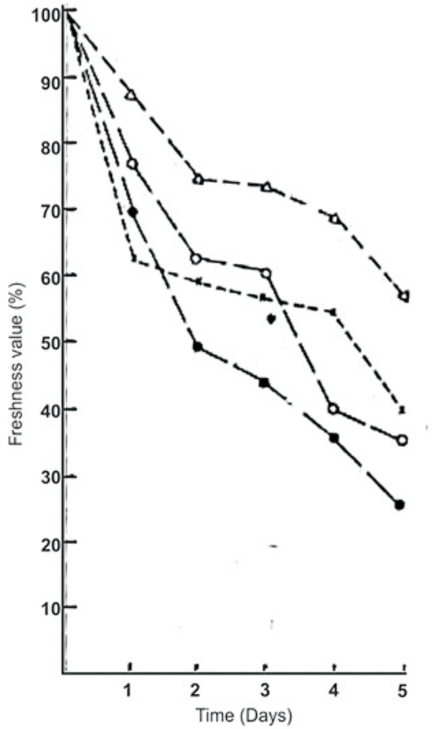


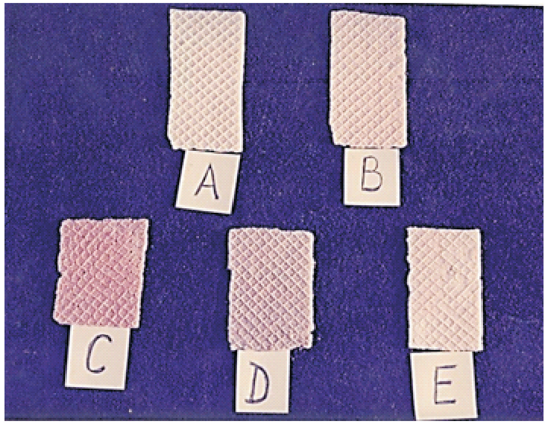
Figure 3: Staling rate of bread samples from wheat and composite flour(▲- - -▲) wheat-corn flour (o--o), wheat-amaranth flour (x--x) and wheat-cassava starch (●–●)

Taste panel scores showed that, except for colour, the values obtained for composite bread containing amaranth flour (65.08) are comparable to those of cassava starch (66.63) or corn flour (66.74). The colour was more of a reflection of the variety of amaranth grain used in this study, which is the popular variety grown in most parts of Nigeria. This would, therefore, indicate the need for the introduction of exotic and improved varieties that would produce lighter and better flour colour. Cake quality and acceptability were found to depend on the level of damaged starch, which could be a reflection of the particle size of the flour which might have contributed to a better internal structure.

3.2.3 Wafer Manufacture from Non - Wheat Flours

Wafers are specialized type of biscuits conventionally baked between pairs of heated metal plates from wheat flour batter. The sheets so formed are typically thin but may bear intricate surface patterns with deep relief. Wafers which are found in biscuit markets are usually formed as large flat sheets which are subsequently cream sandwiched or chocolate enrobed, before cutting. However, wafer variants include cone shapes that are used to hold ice cream, and various rolled and folded forms. The rolled and folded wafers require recipes that are richer in terms of sugar, fat and egg allowing manipulation and rolling immediately after baking and before cooling.

Bamigbade (1990), one of my MSc students, evaluated the suitability of non-wheat flours or starch (cocoyam, green banana and breadfruit) for the manufacture of wafers. Detailed chemical and physical properties of wheat, cocoyam, green banana and breadfruit flours and cocoyam starch were reported. For the purpose of this lecture, I have made use of results reported on the sensory evaluation of wafers manufactured on industrial scale at PeeBee Industries Limited (Manufacturer of Waffel Roll Biscuits), Osogbo. Plate 9 shows the manufactured wafers from wheat flour, cocoyam starch or flour, breadfruit flour and green banana flour.



A - Cocoyam starch wafer
B - Cocoyam flour wafer
C - Breadfruit flour wafer
D - Banana flour wafer
E - Wheat flour wafer

Plate 9: Wafers from composite flours (non - wheat flours)

Results from the study showed that:

i. there was a significant difference in the appearance of the wafer samples with cocoyam starch wafer being significantly different from other wafer samples. This might be due to its bold reeding (pattern made on wafer by the baking plate) and its shiny appearance.

ii. the wafers were not significantly different in internal structure and aroma

iii. wheat and cocoyam starch wafers were the crispiest products, followed closely by cocoyam flour, banana and lastly the breadfruit wafer. Considering the eating quality, banana wafer was significantly different from others which probably is due to its light and spongy nature as well as inherent banana flavour (Simmonds, 1966; Nagy and Shaw, 1980).

iv. there was no significant difference between the wafer samples in eating quality. Taste panel results showed that all the members of the panel found wheat flour, cocoyam flour and starch wafers acceptable. More than 90% of the panelists also found breadfruit wafer acceptable while about 84% of the panelists found banana wafer acceptable.

3.2.4 Development of 'Maissa'

Having witnessed the trend in composite flour technology in the baking industry within the Nigerian context, an attempt was made to develop a baked product which could serve as a baseline for the development of *"Nigerian bread"* (Adeyemi and Idowu, 1990). A product based on a composite flour comprising of maize flour, cassava starch and wheat flour ($\leq$ 20%) was conceptualized and referred to as 'Maissa' coined from Mai - (Maize) and -ssa (Cassava). Composite flour samples containing wheat flour, maize flour (ungelatinized or pregelatinized) and soybean flour were prepared, with wheat flour at 0, 20, 40, 60, 80 and 100% levels. The non-wheat flour fraction consisted of 5% soybean flour. The composite flours were evaluated for physico-chemical properties while specific volume, taste panel evaluation and staling rate were conducted on the 'maissa', samples using standard methods.

Comparative evaluation of four selected samples showed that the best two products were baked from formulations of 1:3:1 containing pregelatinized or ungelatinized maize flour with scores of 69.50 and 65.11, respectively, which were significantly preferred to those baked from ratios 3:1:1 or 2:2:1. It would appear from these results that products from composites containing comparatively high cassava starch were better rated than those containing high maize flour. This may, probably, be due to a better binding property of cassava starch than maize flour.

Result obtained in the study confirmed that 100% maize bread was not acceptable as reflected by poor scores obtained for loaves baked from 80% and 100% wheat-maize composite flours. However, 'maissa', a baked product containing only 20% wheat flour was acceptable when subjected to a taste panel evaluation without using 100% wheat bread as reference.

I. Staling of Bread and 'Maissa' Samples

The staling rate of bread samples prepared from 0% and optimum level of 40% wheat flour substitution was evaluated. Staling was higher in composite bread samples than in the 100% wheat flour bread. The lower retrogradation tendency (i.e. setback value) obtained for composite flour containing pregelatinized flour

(Adeyemi and Idowu, 1990) was not reflected in the values obtained as the corresponding bread samples showed higher staling rate than that from the ungelatinized maize flour. This behaviour is unexpected and would appear to corroborate the view of El-Dash et al. (1978) that collective effect of all baking ingredients would determine the overall performance of any composite flour dough or bread. It is probable, therefore, that this staling behavior of samples containing pregelatinized maize flour may be due to the low water holding capacity of its gel.

The staling rate of 'maissa' with and without 0.5% Glyceryl Monostearate (GMS) (Figure 4) followed a similar pattern as for the wheat-maize composite bread. Inclusion of GMS in the 'Maissa' recipe was found to reduce staling rate in the product, an effect similar to that reported earlier for 100% wheat flour bread (Knightly, 1961). After one day storage period, 'maissa' containing ungelatinized maize flour, with and without GMS, had 83 and 76% freshness values, respectively, while corresponding values of 44 and 37%, respectively, were obtained at the 4th day.

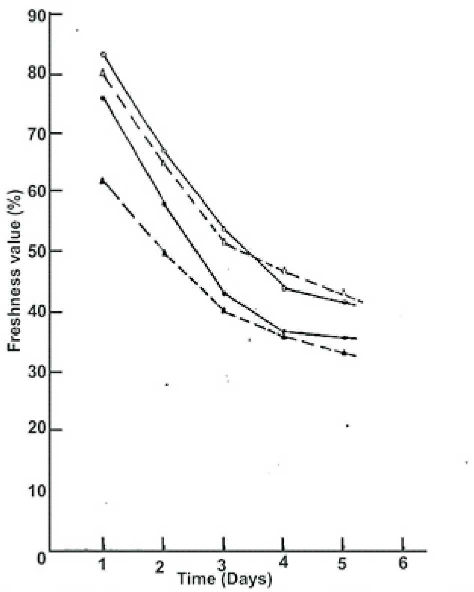


Figure 4: Stalling rate of 'Maissa' containing pregelatinized maize flour with (△—△) or without (▲—▲) GMS; ungelatinized maize flour with (○—○) or without (●—●) GMS

3.2.5 Wheatless Bread from Cassava and Maize

The art of bread manufacture from 100% non - wheat flour is said to have been practiced several hundred years ago, when the ancient Egyptians and Babylonians baked bread from rye and other sources, especially unleavened

bread (Shellenberger, 1971). The Amazonian Indians of South America have an indigenous way of making different kinds of manioc bread from cassava without wheat (Mowat, 1989). Following experimental results on wheatless bread manufacture from cassava flour, starch or sorghum flour, with and without improvers such as pentosan, xanthan gum (Cassier *et al.*, 1979; Satin, 1988), the FAO advocated popularizing it (wheatless bread) in developing countries (Akobundu *et al.*, 1988). In this approach, the vital wheat gluten is replaced by starch gel (Fig. 5).

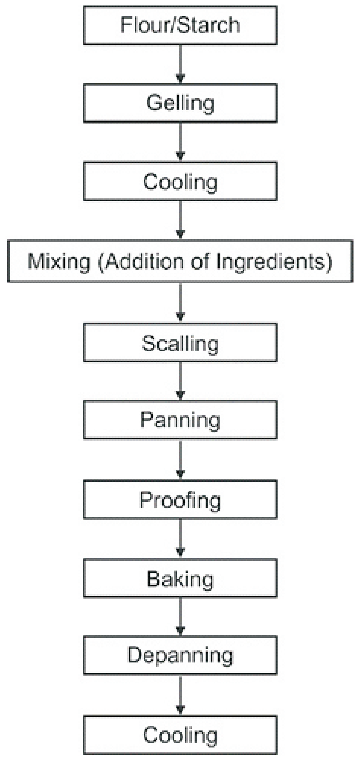


Figure 5: Flow diagram for the manufacture of wheatless bread (Satin, 1988)

Experimental studies on wheatless bread were also conducted under my supervision at the Obafemi Awolowo University, Ile-Ife. Oyintiloye (1990) and Ejilemele (1992) compared the functional properties of flour and starch prepared from either maize or cassava and also evaluated quality of corresponding wheatless bread samples (Plates 10a and b).

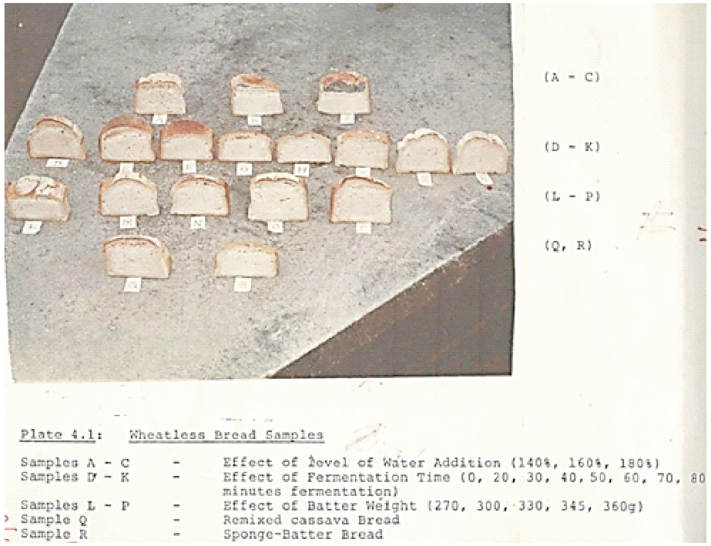


Plate 10a: Cassava - based wheatless bread

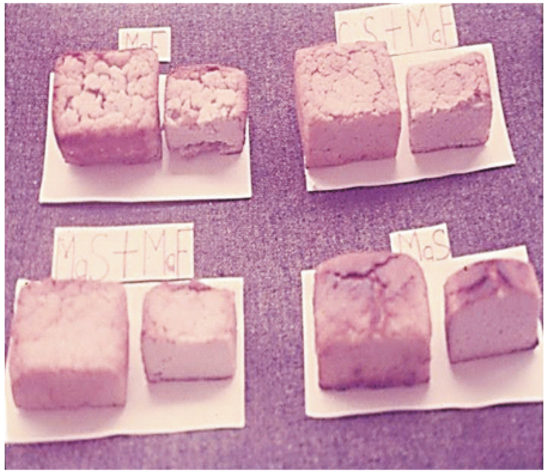


Plate 10b: Maize - based wheatless bread

The summary of their findings showed that acceptable wheatless bread could be manufactured from maize or cassava flour or starch by a modification of the normal breadmaking recipe and method. The gelling of part of the flour or starch sample used for batter preparation was probably responsible for the acceptability of the wheatless bread samples. It was further shown that

wheatless bread from a recipe containing 100% cassava starch was more acceptable than other formulations containing either or both of cassava flour, maize flour or starch. Generally, the cassava and maize wheatless breads had compact, dense, wet and gummy internal characteristics which made slicing difficult. This was due largely due to lack of gluten, higher water addition and source of starch which were consistent with earlier findings (Casier *et al.,* 1979; Akobundu *et al.,* 1988; Satin, 1988). It was observed, however, that keeping for about 20 h before slicing reduced the wetness of the breads.

Experimental test of wheatless bread in Nigeria

Nigeria was not left out of the international research efforts in the development and evaluation of acceptability of wheatless bread. Based on a research proposal that I submitted, through the OAU, Ile-Ife research team led by Prof. O. L. Oke, FAO grant was received for a pilot study on the acceptability of wheatless bread in Nigeria. The project was based at the Federal Institute of Industrial Research, Oshodi (FIIRO). The consumer acceptability of the product was conducted in 1990/1991 in selected towns including Ogbomoso when the Ife group had moved to OSUTECH (LAUTECH). The responses showed some elements of promise for the product.

3.2.6 Developments in the commercialization of composite flour technology in Nigeria

My research interest and active membership of the Nigerian Institute of Food Science and Technology placed me at an advantaged position in playing some roles on the issue of composite flour commercialization within the Nigerian context. Through the Institute, I was nominated, between 1980 and 1983, to serve as member and subsequently the Secretary to the National Composite Flour Committee chaired by Dr. (Mrs) Charity Edwards (late) of the Federal Institute of Industrial Research, Oshodi. The Committee of which the membership included Dr. O. Olatunji (the immediate past DG of FIIRO) operated from the Institute under the Directorship of Dr. O. A. Koleosho. The Committee, in its report, recommended an initial substitution of ten percent (10%), and to be gradually increased upward as the average Nigerian baker develops the technical capability to handle the resultant dough with increasing level of substitution.

Furthermore, acceptability of the product was of paramount importance. The Committee recommended the need to balance economic considerations with product acceptability. Thereafter, an Inter - Ministerial Committee was set up under the Chairmanship of Dr. (Mrs) Remi Aribisala, the then Permanent Secretary in the Federal Ministry of Industries. Membership was drawn from Research Institutes, Universities, Milling and Baking Industries and some selected Ministries including Agriculture and Industries. I could recollect Chief Ogunsanwo, the Chairman of Temitope Bakery, Sagamu serving on the Committee, of which I was a member.

Within the Nigerian context, as far back as the late 70s when General Olusegun Obasanjo (as Military Head of State), efforts had been made by the Federal Government to embark on import substitution, especially in the baking industries. The Shagari Administration sponsored an FAO Team on Composite Flour to Nigeria. On the team was one Mr. Peter Sluimer (a Dutch) and, my host Scientist when I was on a Post - Doctoral Training in Cereal Technology for four (4) months. I was aware of a report submitted to the Federal Government by the FAO Team. It was my belief that the content of the report was not different from that prepared by the committee on "National Composite Flour Technology" and that of the Inter - Ministerial Committee earlier referred to. The regimes of Generals Buhari - Idiagbon and General Babangida advocated and enforced non - wheat flour in bread making. During this period, the flour millers were compelled to change some of their lines into milling maize grains which introduced the incorporation of some maize milling facilities - bringing additional cost. The eight - year governance (1999 - 2007) of Chief Olusegun Obasanjo (GCFR) opened the flood gate for investment into cassava cultivation and processing. One of the major products from the exercise is that of composite flour with cassava flour at 10% level for a start. This has resulted in the incorporation of cassava flour at 10% in most, if not in all, commercial flours currently produced in Nigeria. For the current momentum to be sustained, the following steps must be ensured:

i. availability of non - wheat flour in food grade quantity and quality. This involves value addition and availability of non - wheat flour / starch sources such as cassava, millet, sorghum, maize, rice, potatoes etc. More importantly, food grade soy flour and flours from other plant protein sources should be readily available. It has been established that utilization of composite flour at more than 20% wheat flour substitution demands incorporation of a high protein source; failing which we may end up with protein malnutrition amongst the vulnerable group that may subsist on such products;
ii. production of other baked goods and confectioneries such as cakes, biscuits, etc, from 100% non-wheat flour. Specialized composite flours can be packaged and marketed for such products;
iii. step - wise substitution of wheat flour. For bread manufacture, the existing law of 10% substitution must be enforced and monitored for level of performance for the manufacture of bread by local bakers. This level of 10% could then be subjected to gradual increase with a close monitoring of the resultant bread quality. The Nigerian baker needs to be trained on how to handle composite flour substitute at more than 10% level of wheat flour substitution.
iv. encouragement of consumption of "Nigerian bread". As we have English, German, French or Arabian bread, can't we have a typical Nigerian bread? This is the import for the development of "maissa" reported earlier. This approach demands support from the private sector to sponsor and introduce a new product into the market. However, the element of cost would come into play.
v. maintenance of consistent policy. Government must be consistent in its policy; this is a major bane of governance in Nigeria.
vi. enforcement and monitoring of policies. All agencies of government, especially the Standard Organization of Nigeria (SON), National Agency for Food and Drugs Control (NAFDAC) and Consumer Protection Council (CPC) must be empowered to ensure compliance to quality standards of the flour or starch samples and the resultant composite flour.
vii. local production of other baking ingredients. While flour and water are the major ingredients in baking, manufacture of other ingredients such as yeast, fat and sugar, emulsifiers and anti-stalling agents have been relegated to the background. Nigeria is a major importer of these ingredients. For instance, Nigeria is a huge market for yeasts, enzymes, etc, not only for the food industry (including the baking industry) but for other manufacturing purposes. Local production of these ingredients would not only create job opportunities but also ensure savings of foreign exchange. In essence, there is a need to take a holistic approach to sourcing for baking ingredients locally. Through this approach, we can reduce our import bill on these ingredients.

As mentioned earlier, baking from composite flour was and is still not new either in Nigeria or globally. Recent researches are consistent with established facts as presented in this lecture. However, some of these recent publications have addressed the fundamentals and, using advanced analytical techniques and processing technologies, have offered recent information and explanations of the principles, commercialization and challenges of composite flour technology (Nwanekesi, 2013; Shittu *et al.*, 2007; Ohimain, 2014).

4.0 MAIZE QUALITY AND OGI MANUFACTURE

My works on maize and similar grains (sorghum and amaranth) had been on quality characteristics of the grain, ogi manufacturing processes and quality, and effect of packaging and storage conditions on agidi.

4.1 Maize Quality and Utilization

Industrial utilization of grains depends on the physico-chemical properties of the grain, with these properties being determined by the agronomic characteristics such as grain colour (white or yellow), grain type (dent, flint, intermediate or semi-dent), areas of adaptation and maturity. Other quality factors include physical characteristics (kernel weight and volume, bulk density and kernel size), starch content and pasting properties (Adeyemi, 1993).

Results obtained for some quality parameters of twenty maize varieties (Adeyemi *et al.,* 1987) were comparable to values reported in the literature (Watson, 1977). One of the most important factors influencing food and industrial uses of maize starch are the starch content and pasting properties. Maize starch properties,i.e. starch content (55.8 - 66.8%), peak viscosity (520 - 680 B. U.), stability (110 - 290 B. U.), setback (retrogradation tendency) (-155 - 310) and consistency index (65 - 500) are influenced partly by the amylose content (Watson, 1977). Pasting viscosity results suggested that the varieties were of intermediate amylose content which could range between 17 and 30% (Greenwood, 1979). These properties would appear to show that Nigerian maize grains have promising industrial potentials, nationally and globally. However, for the food and allied industries, modified starches are of commercial importance. Therefore, in meeting the demands for the local and international markets, not only should emphasis be on the native starch but also on modified starches manufacture.

4.2 Studies on Ogi

Ogi is a fermented food product still prepared commercially in Nigeria by natural fermentation (i.e. steeping) of maize, sorghum or millet grains followed by wet-milling, wet-sieving and souring (Akinrele 1970; Banigo and Muller, 1972a; Akingbala *et al.,* 1981).

4.2.1 Wet-milling of grains for ogi manufacture

In our various studies on ogi, the effect of grain type and its physical properties on ogi yield, water absorption during steeping and changes in the physico-chemical properties of the sieved slurry were investigated (Adeyemi and Beckley, 1986; Adeyemi *et al.* 1987; Akingbala *et al.*, 1987; 1994).

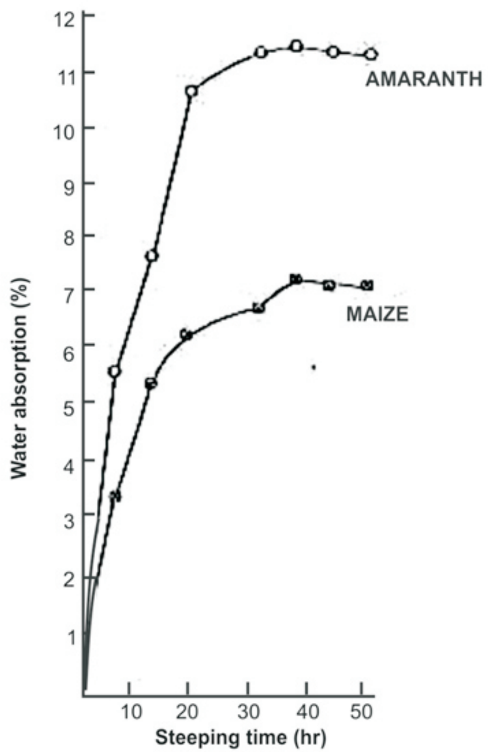


Figure 6: Effect of steeping time on water absorption of amaranth (O———O) and corn grains (☒———☒)

It was established that:

i. amaranth grains showed higher water absorption than maize and reached saturation at the 26th hour with the maximum rate of water absorption occurring between the 18th and 36th hour of steeping (Figure 6). The higher water absorption of amaranth than maize grains, probably, could be due to differences in the size of the grains since smaller sized grains absorb more water than corresponding larger sized ones (Banigo and Muller, 1972a);

ii. there was an increase in the pH of steeping water from 3.78 to 4.06. However, there was an initial sharp decrease in pH of steep water due mainly to lactic acid bacterial fermentation (Akinrele, 1970), then an increase after about 24 h of steeping due to buffering action of solubilized proteins in the steep water (Banigo and Muller, 1972a, b; Fields *et al.,* 1981). This would explain the conventional practice of not exceeding a period of between 24 and 48 h for the steeping of grains in the manufacture of ogi, most commercial processors steep for only 24 h;

iii. steep water of amaranth had higher pH than that of maize;

iv. yield of ogi depends on grain variety, grain type and processing techniques. For instance, with the comparative evaluation of five maize varieties, ogi yield was found to vary between 51.2 and 60.0% while the corresponding yield was 70% for amaranth. Various explanations for losses of materials and nutrients in the course of ogi manufacture have been proffered by some of the above cited workers.

v. it was observed in the course of ogi preparation from amaranth that the highest loss of solids occurred in the souring water as the slurry remained suspended even after long period of sedimentation. The process of squeezing excess water from the amaranth ogi slurry to obtain cake resulted in increased losses of solids through pores of the muslin cloth, probably due to the relative small size of amaranth starch granules compared to maize starch (Yanez *et al.* 1986). Based on these observations, the amaranth ogi slurry was first frozen before drying (45-50^{o}C) in a cabinet dryer. Traditionally, ogi is kept in homes as a sediment under the souring water and only re-constituted into a slurry just before cooking into ogi porridge or a gel.

However, for industrial production of powdered ogi from amaranth ogi slurry, the use of the cabinet dryer as suggested by Adeyemi (1989) might not be feasible since this would involve an initial stage of obtaining the wet cake. Co-milling amaranth-maize mixture caused the ogi to sediment and the loss of solids in the souring water was comparable to that of ogi from maize only. Alternative technology for the manufacture of powdered ogi product from amaranth grains may, however, include freeze, spray or drum drying of the slurry;

vi. changes in some chemical properties (titratable acidity, starch and damaged starch contents, diastatic activity and pasting properties) of the fermenting grains and souring slurry are time dependent. These parameters could serve in determining optimum steeping or souring period, depending on the desired quality; and

vii. indices of ogi quality would include not only titratable acidity, pH, proximate composition, and protein quality, but other factors such as pasting properties, Adams Consistency value and rheological properties (Akanbi *et al.*, 2003).

4.2.2 Dry-milling process of ogi manufacture

Conventionally, ogi is manufactured through the wet - milling process which usually results in high losses of materials and nutrients. Dry - milling was proposed as an alternative approach at reducing nutrient losses and possibly production of varied products through controlled fermentation and possibly easier fortification with plant protein sources (Banigo *et al.,* 1974; Olatunji, 1977). Our investigations on the dry - milling approach involved evaluation of the chemical and physical changes taking place during steeping of maize or sorghum flour (Adeyemi, 1983; Adeyemi and Beckley, 1986; Akingbala *et al.*, 1987; Adeyemi, 1988). From the various studies, the challenges of dry-milling include obtaining ogi product of the desired particle size, sourness and product consistency, especially with flour from maize grains.

One of the most important quality factors of ogi is its particle size which depends on the type of sieve and its aperture, whether dry or wet milling. Thompson (1981) had shown that the most acceptable ogi, in terms of consistency and 'mouthfeel', was that prepared from the flour fraction of <125 μm particle size. However, the finer the particle size, the lower the yield of the product. For instance, it has been demonstrated that the yield of ogi ranged from 12 to 90% depending upon the flour or sieved fraction used; the yield from the wet milling process was 60% (Adeyemi, 1983; 1988).

Justification for dry-milling for sorghum ogi flour

The study with sorghum flour, unlike maize flour, showed the dry-milling approach to be a more convenient method of ogi preparation than the wet-milling process, since sorghum flour could be packaged and sold to consumers for subsequent steeping at home. Furthermore, it is possible to produce high-protein sorghum flour by controlled abrasive milling (Rooney *et al.,* 1972). Sorghum flour also could be fortified with high-protein flour (e.g. soybean flour), vitamin and mineral supplements. Such high-protein or fortified sorghum flour would be of higher nutritional value, especially for infants, for whom ogi is a major weaning food in Nigeria.

In the subsequent study (Adeyemi, 1988), it was established that sorghum flour of desirable sourness could be obtained by steeping the grains either in souring water or in a medium simulating that of the souring water plus the use of starter cultures. Such cultures could include *Lactobacillus plantarum, Saccharomyces cerevisiae, Candida mycoderma, Streptococcus rouxi, Lactobacillus fermentum, Pseudomonas maltophillia, Bacillus subtilis or Bacillus cereus* (Akinrele, 1970; Banigo *et al.*, 1974).

Fermented flour of acceptable particle size is obtainable by using appropriate sieves, air classification or perhaps abrasive milling (Rooney *et al.,* 1972; Thompson, 1981; Adeyemi, 1983). It is possible, therefore, through controlled fermentation and milling processes to produce ogi flour of acceptable quality characteristics by dry-milling fermented grains. Current studies on ogi have also laid emphasis on microbial, chemical and nutrient changes, and improvement in the nutritional quality of ogi (Otunola *et al.,* 1998; Teniola and Odunfa, 2002; Osundahunsi and Aworth, 2003; Bolaji *et al.*, 2015; Ajala, 2016).

4.3 Exploratory Study on Agidi

Agidi (Plate 11), a gel prepared from maize ogi slurry, serves as a meal for children and adults in most parts of Nigeria (Muller, 1970; Umor and Fields, 1981; Akingbala *et al.,* 1981). In our study on agidi, investigation was carried out on the effect of storage temperature, ogi souring and type of packaging material on the staling rate and changes in sensory qualities of the product (Adeyemi and Oluwamukomi, 1989).

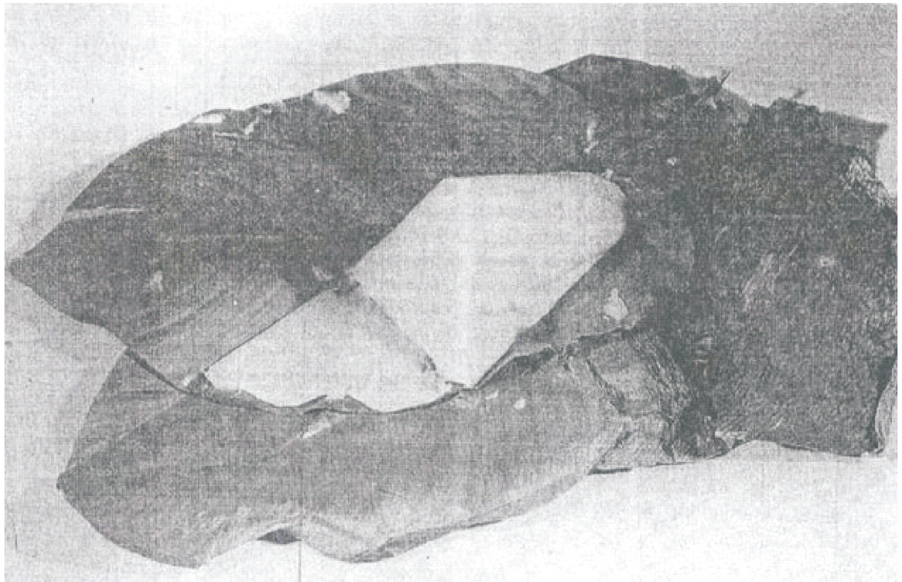


Plate 11: Agidi wrapped in leaves

In the study, the results of chemical tests were complemented with sensory observations (Table 1). Rate of firming of agidi was fast at 8°C.Syneresis in agidi samples stored at 28 or 50°C was not pronounced as in that stored at 8°C.

Table 1: Sensory observations of agidi samples stored under different conditions

Storage period	Agidi wrapped in leaves: Market sample 28°C	2-day soured ogi 8°C	2-day soured ogi 28°C	2-day soured ogi 50°C	4-day sourced ogi 28°C	Agidi stored in: Poly-ethylene 28°C	Aluminium foil 28°C	Can 28°C
3	↓	Turgid texture due to firming. Higher syneresis than agidi stored at 28°C or 50°C ↓	↓	↓	↓ Mouldy and soft	↓	↓	↓
6	↓	↓	↓	Mouldy and soft		Mouldy and soft	↓	↓
9	Mouldy and soft	↓	Mouldy and soft				↓	↓
16							Mouldy and soft	↓
56								↓

*Arrows (↓) indicate length of time each sample was intact without evidence of mould growth

Texture of canned agidi was observed to be intact after 56 days' storage period. Canning was, therefore, found to be an effective method of preservation as reported earlier for agidi and some traditional African food products (Brennen and Ogazi, 1978; Andah and Muller, 1973; Adeniji and Potter, 1980). However, the cost and availability of canned food products in developing countries are issues to be contended with. Recent studies are focused on improvement in nutritional quality and means of enhancing the stability of the product (Otunola *et al.,* 2006; Zakari *et al.,* 2010; Ikya *et al.,* 2013).

4.4 Enhanced Utilization of Fruits

Tropical fruits such as pawpaw *(Carica papaya),* banana, mangoes, etc, grow wild in most parts of Nigeria. However, their food and industrial potentials have not been explored as in some other parts of the world such as India and Hawaii (Arriola *et al.*, 1980). Furthermore, fruits are not accorded the importance they deserve in the diet of Nigerians, probably because of ignorance of its nutritive value, cost, difficulty of storage and utilization (Tindall and Sai, 1965). When ripe, fruits can impart colour and taste to food because of their carotene content and sugar levels. A feasible way of increasing the utilization of fruits in Nigeria could be to include them in traditional cereal-based foods such as 'ogi' (Adeyemi and Soluade, 1993) and related cereal - based foods or extract. Earlier studies have indicated that non-cereal plant materials such as soybean flour could be incorporated into ogi to improve its nutritive value (Anon, 1970).

4.4.1 Development and quality of pawpaw-ogi

Pawpaw-ogi was prepared (Figure 7) from mixes of ogi slurry and ripe pawpaw and evaluated for some quality characteristics and acceptability.

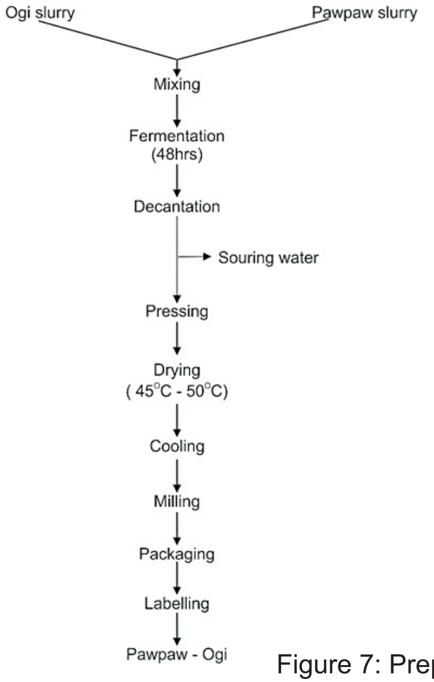


Figure 7: Preparation of pawpaw-ogi

Proximate composition, mineral profile and vitamin C content of pawpaw-ogi

As expected, the protein content did not increase significantly with the addition of pawpaw, since pawpaw is not a good source of protein (Arriola *et al.,* 1980), however, there were variations in the starch content with increasing levels of added pawpaw. This could be a reflection of the inconsistency in the activities of the microorganisms involved in wild fermentation of ogi slurry (Akinrele, 1970; Adeyemi and Beckley, 1986). There was no significant difference in the fat content of the ogi samples, which varied between 4.4 and 4.7%. The ash content was found to increase with increasing amounts of pawpaw. This was not unexpected since one of the most important contributions of fruits to human diet is the provision of minerals (Tindall and Sai, 1965).

The mineral content of ogi increased with increasing levels of pawpaw. Sodium, potassium and calcium contents of ogi with no added pawpaw were 4, 64 and 156 mg/100 g, respectively. Corresponding values in pawpaw ogi with60%

pawpaw were 19, 360 and 400 mg/100g, respectively. Values of 55 and 490 mg/100g obtained for sodium and calcium in the pawpaw fruit were higher than reported values (Duckworth, 1966).That could be attributed to varietal differences and soil conditions. The addition of pawpaw significantly increased the vitamin C content of ogi A value of 60.57 mg/100g obtained in the edible portion of pawpaw is within a range 23-150 mg/100g reported by earlier workers (Arriola *et al.*, 1980; Duckworth, 1966). The total sugars (reducing and non-reducing) of the fresh pawpaw was 8.6 g/100 g (wet basis), which is close to 9 g/100g reported by Arriola *et al.* (1980). Total sugars of ogi increased with an increase in the level of added pawpaw.

Sensory properties of pawpaw-ogi

Colour measurement of the product showed that the colour became yellowish - orange. However, visual observations after four months storage at ambient temperature showed a slight reduction of the colour intensity in the samples containing pawpaw. These changes may be attributed to the susceptibility of carotenoid pigments to oxidative breakdown. There is, therefore, a need to investigate the storage stability of the product further. There was no significant difference between the samples in their preference by the panelists for colour, flavour and appearance of pawpaw - ogi powder. It was apparent that pawpaw-ogi was acceptable as porridge.

4.4.2 Physico-chemical properties of maize extract - banana mixes

Flour mixes obtained by the addition of banana pulp in various proportions (0-50%) to maize 'extracts' were evaluated for some quality characteristics (Okezie *et al.*, 2003). Result, showed that the values of the total sugar ranged between 1.81g and 33.38 g/100 g. In all cases, the value increased with increasing levels of banana substitution. This observation is not unexpected since banana contains a considerable amount of sugars (Lii *et al.*, 1982; FAO, 1989). Moreover, the variety used in this study (Clone A) is known to be one of the sweetest varieties available in Nigeria.

The diastatic activity of the samples ranged between 0.012 and 0.25 g maltose/100g, with maize starch having the least value. These values, which could be an indication of increasing level of gassing power, increased with increasing level of banana substitution. This is in agreement with the earlier observation that there is increased activity of alpha and beta - amylases during the ripening of banana. The diastatic activity is of industrial importance in baking industry. During baking, the fermenting yeast uses the little amount of sugars originally present in flour, and a further supply of fermentable material is required. This will be supplied by the banana substitution. However, excessive diastatic activity may cause heaviness and stickiness of the crumb (Reed, 1966).

Furthermore, the results of the isotherms of the mixes however indicated that the product will store well and have higher capacity to absorb more moisture.

This would therefore suggest its potential suitability for baking purposes, especially when kept under conditions of water activity of 0.30 and below.The import of this study is the potential of starch - fruit mix being a feasible means of starch serving as a "carrier" for ripe fruits in its utilization for various food and industrial purposes.

5.0 COMPLIMENTARY/WEANING FOOD AND PREGELATINIZED PRODUCTS

In other to ascertain the status of complimentary and weaning foods in Nigeria, a case study was carried out using Ile - Ife community (Awoyinka *et al.*, 1992). Traditional cereal porridges (maize or sorghum ogi) were the most commonly used non-milk solids (Figure 8), the proportion being 54% and 80% for urban and rural mothers, respectively. It was gathered that most mothers, especially in the rural areas, feed their infants with ogi as from four months of age. Branded cereal products such as Cerelac and Nutriend were also given as from the age of 3 months, especially among urban mothers while only 4% of the rural mothers gave these products. Roots and tubers like cocoyam, yam, potato and cassava (gari) were fed to infants as from 12 months of life. Thirty-four percent of urban mothers and 44% of rural mothers fed their infants with these products.

Solid foods, like pounded yam and "amala" (yam flour dough) were also given to older infants. All mothers gave water to their children, especially as from the first day of life. Fruits like oranges, pawpaw and banana were also given but not frequently. One of the factors limiting the use of commercial weaning foods such as Cerelac or Babeena is their cost which is above the purchasing power of an average Nigerian mother (Adeyemi, 1989). Results shown in Figure 8 confirmed that traditional starchy foods, which form the bulk of weaning foods in developing countries, partly explains the high incidence of malnutrition that was and is still predominant in these countries (Orwell *et al.,* 1984; Samuel, 2013).

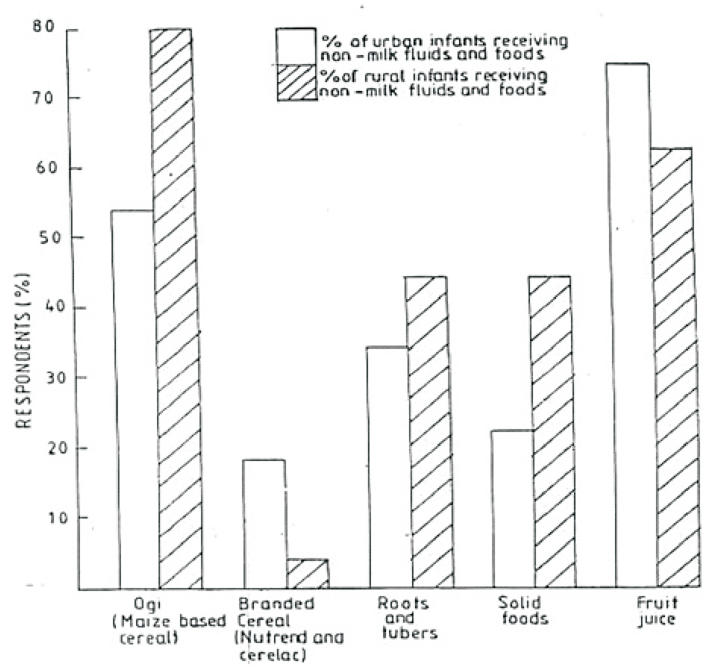


Figure 8: Percentage of rural and urban infants fed on non-milk supplements

5.1 Steam Blanched Maize Flour as a Constituent of Weaning Food

Industrial processes for weaning food manufacture in developed countries include drum-drying, canning, spray-drying, foam mat drying and extrusion cooking, among others. Although drum-drying has been described as a cheap means of producing an instant weaning food in developing countries, its commercial application is limited. Application of drum or spray - drying in ogi powder manufacture has been reported, however, this is yet to be commercially feasible in Nigeria (Banigo *et al*, 1974; Anon, 1977).

The need to develop cheap processes for weaning foods in developing countries has been stressed. This has led to the development of such a process which involves mixing cereal flour with vegetable protein flour or concentrate (Akobundu and Hoskins, 1987). Following this suggestion, dry - milling of steam blanched maize grains was employed in producing pregelatinized maize flour (Adeyemi *et al.*, 1989). The procedure involves steaming of steeped grains in a Barlett steamer, drying in a cabinet dryer (45 - 50^{o}C), milling on a Premier mill (a plate disc mill) and sieving (Figure 9) and mixing with soybean flour, vitamins, minerals , etc.

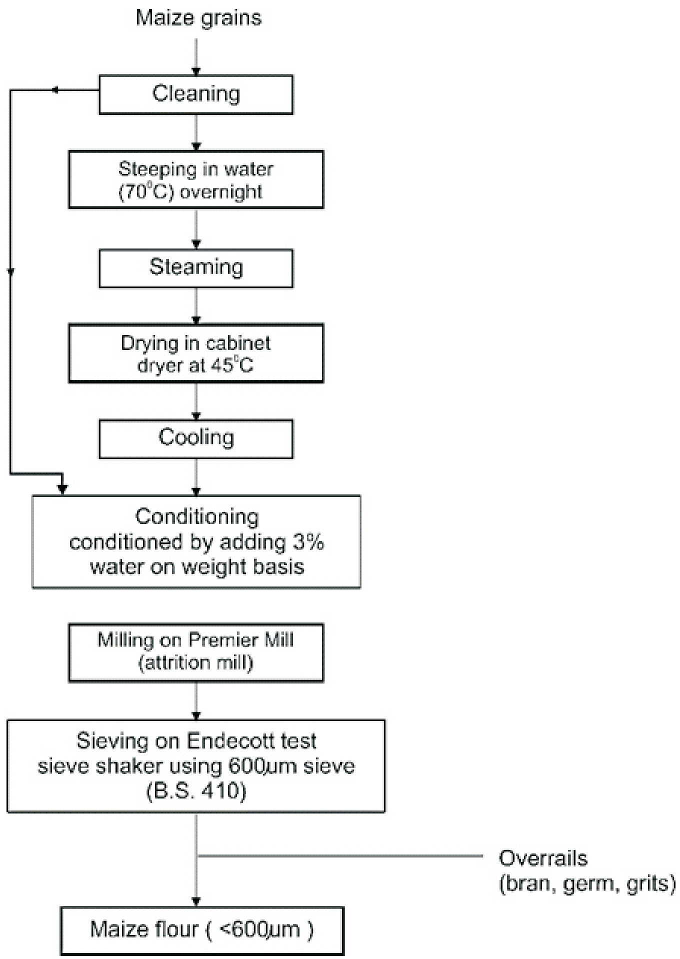


Figure 9: Preparation of ungelatinized and pregelatinized maize flour samples

Result from the study showed that:

i. the degree of gelatinization depended on steaming period (Figure 10). Water hydration capacity and ease of reconstitution depended on the extent of gelatinization. While the "weaning food" reconstituted easily just like commercially available weaning foods such as cerelac, ogi and soy-ogi did not because of the presence of raw starch which requires boiling in the course of its preparation (Figure 11);

ii. product fortification improved the protein content and protein digestibility of the product;

iii. fermentation or heat treatment improved protein digestibility with the latter producing a higher value.

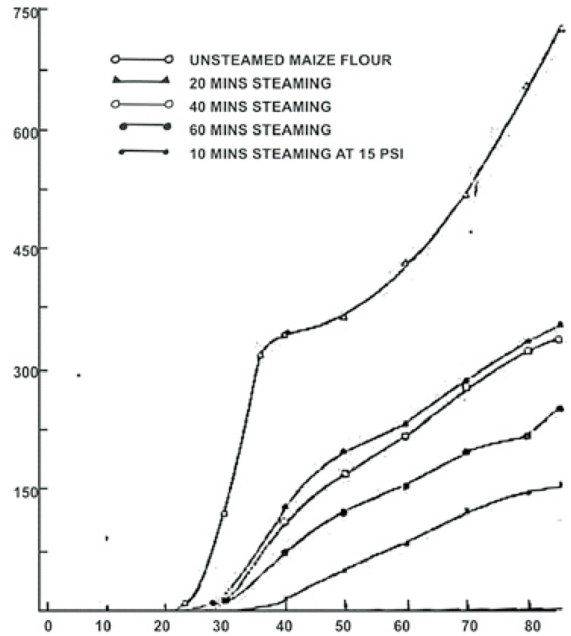


Figure 10: Brabender amylograph pasting viscosities of maize flour samples

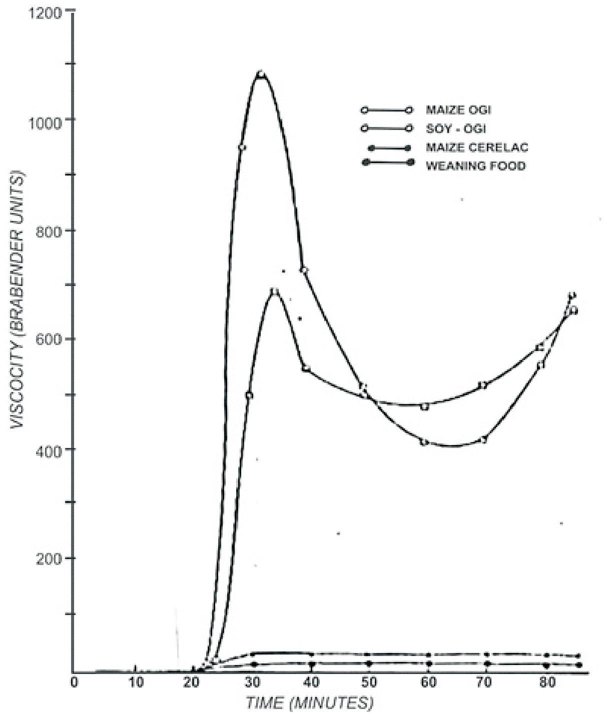


Figure 11: Brabenderamylograph pasting viscosities of ogi, soy-ogi, cerelac and weaning food

It is apparent that a Barlett steamer could find useful application in developing countries, especially in the rural areas since the built-in boiler is gas fired and thus the steamer does not rely on electricity for its functioning. Such a steamer would be useful in the production of pregelatinized maize flour for the manufacture of weaning food at a regional or local level and this may reduce overhead cost and thereby ensure availability at reasonable prices.

5.2 Drum Dried Pregelatinized Maize - Sweet Potato and Maize-Soy Mixes

Pregelatinized maize - sweet potato mix, fortified with soybeans and groundnut flours, was evaluated for its acceptability as a weaning food and for nutrient composition. The acceptable product had 14.3, 6.4, 2.4 and 67.4% for its protein, fat, ash and carbohydrate contents, respectively. Values for calcium, phosphorus and iron contents were 59.6, 187.5 and 2.4 mg/100g, respectively, while the most predominant fatty acids were linoleic, oleic and palmitic acids. The product, which had a chemical score of 85.34 for its protein value, was

found to be limiting in threonine (Idowu *et al.,*1993). In a related study, Adeyemi *et al.* (1991) showed that a drum-dried maize-soymix containing soybean milk was more acceptable than similar products from either soybean flour or the defatted residue.

5.4 Development of Canned Weaning Food

Infant foods are marketed in solid or semi-solid form, the former is usually preserved in powdered form which is reconstituted in warm or hot water. The latter, semi-solid is in emulsion form and the only home treatment required is warming before use. The advantages of the semi-solid type are that it eliminates the tendency of nutrient loss during the process of home preparation and fear of mothers not sticking to specifications. Canning or bottling is employed for the manufacture of such semi-solid weaning foods. The motivating force in the purchase of such products, especially in developed countries, is the convenience it offers.

The application of canning as an option for weaning food manufacture is apparently non-existent in Nigeria, therefore, such canned food products are usually imported. A study was carried out at producing a canned baby food from formulation containing mainly soybean flour, banana, liver, maize starch and skim milk powder (Adeyemi *et al.,* 1989). The product was found to meet the specifications of a weaning food in terms of physico-chemical and nutrient profiles. The major factor that would limit acceptability of bottled or canned weaning foods in developing countries is the high cost of the product. However, it's development and commercialization might cater for the demand of the few elites and urban dwellers.

6.0 KUNUN ZAKI

Kunun zaki, a non-alcoholic beverage from millet extract, is widely consumed in most parts of Nigeria, especially during the dry season. The traditional process of its manufacture involves wet - milling of millet grains with spices (ginger, cloves, and red and black pepper) (Figure 12). In the investigation, quality parameters of kunun zaki prepared from the traditional and improved processing techniques were reported (Adeyemi and Umar, 1994).

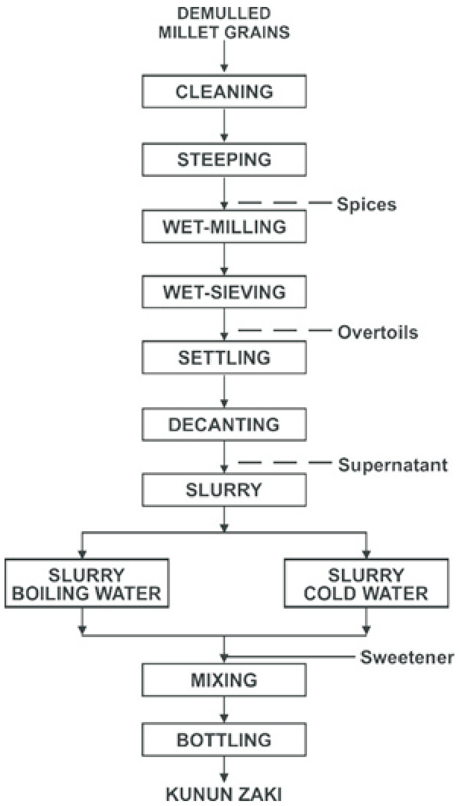


Figure 12: Flow Chart for the traditional process of kunun zaki manufacture

Result of preference test showed that 73.3% of the panelist preferred the product prepared from the slurry containing 4% solid material. Increasing slurry solids level above 4% resulted in a more viscous product which formed a gel, thus resembling ogi porridge (Adeyemi *et al*. 1987) rather than a beverage.

The product sweetened at 8% sugar level was the most preferred while there was no favourable response at lower concentrations because the products were not sweet enough. Also, 46.7 and 33.3% of the panelist preferred sugar levels of 8 and 10%, respectively, an indication that variation exists in consumer preference for sugar levels in a beverage. The formulation consisting of ginger (65%), cloves (5%), red pepper (25%) and black pepper (5%) was the most preferred (60% of the panelists) while other formulations containing higher levels of ginger, cloves, red or black pepper were rejected probably due to the high content of cloves in the formulation. Cloves contain a large amount of volatile oils which may contribute unacceptable strong flavour when used at

high concentrations (Lewis and Lewis 1977). This is not unexpected since the higher the concentration of the spices, the more pungent is the flavour of the product.

6.3 Development of Kunun Zaki Concentrate and Comparative Evaluation of Kunun Zaki Samples

Kunun zaki concentrates were prepared from blends, at different proportions of raw (ungelatinized) flour obtained from the conventional method of kunun zaki preparation with pregelatinized flour from steeped, spiced grains obtained by steam blanching or drum dried spiced slurry (Adeyemi and Umar, 1994).

Result obtained in different products(i.e. commercial, pasteurized laboratory sample, steam blanched and drum-dried concentrate) had range of 4.6-5.0, 0.04-0.05% lactic acid, and 1.02-1.03 for pH, titratable acidity and specific gravity, respectively. While the commercial sample had the least total solids content (9.0 g/100ml), the sample from steam-blanched concentrate had the highest value of 18.5 g/100ml. Kunun zaki from drum-dried concentrate had the highest microbial count (2.5×10^6) while the laboratory pasteurized sample had the least microbial count (3.0×10^5). The high microbial count for products from the concentrates could be due to the use of unsterilized water from the tap in preparing the slurry and the non-pasteurization of the product.

Laboratory pasteurized sample had the highest peak viscosity (Figure 13), an indication of its high total solids and concentration of raw starch (Banigo *et al.,* 1974). Taste panel results showed a significant difference in consistency among the samples while there was no difference in mouthfeel. The product prepared from the drum-dried concentrate was rated higher for consistency and mouthfeel than any of the other samples. This was probably due to sticking in the mouth of swollen gelatinized starch granules thereby giving body to the product (Anderson *et al.,* 1969). Pasteurized sample had highest score (7.5) for flavour than that prepared from either of the concentrates, which might be due to a slight loss of volatile flavour components during drum-drying or steam blanching.

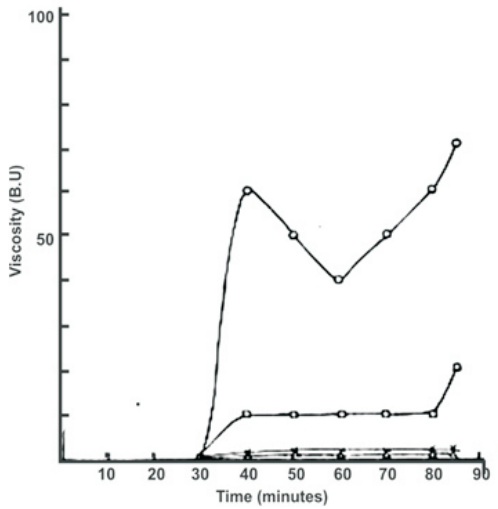


Figure 13: Amylograph pasting viscosity of kunun zaki samples

It is apparent from the study that the proportion of ingredients and the method employed in the manufacture of kunun zaki would affect product quality and acceptability. It is desirable, however, to improve the storage stability of the product by reducing the initial microbial load perhaps through controlled fermentation of steeped grains, use of treated (potable) water for preparing the slurry or the addition of a chemical preservative such as sodium benzoate. Recent studies have also focused on the production of an instant product (Ndulaka, 2014), microbial flora and the use of starter culture for kunun zaki manufacture (Agarry *et al.*, 2010; Ayo, *et al.*, 2011).

7.0 RICE QUALITY AND PROCESSING

Investigations were conducted on paddy quality, local rice processing techniques and quality of the processed products (Adeyemi and Mustafa, 1979; Adeyemi *et al.,* 1985, 1986; Omobuwajo and Adeyemi, 1987). Based on our findings, technological options for the Nigerian rice industry had been proposed.

7.1 Quality of Milled Paddy

Physico-characteristics of ten rice varieties were evaluated. The results indicated that the rice varieties were long grain in size except FARO 21 which was short. Crude protein content of the samples ranged from 7% to 8% which is within the range of 6% to 11% reported for rice varieties in South-east Asia (Juliano *et al.*, 1964). Values for amylose content, gel consistency, alkali spreading value, gelatinization temperature and peak viscosity ranged from 25 to 28.9%, 25 to 59mm, 3.0 to 7.0, 66^{O}C to 74^{O} C, 620 B.U. to 1,005 B.U.,

respectively. These results showed that most of the varieties were of high amylose content, hard gel consistency and low to intermediate gelatinizing temperature. The attributes confirmed that quality characteristics of Nigerian varieties were comparable to reported values in literature (Webb and Stermer, 1972).This confirmed that it is processing that limits acceptability of Nigerian rice and not the poor quality of the paddy.

7.2 Traditional and Laboratory Rice Processing Operations

Preprocessing operations which include harvesting, threshing and pre-cleaning, among others, are factors affecting quality of processed rice. Traditionally, threshing is achieved by human treading on the panicles. Pre-cleaning involves washing in water or in brine solution of specific gravity of 1.13 - 1.15 before soaking in water at ambient temperature for 4 to 5 days, with or without alum or in warm water of initial temperature of 80^{O}C overnight. Steaming of paddy in jute bags is carried out in big drums until splitting of the husks is observed which takes between 15 and 20 min. The paddy is then drained and sundried on raffia mats or concrete floors. Drying is completed when grains selected at random give a sharp cracking sound on breaking with teeth. Milling is mostly done with Grantexdehuller after which the milled rice is packaged, without grading and colour sorting, and ready for sale.

Processing steps at National Cereals Research Institute, Badeggi, one of our study Centers then, involved pre-cleaning of paddy in 12% brine solution, soaking in previously boiled water for 5 - 6 h and steaming for 10 - 15 min. Steamed paddy was first sundried to 16% moisture content, then slowly dried to 13 - 14 % in the shade and tempered for 12 - 24 h before milling.

For laboratory processing in the Department of Food Science and Technology (OAU, Ile - Ife), three methods of steeping were investigated as indicated below:

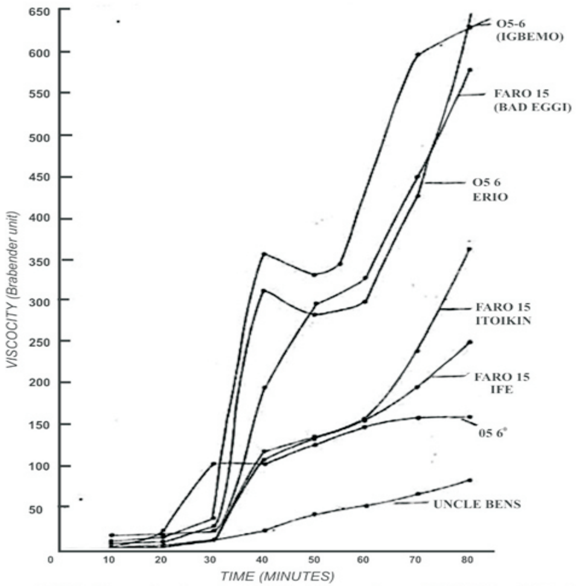
i. Steeping in cold water for 4days with and without alum (0.5% of weight of paddy)
ii. Steeping (a) overnight in warm water of initial temperature of 70^{O}C and (b) at a constant temperature of 64^{O}C for 4 h.
Steaming of the samples was either for 1 h in a false bottom drum or in an autoclave at 15psi for 8 min. Parboiled samples were dried under the shade until the moisture content was between 12 and 13% before milling with a Grantex dehuller.

7.3 Quality of Parboiled Samples

Samples subjected to the above processing techniques were evaluated for degree of parboiling, moisture content, milling and cooking quality, and sensory evaluation.

7.3.1 Degree of parboiling

The amylograms (Figure 14) showed that none of the samples, except OS6 a (Ofada variety) and Uncle Bens (reference sample), had their starch granules fully gelatinized by the steeping and steaming techniques. FARO 15 (Ife) was "nearly parboiled" while all the other samples were "partially parboiled". Both OS6 (a) and Uncle Bens were "fully parboiled", thus indicating a more efficient thermal treatment (Webb and Stermer, 1972). The degree of parboiling is an indication of hardness and compactness of the endosperm of fully parboiled rice, which tends to improve the storage qualities of the processed rice.This makes it resistant to perforation by insects and less liable to absorb moisture (Gariboldi, 1972). A "partially parboiled" rice may not keep as long as a "fully parboiled" sample.



O56° Paddy sample steeped at 64°C for 4 hours steamed at 15PSI for 10min, dried and milled)

Figure 14: Brabender amylograms of parboiled rice samples

7.3.2 Moisture content and milling quality

Moisture content of the parboiled samples varied between 12 and 14% (Table 2) thus indicating that the samples would keep for not less than 6 months (Gariboldi, 1972). Breakage in all the samples (except Uncle Bens) ranged between 13 and 26% (Table 2). Studies have indicated that parboiling reduces breakage in rice, however the extent of breakage depends on parboiling and drying techniques, moisture content at milling, type of mill and degree of milling (Bhattacharya, 1980). All the samples, except FARO 15 (Ife), were subjected to sun drying and gave higher percentage breakage than the latter which was shade dried. The low breakage of 3.7% in Uncle Bens could be ascribed to better processing operations and, perhaps, mechanical separation of broken grains from whole grains after milling (grading).

Degree of milling results showed that laboratory processed FARO 15(Ife), was comparable to Uncle Bens (Table 2), which could be classified as "well - milled" according to the classification of Watson *et al.* (1975). All the other samples had degree of milling ranging between 0.47 and 0.58 % and were classified as "reasonably well-milled". Factors affecting degree of milling include drying conditions and severity of the milling process (Watson *et al.,* 1975). Majority of consumers would prefer well-milled rice to an under-milled product with little or no bran adhering to the endosperm exept in a rice delicacy like "ofada", which is of better nutrirional value.

Table 2: Moisture content and milling quality of parboiled rice

Sample	*Moisture %*	*Breakage %*	*Degree of milling index[a]*
FARO 15 (Itoikin)	13.84	26.1	0.47
FARO 15 (Bad eggi)	12.24	23.5	0.58
FARO 15 (Ife)	13.67	13.60	0.33
O56 (Ibese)	13.84	21.4	0.53
O56 (Erio)	13.88	26.6	0.46
O56 (Igbemo)	n.d.	18.6	0.51
Uncle Bens	10.12	3.7	0.36

a *Percent surface fat of milled rice*
n.d. *not determined*

7.3.3 Cooking quality and taste panel evaluation

Results from our studies have indicated that processing operations, especially the degree of parboiling affect cooking quality of parboiled rice such as water absorption, swelling capacity and elongation ratio (Adeyemi *et al.*, 1985; Omobuwajo and Adeyemi, 1987). The higher the degree of parboiling the lower was the water absorption and swelling capacity of rice (Kurien *et al.*, 1964). The absorption of water needed for the hydration of incompletely gelatinized starch granules would appear to account for the higher water absorption and swelling capacity of under-parboiled processed samples.

Result of taste panel evaluation showed that off-flavour was very strong in the sample that was cold steeped for 4 days without alum, and was therefore not acceptable. Cold steeping with alum or warm steeping for a few hours (FARO 15 Badeggi) or overnight (FARO 15 Ife and Itoikin) significantly reduced off-flavour. Off-flavour in rice has been indicated to be due to the growth of coliform bacteria and production of odorous products such as thioalcohols and thioethers as a result of fermentation during the long period of steeping and subsequent steaming (Pillayiyar *et al.*,1980). The action of chemicals, such as copper sulphate, alum and ferric chloride, in reducing off-flavour in parboiled rice has been ascribed to the inhibition of microbial activities during steeping (Pillayiyaret al., 1980). Preference of samples was found to be dependent on the treatment and method of processing. Under-parboiling, as in the local samples, was found to significantly reduce acceptability of cooked sample. Efficient thermal treatment produced well parboiled samples which were more acceptable than under-parboiled samples.

7.4 Rice Processing Technology - Options for Nigerian Rice Industry

There has been preference, over the years, for imported rather than for locally processed rice, with the former having better processing and cooking qualities. Some of the factors limiting consumer acceptability of locally processed rice include off-flavour (odour), high percentage of broken grains and contamination with stones and other extraneous matters (Adeyemi and Mustafa, 1979). Therefore, in proffering options for the industry in Nigeria, these have to be from two major perspectives which are the small - and large - scale processors, which have been the focus of current developments in the Nigerian rice industry.

7.4.1 Small - Scale Processors

Pre - processing operation, especially threshing, would include methods such as either beating rice heads against a solid object, such as a tub, ladder, screen, wooden platforms, or the use of a portable drum thresher (Stout, 1966). Pre-cleaning using sodium chloride appears ideal since the salt is cheap and readily available. Cold steeping with alum could be practiced while a better alternative is either steeping in warm water overnight or for 5 - 6 h (as in Badeggi process). Steaming using false bottom drums, rather than boiling in jute bags, would produce a better parboiled product. However, a combined steeping/steaming unit as designed by Onwuka *et al.* (1981) has been found ideal for small scale processors. An alternative to sun - drying is a mechanical dryer that can be used cooperatively or by commercial operators who will provide drying services for processors (Onwuka *et al.*, 1981). For milling, the essential aspects are cost, reliability, maintenance of the mill and the milling techniques.

7.4.2 Mechanized Plant

For large - scale processors, highly mechanized plants as being currently encouraged, could be set up in major rice producing areas. Processing operations will include mechanical pre-cleaning, steeping at controlled temperature of 64 - 70^{O}C for 4 - 5 h or less, steaming under pressure for 5 - 10 min, mechanical drying and milling. Post-milling operations would include separation of broken grains (sizing / grading), colour sorting, fortification with B - vitamins (i.e. thiamine, riboflavin and niacin) and iron, followed by packaging. In proposing this alternative, the challenges of regular supply of raw materials (paddy) and plant maintenance must be considered (Adeyemi *et al.*, 1985). Subsequent studies have also addressed quality parameters of new rice varieties (Oko *et al.*, 2012) and challenges facing Nigerian rice industry (Ajala and Gana, 2015).

CONCLUSION & RECOMMENDATIONS

Mr Vice-Chancellor Sir, in concluding this lecture, I hereby make the following recommendations as highlighted below:

i. Cereals in the Agricultural Revolution in Nigeria: Cereals are the major economic crops and occupy a major position as an article of trade globally. Currently, Nigeria could hardly meet her demand for cereals, not only for food and feed but also as industrial raw materials. It has been projected that the shortfall/surplus for cereals in sub-Saharan Africa, Nigeria inclusive, will amount to - 88.7 million tons by the year 2025, while the global figure has been estimated at 68.5 million tons (Dyson, 1999).The import of this, therefore, is the potentials for Nigeria to increase production, not only for home consumption but for export purposes. This could then bridge the vacuum that could be created in the envisaged low demand for crude oil in future.

ii. Improved Level of Funding for Cereal Breeding and Processing: There is the need to improve the level of funding for cereal research, especially in the areas of genetic engineering, chemistry, storage and processing. Nigeria cannot run away from the application of genetically modified foods which we are already consuming, anyway, regardless of the opposition. For Nigeria to be self-sufficient in cereals production, application of frontline technologies for agricultural production and post harvest operations must be adopted. A case in point is wheat production which was 150,000 MT in 2015 while the corresponding import was 4.1 MMT gulping about \$3.2 billion. It has been projected that Nigeria's wheat importation would reach a figure of 10 MMT by 2030 (ICARDA, 2015).

   It has been established that Nigeria has been growing rain fed wheat since the 16th century in Mambilla Plateau (Taraba State), Jos (Plateau State), Lake Chad basin area and Obudu (Cross River State), among other potential ecological zones (KPMG, 2016). Lake Chad Basin has been identified as traditional area of wheat production. Rather than our futile efforts at sourcing for crude oil in Lake Chad Basin area, a better and economically rewarding alternative would have been wheat. I had in the 80s assisted my colleagues at the Institute for Agricultural Research (IAR), Samaru in evaluating the quality of locally grown wheat from that region. The results had shown some elements of promise. The breeding programme should also include other cereals such as maize, sorghum, millet, rice and other cereal-like grains like amaranth and acha. Like most other Nigerian research institutes that exist mainly for administrative purposes, the National Cereals Research Institute (NCRI), Badeggi should be strategically positioned with different out stations, not only to carry out breeding but also to be fully equipped for postharvest research activities on grains peculiar to each ecological zone.

iii. Dearth of Cereal Scientists in Nigeria: The Nigerian research trend, especially within the University system is worrisome. Unlike in developed countries where each researcher pursues his / her narrow research interest, the current trend in Nigeria is a situation where most researchers do not focus on specific areas but can be regarded as 'jack of all trade'. This is not unexpected as facilities are not available to pursue narrow research interests. It is important therefore to train more personnel in the field of cereal science and technology and adequate facilities must be provided for teaching and research in relevant departments in various institutions and research institutes.

iv. Development of Traditional and Novel Foods for Export Purposes: Nigeria is rich in many traditional cereal foods and beverages, most of which are already going into extinction. Cereals are basic raw materials for several snacks and beverages which a young entrepreneur can invest in and earn a living. We live in a globalized world where tastes are being developed for exotic foods, snacks and beverages. This is an area that has not been tapped by Nigeria, rather, we imbibe more of foreign based products. Cereals have the potentials for reversing this trend.

ACKNOWLEDGMENTS

All glory and honour go to the Almighty God for the grace to give this lecture at this point in time in my academic career. It is indeed "A Measure of Grace" that I have enjoyed. "It is not by might, nor by power but by His grace and mercies (Zechariah 4: 6; Lamentations 3: 22 -). I therefore thank my Maker, the God of Heavens.

My parents, of blessed memory, Chief Zacchaeus Adewunmi Adeyemi (JP) and my mother, Madam Julianah Ebun Ledun, who in no small measure contributed to my educational development and deposited in me the principle of the fear of God, hard work and tolerance. I cannot forget my maternal grandmother, Mrs Dorcas Alayo Ledun, who like the Biblical Dorcas brought me up with caring and tender love coupled with resilience to survive in a competitive world. My appreciation also goes to my late mother-in-law, Mrs. Julianah Adenihun Ajibola, who was always available to fill in the gap while raising up our children whenever my wife and I had to leave home in the struggle to survive. My late admirable senior brother, Emeritus Professor Adedokun Adeyemi, a world renowned Professor of Criminology; played an unquantifiable role in propelling me right from the onset of my student days to the time he answered the call on

November 1st, 2016. He was, and still remains, a gem to me and my nuclear family.

The academic journey of a cereal scientist began at the University of Ibadan through a well thought out programme in Agricultural Biochemistry and Nutrition which provided the introductory background in Food Science. For this I am indebted, like my other colleagues, to the late Emeritus Professor V. A. Oyenuga and his wonderful team who showed and encouraged me into the realm of academics. They were and still are our role models.

Divine providence brought me in contact with my mentor in cereal science and technology, Professor Edward Banigo, who 'initiated' me into the field and recommended me to his supervisor for my doctoral work. He has been my mentor ever since through the love and affection he had shown over the years. I cannot quantify the words of advice and tutelage I received while working with Professor (Mrs) Bola Osifo. She deposited in me the art of scientific writing, vetting and editing at an early life of my academic career. My Ph.D. Supervisor, Dr H.G. Muller (of blessed memory), an international figure in cereal science and food rheology taught me what research discipline entails and the importance of research focus. He moulded my academic life and through him I had contact with the then leading and global experts in the field.

My appointment at the University of Ife, now Obafemi Awolowo University (OAU), Ile - Ife wouldn't have been possible if not for the role of Professor Patrick Ngoddy (FAS) who, through my curriculum vitae, believed in my capability. Through his insistence, I was offered the job as Lecturer II in the Department of Food Science and Technology in 1978. He, Professor Ngoddy, propelled me into several activities, including active participation in the activities of the Nigerian Institute of Food Science and Technology (NIFST) which later paid off in my career. I equally appreciate the Obafemi Awolowo University, Ile-Ife for providing the enabling environment for my research activities. I will always cherish past and present staff of the Department of Food Science and Technology, (OAU, Ile-Ife). Worthy of mentioning is Mr. Kunle Adetona for his technical support.

The contact I had with Professor Olusegun Oke (FAS) through our common research interest changed my academic base in 1990 to Oyo State University of Technology (OSUTECH) now Ladoke Akintola University of Technology (LAUTECH), Ogbomoso. This contact was partly responsible for the opportunities to combine my academic duties with administrative responsibilities. This also gave me the unique opportunity of midwifing the first Department of Food Science and Engineering in Nigeria. To all the present and past staff and students of the department, I say you are highly appreciated.

I want to express my gratitude to the following bodies and organizations for scholarships and awards enjoyed in the course of my educational and professional careers: Nigerian Cocoa Marketing Board, (1971-1972); UNICEF (1972-1973); Federal Government of Nigeria (1974-1978); The Dutch Government (March-June, 1980); and Association of Common wealth Universities (ACU) /Carnegie Corporation Senior Fellowship Award as Visiting Professor, University of Alberta, Edmonton, Canada: (July -November,1993).

The NIFST (Nigerian Institute of Food Science and Technology) family is a wonderful one which I passionately admire. I will ever be grateful for opportunities given me to serve culminating in my serving as the national president between 2008 and 2010. I therefore express my appreciation to the President and members of the Institute.

This inaugural lecture would not have been possible if not for the understanding and drive of the Dean of the Faculty of Engineering and Technology (FET), Professor K. A. Adebiyi, who was able to set all administrative machineries in motion for this lecture. Professor S. O. Jekayinfa is highly appreciated for stepping down to enable me to give this lecture today.

My students, undergraduate and postgraduate students especially at Masters level, whose works form the backbone of this lecture, I cannot thank you enough. All my thirteen Ph.D. graduates have given me academic satisfaction. How I wished all of them were in the same discipline as mine, cereal science! I wish to appreciate my academic daughter, Professor (Mrs) Bolanle Aishat Akinwande, who propelled and gave me words of encouragement at the time I almost gave up the intention of delivering this lecture.

The story of my academic journey cannot be complete without Bells University of Technology, Ota where I worked with men and women of honour and integrity in a disciplined academic environment. I appreciate all of you. God sparing our lives, individuals and other bodies/associations will be fully appreciated in my valedictory lecture in October 2018.

I wish to appreciate Professor Akin Odebunmi of the Department of English, University of Ibadan for the honour given to me to proof read the manuscript at very short notice. Mr Timilehin Alamu perfected the formatting of the manuscript and also prepared it for printing. He is highly appreciated for the sacrifice, dedication and working under pressure.

I cannot think of a better woman to have other than someone who has been divinely placed to make up for my inadequacies and areas of weaknesses. Olubamike Aduke has combined the virtues of a Deborah and a Dorcas. She is indeed the "bone of my bone" and "flesh of my flesh". The God Lord will grant her

the grace to enjoy the fruits of her labour. My biological children, Tola, Tolu, Tope and Toni, and their spouses, Segun (Sege),Yinka (APY), Akin (Akinzo) and Eniola (daughter, daughter), have all been sources of joy and appreciation to God for the lovely, wonderful and disciplined grandchildren God has given us through them.

To the entire LAUTECH community, I wish to place on record my admiration and appreciation for the love and respect always accorded me.

Finally, I wish to thank the Vice-Chancellor, Professor Adeniyi S. Gbadegesin for the opportunity given to me not only to deliver this inaugural lecture but also for encouraging and propelling me in getting the manuscript prepared. Furthermore, as a member of one of the committees that prepared the working curricula at the establishment of the University in April, 1990 and as a foundation Professor at the take-off in September same year, and having played prominent roles in the growth and development of this institution, we had our goals, aspirations and dreams in line with the vision of the founding fathers. I want to seize this forum to formally appreciate the Vice-Chancellor for the new lease of life and directional leadership in his strive to build a true academic community in line with the dreams and wishes of the founding fathers and previous academic 'pilgrims'. We are not yet there. I hope and pray that the momentum would be sustained.

I thank you all for coming and for your attention.

May the good Lord grant you journey mercies to your various destinations.

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