UNIVERSITY OF PORT HARCOURT

PLANT PATHOLOGY AND POST-HARVEST FOOD LOSS

An Inaugural lecture

By

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DEDICATION

This work is dedicated to

My wife, Stalla

And

Our children, Anthony Chinedu Arinze Jnr (late),

Mrs Chineze Ajua, Chuwuemeka, Chijioke and

Chinyei.

Vice-Chancellor, Sir,
Members of Governing Council,
Deputy Vice-Chancellors,
Principal Officers of the University,
Provost, College of Health Science,
Dean of Graduate School,
Deans of Faculties,
Distinguished Professors & Scholars,
Heads of Departments,
Staff & Students of this Great University,
Distinguished Guests,
Ladies & Gentlemen.

Going by tradition, a Professorial inaugural lectures is an academic exercise in which a Professor at sometime during his/her professorship is expected to formally tell the community what he/she has been professing. The Professor, because of the mixed audience is expected to avoid professional jargons so that he can be understood by all. I intend in this lecture to do just that. I must sincerely thank the Vice-Chancellor for the opportunity given me to deliver this lecture and I thank you all for gathering here to hear me out.

The first time I was asked to say what I have been professing was at my professorial interview. I was required by the examiner to say in a few sentences what I had been doing. I did; my sentences were few. Today I am being asked the same question; this time not briefly but to take up to 1 hour or more to explain. It is indeed a privilege and I want to thank the Vice-Chancellor, once again, for the opportunity.

Permit me, at this stage to pay tribute to Professor SHZ Naqvi and late Professor J. A. Ekundayo under whose tutelage at the University of Lagos I was first introduced to the subject of post harvest Pathology. These two distinguished Professors also taught me to always “keep it simple”.

I have chosen for this lecture the topic “Plant Pathology and Post Harvest Food Loss”.

Distinguished audience, this lecturer is a Plant Pathologist. The Dictionary defines Pathology as “the branch of medicine concerned with the causes and effects of diseases. Of course it is clear from this definition that that medicine being referred to is human medicine or speaking generally animal medicine. Plant medicine or phytomedicine as it is called in some developed world is relatively unknown principally because the plants we treat do not talk, do not complain, do not cry as little children do in hospitals; they show no emotions, yet we treat them,. When human patients complain, doctors and nurses run around to bring them succor. When our dogs and cats are sick we run to the Vet Doctor. Sickness is never attributed to plants because they neither complain nor show emotional distress. Many People do not know that just as you have paediatricians, we also have phytiatricians. As plant pathologists we deal with diseases of plants is our concern. Our clinics are our research laboratories in the Agric Research Institutes and in the Universities where and when they are provided!

PLANT DISEASES OVER THE YEARS

Plant diseases are now new. Indeed they are as old as man!

The importance and plane of plant diseases dates from Biblical times (1King 8: 36, 37, 39).

After Solomon had built the Temple of God and brought in the ARK of the Covenant, he prayed for his people, the people of Israel

> *"Should there be famine in the land or PESTILENCE, BLIGHT or MILDEW, locust OR Caterpillar……………*

Hear from heaven where your home is, forgive and act dealing with each as his conduct deserves. For you know every heart – you alone know the hearts of all mankind – and so they may come to revere you as long as they live in the land you gave to our fathers". I king 8: 37, 40.

The references to *blasting, mildews,* locust, caterpillar and invasion by *ENEMIES* show that plant disease and insect pest were a menance at those times. However the ancient Hebrews associated these diseases and pest with the anger of GOD as a punishment form men's doing. Rightly they attempted to prevent these diseases and pests by prayers and righteous living. From the biblical times to the ancient Greece, through the Romans into the Christian era, there have been several ceremonies and rituals performed to solve the problem of plant diseases especially the *Rust* and *Mildews* of wheat and barley as well as the Ergot of rye (see Shakespeare's – King Lear Act III, Scene IV). Those 16^{th} century diseases are still here with us TODAY!

All sorts of superstitious beliefs and wrong deductions persisted until the arrival of the microscope revealed the world of plant pathogens. Even after the invention of the microscope in 1590, by Leeuwenhook, it took 100 years again for people to understand microorganisms.

The first known attempt to alleviate a plant/disease situation was in 1660, when a law was passed in France requiring the eradication of barberry bushes because of the evidence that the rusts of cereals were prevalent in their vicinity. During the 19th century, a causal relationship between fungi and plant diseases had been accumulated but many scientists still believed that the fungi were the *result* rather than the *cause* of the diseases. It took centuries to free the minds of even scientists from misconceptions and misinterpretations.

Between 1830 *and* 1840, the Potato Blight devastated Western Europe and N. America. In Ireland where potato was the lifewire of the people, about one million people were said to have died of starvation. The result of these two calamities was the intensive study of the nature and cause of plant disease. We note here the efforts of De Bary, the father of modern plant pathology who showed conclusively that the *fungi* could cause plant disease. The discovery that bacteria and viruses also cause plant diseases followed shortly.

WHY STUDY PLANT PATHOLOGY/ SIGNIFICANCE OF PLAT DISEASES

1. Plant diseases constitute one of natural hazards in crop production. Other natural hazards are insect pests and unfavourable weather. These hazards are usually unexpected and when they occur, can have very destructive effects especially when the conditions are favourable for devastation.
2. In a word where man is constantly menaced by starvation and malnutrition, losses in crop due to diseases and pests cannot be taken lightly,
3. Diseases cause actual damage to plant. We cannot here begin to lecture on the importance or plants to life. Professor Onofeghara in his inaugural lecture 1986 titled "Botany and Human Affairs" and that beautifully.
4. Attempts at the control and prevention of plant diseases cost money.
5. Effects on plant products.
   (a) The problem of storage moulds, rots of crops
   (b) Destruction of wood and wood products
   (c) Food poison e.g. Ergot poisoning due to (*laviceps purpurea;* also botulism, Aspergillosis, mycotoxicoses (Aflatoxins).
   (d) Disfiguring of food products can reduce their market value e.g. scabs, blotches, spots on leaves/vegetables and on ornamental plants.

6. Plant diseases have not only affected movement of populations but have also affected social habits. For example, it is believed that Britain is today an island of tea drinkers instead of coffee drinkers because of the effect of coffee *rust* in Ceylon (now Srilanka) between 1970 – 1892.

Permit me at this stage Mr. Vice-chancellor to pay tribute to those Nigerian plant pathologists who have been working silently and assiduously along with plant breeders to ensure that we grow today not only *high yielding* but *disease free crops.* These plant pathologists are busy in the various Agricultural Research Institutes of this country – IITA, NRCRI, RRIN, FRIN, CRIN, NCRI, SPRIN, NIHORT, and it is hoped that very soon our own IAR UBIPORT will join them.

As consumers of plants and plant product, we take a lot of things for granted. We are hardly conscious of the changes that continually take place in our farms and market environments. Today the yams, maize, cassava, sweet potato, beans which we grow in our farms and consume in our homes are not the same as what we and our fathers grew and consumed fifty years ago. These plants have been modified by *breeders* and *pathologists* for the benefit of mankind.

Mr. Vice Chancellor, Sir, I profess Physiological Plant Pathology within the sphere of post-harvest pathology. I therefore deal primarily with post-harvest diseases or what are called market or storage diseases. I have chosen the topic, “Plant Pathology and Food Loss”, to call attention to the national disaster caused by pathological factors which reduce the quality and quantity of the farmers produce and deny us food on our tables.

In Sept 1975, the United Nations General Assembly sitting in N. Y. resolved thus:
“The further reduction of post harvest food losses in developing countries should be taken as a matter of priority, with a view to reaching at least a 50% reduction by 1985. All countries and competent international organizations should cooperate financially and technically in the effort to achieve this objective”

How did Nigeria fare and how is it faring in meeting this UN objective. Were we able to reduce post harvest loss by 50% in 1985 and have we been able to do so twenty years after the declaration?

For long the solution to food shortage in the world has been centred on increased production by farmers in the field. It was assumed then that increase in production would solve the problem of hunger and starvation. Unfortunately, although we have been successful in increasing production in the field, we have not been successful in *protecting* the food we have produced. The result of this failure is that much of what is produced is lost primarily due to *poor post harvest handling and storage.* It is only recently that attention has been seriously focused on post harvest losses in contributing to world hunger. Apart from the direct economic loss to the farmer and the nation, post harvest loss reduces the nutrients available to the population and so hunger and malnutrition are direct consequences. There is, therefore, no incentive for a farmer to raise the level of his production in the field if he is faced with the realism that high percentage his produce will be lost after harvest.

More often them not, because we are in a hurry "to develop", solution to problems of post harvest loss (as indeed many of our problems) are on an adhoc basis. The result of this adhoc approach is that the solutions we proffer are not lasting because the problems are hardly approached from first principles. This realization has informed the approach adopted here of firstly attempting to understanding the nature and cause of the problem before recommending solutions based on our findings.

NATURE OF THE PROBLEM

The tropical environment, our environment, has special problems of food loss which are not experienced by the sub-tropical and temperate regions of the world. These problems arise from the special *climatic factors* of the zone as well as the socio-*economic* problems which the inhabitants of the area have to grapple with. Indeed it has been stated that even if the tropical countries had the same *per capita* incomes as the countries in the developed world (which are invariable located in temperate climates) they would still be fighting an uphill task in their attempt to preserve what they have produced.

CLIMATIC FACTORS

1. **High Temperature**

The tropical environment, our environment, is characterized by high temperature, 20 – 40^0C, all the year round with the mean at

25 – 30^{0}C. This high temperature is very suitable for the rapid multiplication of not only disease causing agents but also of such pests as rats and insects which pose serious problems to storage of produce. Observation shows that in contrast, in temperate climate, the activity of these pests is drastically slowed down when the temperatures drop below 15^{0}C. Indeed when the temperatures fall to as low as 0^{0}C, a number of these organisms are killed and it is only the very resistant ones that survive the extreme cold.

Furthermore, the high temperature of the tropics has its adverse effect pm the keeping quality of the harvested crops. The chemical and biochemical changes which occur in tem proceed at a faster rate as a high temperature than at a low temperature. The result of these biochemical changes is rapid deterioration of the crops. For is appreciably reduced resulting in irreversible conversion to sugars. The sugars are then quickly oxidized resulting in low food reserve in the tissue.

Sprouting also occurs more readily at a high temperature than at a lower temperature. It means, therefore, that to successfully prevent loss of the harvested crops, resulting directly from a high temperature, some kind of cooling is necessary.

2. **High Humidity**

In the rain forest belt of Nigeria the relative humidity most of the time is 80% and more. This is to say that the moisture content of the atmosphere, most of the time, is high. Again, this poses a problem because microorganisms causing deterioration of harvested crops are *more active when the moisture content of their environment is high.* If the moisture content of the food material is low, the organisms are less active. However if the moisture content of the food is reduced in order to prevent microbial attack, *the food material absorbs water from the atmosphere in order to maintain equilibrium with the surrounding air.* Thus, it is practically difficult to reduce the moisture content below the level in the atmosphere. This situation does not arise in the temperate regions where the relative humidity is humidity is below 80%.

SOCIO-ECONOMIC FACTORS

Our country, like many other developing countries, belongs to the Third World category with all its implications. We are characterized by low level technology, financial constraints and large populations. The first two factors have resulted in the lack of the infrastructure for proper storage of food products.

i. Lack of know-how

Unlike the developed countries our country lacks adequate number of experienced personnel with relevant knowledge of the techniques of harvesting, handling, transportation, packing and storage of different crops. This lack of information is on three different levels. Firstly, at the research level-not enough research is being carried out locally and regionally to arrive at recommendations to overcome the problems. Secondly, there is lack of information at farmer's level in terms of knowing what to do about the problems and thirdly there is lack of information at the handler (seller) stage. Experience shows that even when information is available, there is lack of interest – because of poor incentive arising from poor wages. The overriding factor is that because of the socio-economic problems, our-farmers are not really committed seriously to seek knowledge on storage technology. The result is high percentage loss.

ii. **Poor Packaging**

There are no proper packaging materials. Baskets, bags, basins are simply used to pack goods of all types without special attention being given to suitability of the containers for the specific crop. The larger root tubers e.g. yams are simply heaped on market floors and from there packed on lorry floors for transportation from one place to another. There are no scientifically designed containers and the results is that loss results from *bruising, scarring, squeezing, poor ventilation* and, of course, rot.

iii. **Poor Transportation**

This problem ranges from complete absence of roads to poor condition of the available roads and poorly structured transporting trucks. When there are no roads at all, the harvested crops cannot all be carried to the main roads where the vehicles ply. The farmers usually carry their produce on their heads and walk long distances either to the main roads or to homes. Where the harvest is abundant, not all of it may be carried or it may take a longer time to carry all to the destination. The result of this delay may be over-ripening before the market is reached or outright deterioration at the farm site.

The condition of the roads is also a major contributory factor in encouraging damage. The roads are often rough, unkempt and dotted with gaping pot-holes. Perishable goods carried by vehicles plying on these roads cannot be expected to reach their destination in a healthy state.

Finally, the condition of the vehicles themselves is not suitable for carrying perishable agricultural materials. It is not uncommon to see people in lorries perching on the top of huge bags in which these agricultural produce are packed. The result of these is mechanical damage.

iv. **Absence of Proper Storage Facilities.**

A majority of our farmers do not indeed consider storage as a necessary part of the farming system. As indicated earlier, there is an overwhelming obsession to increase yield without the attendant realization to provide storage facilities. Where the result is loss arising principally from poor ventilation, microbial decay and biodegradation arising from high temperature of storage. Again because of the lack of proper storage, the produce is pushed to the market and where some of the harvest are already deteriorating they are sold at give-away prices resulting in market losses.

v. **Absence of Facilities for Processing**

Although in some developing countries, considerable success has been achieved in processing some produce such as tomatoes and citrus, there are no processing facilities for a lot of other food crops. This lack of processing technology gives the impression of abundant harvest or indeed of over production.

If the produce were processed as soon as they were harvested wastage would be greatly minimized. Limited success is achieved by the available traditional means of processing a few crops. This is mainly because of consumer preferences for food in their fresh rather than processed states.

vi. **Marketing System**

The market arrangement in Nigeria is another factor which encourages loss of produce. Because farmers operate at subsistence level they have to harvest their crops in order to meet the particular market where they will sell. Sometimes because of this pressure, immature crops are harvested or the grains requiring drying would not be properly dried. *Instances, abound where garri, a processed product of cassava, is improperly processed because of the rush to meet a market day.* Furthermore, with market days being confined to specific days of the week, limitation is imposed on the days harvest may be made. Outside these days, crops ready for harvest are wasted as they may become overripe. Furthermore the activity of the middlemen sometimes aggravates the problem instead of solving it. Often in an attempt to maximize profit the middle man accumulates more crop than he can properly store with the hope of creating artificial scarcity.

In course of this, food is lost owing to poor storage. Furthermore, inside the market the crops are kept on insanitary floors; they are squeezed with bare hands by prospective buyers in order to determine their quality. Finally, the effect of the scorching sum on the produce in the open markets aids rapid deterioration of the corps. Often the heat from the sum is sufficient to "cook" the crops in the markets before they are bought.

HOW MUCH FOOD IS LOST

> *"If a farmer was told ½ or 1/3 of his grain had been stolen one night he would surely become very angry and make a great effort to recover his stolen property and punish the thief, yet each year many farmers lose 20 – 30% of their harvested grain, a little at a time, from the action of rats, birds, insects, molds and other causes. These stealthy thieves help to keep him in poverty and his family under-nourished." David Ditcher (1976).*

It is not easy to say for certain how much food is lost both directly and indirectly from the moment the food is harvested up to the time it is consumed. There is a great deal of variability in the amount of food lost in the tropics and this depends on a number of factors.

(a) The conditions of handing of the food in the particular country

(b) The type of food substance being considered.

(c) The length of time that the food can be store.

Tropical countries generally labeled “developing” are at different levels of development and as such at different levels in their capacity to handle the problem. Also, perishable crops naturally store poorly and record much higher losses than the non-perishables and, of course, the longer the period of storage the greater the loss. Because of these variables it is difficult to obtain reliable statistics on post harvest losses. Often, a wide range of figures for a particular crop is quoted to give room for variations. Indeed, it is possible to find losses for a particular crop ranging from 0-100% but average figures are usually quoted. A presumably reliable estimate is the figures quoted by F. A. O. In developing its action programme for Prevention of Food Losses, F. A. O. estimate that 10% of cereal grains is lost by *all developing countries* and that losses of up to 25-50% occurs in perishables in some tropical countries. The figure definitely exceeds 30% in most of these developing countries.

Table 1: Post-Harvest Losses by Country

Country	Root/Tubers % Loss	Fruits/Veg. % Loss
Ghana	10 – 20	30 – 35
Nigeria	15 – 60	10 – 50
Rwanda	5 – 40	50
Indonesia	10	25
Malaysia		20
India		20 – 30
LATIN AMERICA		
Dominican Rep.	24 – 26	25
Chile	30	30
Brazi	5 – 30	8 – 10
Bolivia	30 – 50	17 - 30

Source: *United State National Academy of Science (1978)*

If a comparative extrapolation of losses is made in monetary terms, the value of the losses is staggering. For example, using this conservative estimate a National Academy of Science (1978) loss estimate shows that staggering sum of 11 billion dollars was lost in 1985 by developing countries. From these figures it is easy to see the magnitude of the problem especially for perishable crops. No responsible government can in fact afford to hold its hands while losses continue to occur. The figures are enough justification for concerted action by all developing countries to reduce losses to a tolerable level.

Commodity	Production in Developing Countries (1,000 tons)	Estimated Losses (%)
Grains and Legumes		
Rice	349,782	1-40
Maize	111,113	2-40
Sorghum	47,931	0-37
Roots/Tubers		
Carrots	557	44
Potatoes	26,909	5-40
Sweet Potatoes	17,630	33-95
Yams	20,000	10-60
Cassava	103,486	10-25
Vegetables		
Onions	6,474	16-35
Tomato	12,755	5-50
Fruits		
Banana	36,998	20-80
Citrus	22,040	20-95
Grapes	12-720	27

Data from FAO Production Yearbook (1978) and National Academy of Science Report (1978)

CAUSES OF LOSS

It is tempting to attempt to classify the causes of disorders in post harvest produce purely on etiological basis i.e. the basis of what causes what. This has the advantage of knowing what remedy to apply to eliminate the cause or reduce the disease severity. There is also an advantage in classifying loss on the basis of where in the production, marketing and consumption chain the loss occurs or where in the chain the condition has been created for its manifestation later. This is advantageous in knowing where along the chain control measures may be

Applied and more importantly it is easier to recommend workable preventive measures since the actual origin of a defect can be traced. We shall attempt to marry both methods because of their obvious advantages.

We shall therefore classify causes of losses as those resulting from:

(a) Poor handling factors
(b) Environmental factors
(c) Parasitic disease factors

It will be appreciated that the activity of man holds the key to proper management of crops, and that it is mostly mismanagement by man (Factor a) that aggravates and sometimes even causes factors b and c. Factors interact to cause loss and so sometimes a multidisciplinary approach is advocated in recommending control measures. An understanding of the factors which lead to the manifestation of symptoms is important before control measures can be recommended.

A POOR HANDLING FACTORS

Perhaps the best way to appreciate the various factors responsible for loss either directly or indirectly is to approach the subject by looking at the various stages which a harvested crop, goes through before it is processed or consumed. Depending on the nature of the crop, the stages might be few or many. Naturally, where a crop has to be processed before consumption the processes undergone would be more than that for a crop which is consumed directly. For convenience we shall consider only 2 groups of crops: the fruits/vegetables and the tubers. Among tubers, cassava, shall be treated separately because of its peculiarity.

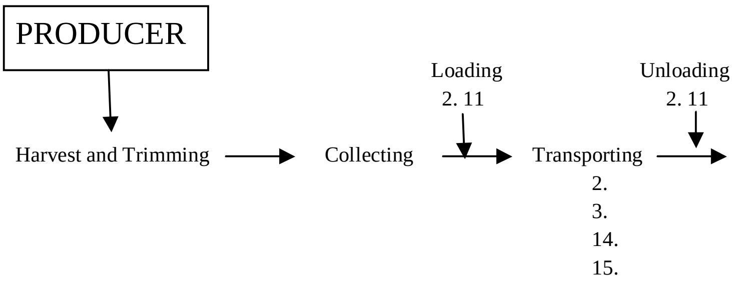
In discussing the handling steps for these broad groups of crops the situations (factors) which cause loss in each of the steps will be indicated. It is evident that some factors will contribute more to loss than others in each step, and as indicated earlier, particular crops in each grouping will be affected to different degrees.

POST HARVEST HANDLING STEPS FOR FURITS AND VEGETABLES

The fruits and vegetables have been described as high perishable crops. The most important characteristics which affect their life are their high moisture content (50-95%) and their high rate of respiration and other metabolic processes. Other factors contributing to loss are their general soft texture, lack of hard protective covers and their large size as compared to grains. These factors make it possible for the crops to be easily damaged and hence they deteriorate very fast. A major problem in handling these crops is that they are required or preferred fresh by the consumer and as such effort has to be made to keep them as fresh as they were at harvest. Being highly delicate crops, changes in the quality characteristics of appearance, feel and texture are readily discernible by the buyer and result in market loss. Furthermore, because of their high moisture content, any changes in the environmental condition irreversibly affect the quality of the crops.

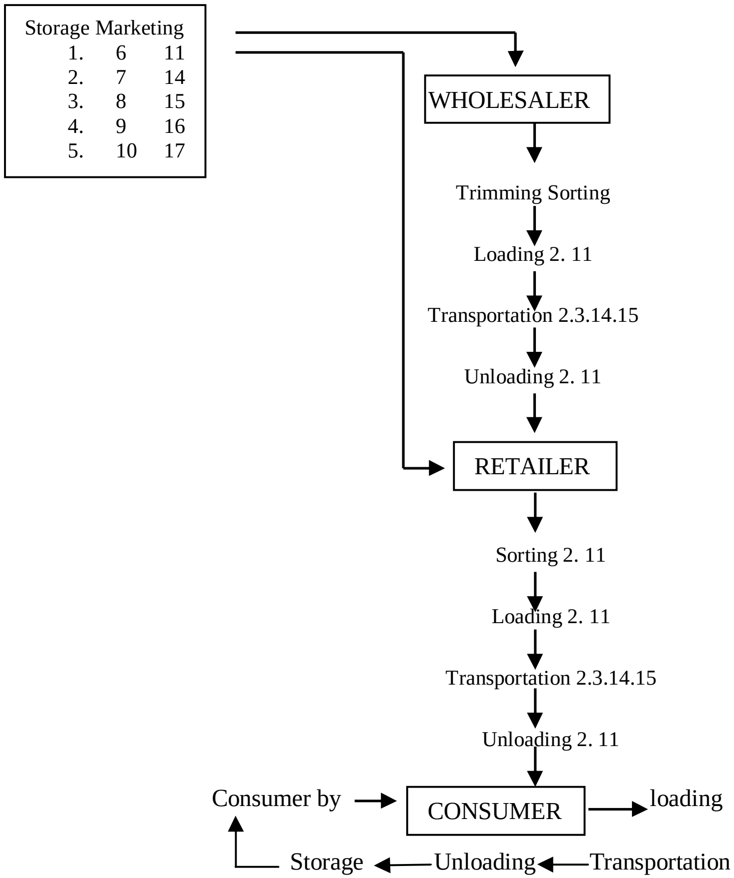
Losses occur during the handling steps in Fig. 1.

FIG 1. POST HARVEST HANDLING STEPS FOR FRESH FRUITS AND VEGETABLES



Loss causing factors

1. Immaturity/Over maturity
2. Mechancial damage
3. Tissue breakdown
4. Sprouting
5. Crushing
6. Bruises
7. Poor Ventilation
8. Over ripening
9. Rotting/decay/spoilage
10. Browning
11. Loss in no.
12. Insect damage
13. Puffiness
14. Shrivelling/wilting
15. Weight loss
16. Poor sanitation
17. High temp. cooking.



Storage Marketing
1. 6 11
2. 7 14
3. 8 15
4. 9 16
5. 10 17
WHOLESALER
Trimming Sorting
Loading 2. 11
Transportation 2.3.14.15
Unloading 2. 11
RETAILER
Sorting 2. 11
Loading 2. 11
Transportation 2.3.14.15
Unloading 2. 11
Consumer by
CONSUMER
loading
Storage
Unloading
Transportation

HARVEST LOSSES

(1) **Immaturity:** Some fruits e.g. oranges need to mature before harvesting. If harvested immature, it is waste.

(2) **Overmaturity:** Other fruits e.g. Okro should be harvested before they mature. If harvested overmature the fruit is fibrous and unacceptable. Sometimes overmaturity leads to over-ripening and microbial deterioration.

(3) **Mechanical Damage:** Bruising, crushing and cuts on the skin of the produce result from unsuitable harvesting tools and from falling from considerable heights well as careless handling during harvesting operations.

TRANSPORTATION LOSSES

(1) **Poor Packaging:** A major setback suffered by fruits and vegetables during transportation is the type of container in which these crops are packed. Generally the containers are of poor quality consisting usually of baskets and jute bags. Well aerated wooden crates are not used in many areas because they are more expensive. In their study on the loss of vegetables and fruits in Asia. Mendoza Pantastico and Bauitista (1980) reported that there was a loss of 34.7% when pepper was transported in wooden crates as against 48.1% when bamboo baskets were used. Also a loss of 9.4% was recorded when tomatoes was transported in wooden crates against 12.2% when bamboo baskets were used. The result is either crushing, cut and bruises or loss due to poor ventilation.

(2) **Rough Handling:** This causes considerable mechanical injuries. Rough handling takes place mostly during the process of loading and unloading. This is further aggravated by the condition of the roads along which the crops are carried. As mentioned earlier, many of the feeder roads leading from the farming areas to the major trunk roads are laterite roads with uneven surfaces and the rocking movement of the vehicles is sufficient to damage such delicate crops.

It is not uncommon to find perishable crops being covered with tarpaulins which will not permit any ventilation. The produce are usually piled high at the back of the trucks and when not covered, the crops are exposed to the scorching heat of the sum during transit. The heat built up results in later rapid deterioration of the products.

STORAGE/MARKETING LOSSES

Because of the nature of the crops as indicated earlier, the producer, wholesaler, the retailer and the consumer cannot afford any delay in handling the crops. Even under the best storage conditions available, fruits and vegetable have a short storage life. In fact, some fruits and leafy vegetables cannot be kept for more than 2 – 7 days. Every handler of these crops would prefer not to store them if they can have ready market for them. Where ready market is not available and the crops must be stored for sometime, the following loss situations become inevitable.

(1) **Physiological Breakdown:**

As perishable crops with a high metabolic rate, the tissues readily deteriorate because of internal physiological processes. The enzymes presents in the fruits naturally help to bring about deterioration resulting in tissue softening, yellowing, browning, formation of fibrous materials and production of undesirable flavours. Bulbs (e.g onions), on the other hand sprout readily if the temperature of storage is high. Wright et. Al. (1935) showed that in general the amount of sprouting in onions was little influenced by humidity but increased with increase in temperature (over a range of 0 – 10^{0}C) whereas rooting increased with humidity and was little influenced by temperature. Furthermore, a number of fruits and vegetable (e.g tomatoes) produce the gas, ethylene, during storage. This gas accelerates the metabolic activity of the living tissues thus accelerating deterioration.

(2) **Mechanical Damage and its Consequences:**

The effect of mechanical damage caused during the harvesting operation manifests during storage and marketing. The wounds created during the operation are ready portals of entry for rot – causing microorganisms – moulds and bacteria which readily devastated the tissues causing soft rots. Furthermore, because of the marketing arrangement, customers are usually permitted to feel by touching the produce to determine their quality, thereby inadvertently causing bruising and crushing of the fruits and vegetables. These bruises not only lower the quality of the produce but also are avenues of entry for rot-causing microorganisms.

(3) **Shrivelling/Wilting/Weight Loss**

Fruits and vegetables are often exposed on market floors and tables under the heat of the scorching sun. The crops as a result lose water, and shrivel. This is an important source of loss. Also since many fruits and vegetables are sold on the basis of their weight, the attendant weight loss results in market loss. And of course the heat of the sun accelerates physiological breakdown resulting in discoloration and of softening of the produce.

(4) **Over-Ripening**

Like the other factors discussed above, over-ripening in storage or in the market occurs because of delay in consumption of the produce. Here again the product quality prior to marketing is significant. For example, tomatoes should be harvested and marketed when the fruits is mature and green not when it is already ripened.

(5) **Poor Packaging/Ventilation/Sanitation**

Both in storage and in market the products suffer from poor packaging, poor ventilation and poor sanitation. In markets, where there are no proper packaging materials, ventilation is hardly taken into consideration. This causes physiological breakdown. The sanitary conditions of most markets are also appalling, and so the environment is a ready source of pathogenic microorganisms. The practice of mixing rotten vegetable materials with the health ones helps to contaminate the health ones. This practice is common in areas where for economic reasons consumers are not very mindful of the quality of what they buy. There is also the deliberate attempt by the seller to deceive the consumers by concealing the diseased fruits and vegetables beneath the health ones. This practice usually boomerangs as the disease usually quickly spreads to the sound ones resulting in rapid loss of all produce.

The loss situation described above though referring specifically to the producer are applicable to the retailer, wholesaler and consumer. All of them need to purchase the produce, transport, and store for varying lengths of time. At the consumer level loss is generally less especially as many of the products are hardly stored at home and used within a few days. With the small enlightened percentage of the population, longer period of storage in refrigerators and deep freezers is possible. Furthermore produce showing early signs of deterioration are consumed first resulting in the overall lessening of food loss. At whichever level of handling it must be emphasized that the most important consideration in the handling of fresh fruits and vegetable is the maintenance of the freshness and no matter how efficient the systems of handling, delay cannot be afforded.

POST HARVEST HANDLING STEPS FOR ROOTS AND TUBERS

Like the fresh fruits and vegetables discussed above, the main roots and tubers cultivated in the tropics (cassava, cocoyam, potato, sweet potato and yams) are highly perishable crops. They thus share with the fruits and vegetables a number of characteristics which affect their life-the most important being **their high moisture content and high respiration rates.**

In discussing the handling system of these tubers, we shall consider cassava as a "special crop" because of its special characteristics which make it impossible for it to be stored like the other tubers. The others have two features which are peculiar to them and which are significant in postharvest handling. These are; their ability to stay dormant for some time, and the breaking of dormancy resulting in sprouting.

HARVESTING LOSS

1. **Immaturity:** The scarcity of food during the growing season is often responsible the for producer harvesting the root crops before they are mature. When, for example, yams are harvested before they mature the tail end of the tuber has a bitter taste. This part of the yam is consequently cut off before cooking resulting in loss. And of course the immature yams do not attract good price in the market. Furthermore, food processed with immature tubers usually have off-flavours.

2. **Overmaturity:** For the root crops the only problem of over-maturity is that tubers are exposed to attack by soil insects, and microorganisms which result in damaged before they are lifted from the soil. Indeed for a crop like cassava because of the poor storability of the tubers the practice is to leave the tubers in the soil for many years after maturity until when the producer has need for them. Of course as a result of this practice, a number of the tubers suffer from pre-harvest rot problems.

The handling steps are represented diagrammatically in fig. 2.

FIG. 2 POST HARVEST HANDLING STEPS FOR ROOTS AND TUBERS

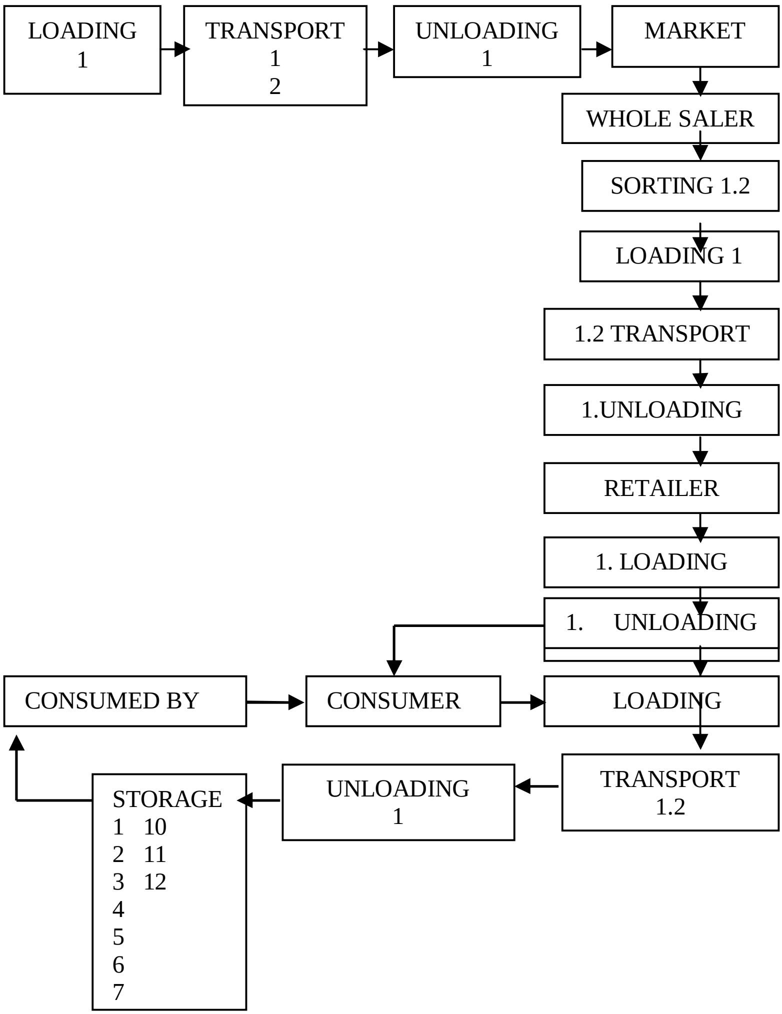
PRODUCER

HARVEST →	COLLECTING →	LOADING →	TRANSPORTING →	STORES INBARNS etc.
2	1	1	2	1
7	2		10	2
8	7			3
9				4
				5
				6
				7
				10
				11
				12

Loss causing factors

1. **Mechanical damage- Crushing/bruises**
2. **Severe cuts**
3. **Poor sanitation**
4. **Poor ventilation**
5. **Rotting-fungi/bacterial**
6. **Spouting**
7. **High temp. exposure**

9 Soil insects/Rodents attack
10 Immaturity
11 Nematode attack manifests
12 Tissue breakdown



3. **Mechanical Damage/Cuts:** The type of harvesting instruments used and the degree of care taken during harvest determine the extent of mechanical damage suffered by the tubers.

The harvesting instruments range from cutlasses, hoes, chisels, pointed sticks to mattocks. If not properly used, these implements can variously caused deep or shallow cuts on the tubers.

4. **High Temperature Exposure:** Freshly harvested tubers are not immediately protected from the direct heat of the sun. After lifting from the ground, the tubers are gathered and the soil removed from the body with sticks or blunt knives. In many communities it is traditional to give the yams identity marks after which they are left on the soil surface until the producer is ready to move them. While on the farm site there is little or no provision to protect the tubers from the direct sun. The result is an initial “cooking” by the heat from the sun. Although some heat is necessary to quicken healing of wounds created on the tuber this direct heat from the sun is not regulated.

5. **Bruising/Crushing:** The bruising and crushing of the tubers which become intensified during transportation and marketing sometimes commence during harvesting operations. These occur during carless handling, after the tubers have been lifted from the soil. This can happen at the collection centre of the tubers either when the soil is being remove from the tubers or when the yam tubers are being marked or indeed when the tubers are being deposited in heaps by women and children.

TRANSPORTATION LOSSES

Roots and tubers suffer virtually from similar transportation losses as do fruits and vegetables. As indicated earlier the transportation losses are caused by *poor or lack of proper containers* for packing the produce, careless handing of the produce during loading and unlading of the transporting vehicles, use of transportation vehicles poorly equipped to transport delicate perishable crops and the poor condition of the feeder or minor roads. These deficiencies in the transport arrangement result in one or more of the following: bruising and crushing of the tubers, complete shattering of the tubers (especially yam tubers). And exposure of the tubers to direct heat of the sun during transportation.

It is pertinent to restate that these transportation losses occur at every level of transportation in the handling steps (see Fig. 2) whether at the producer, wholesaler, retailer or consumer level.

STORAGE LOSSES

With the exception of cassava, all the tubers can be stored for a considerable length of time without losing their quality before consumption. A critical factor again influencing the degree of loss at any level of the handling step is the length of time that the handler stores the tubers. *If the producer quickly disposes of the tubers* to the retailer who in turn sells to the consumer without much delay the likelihood is that the tubers would be consumed without the storage loss situation manifesting. Another important factor to be considered is the *initial quality of the tubers before storage.* In order to be of high quality when the tubes reach the consumer it is essential that the tubers have an initial high quality. This means that the problems associated with harvesting and transportation must be reduced to be barest minimum. Depending on the degree of care taken to eliminate these harvesting and transportation problems the following storage losses may or may not be severe.

1. Loss from bruising and crushing
2. Loss from over exposure to high temperature resulting in scabs formed beneath the skin cover.
3. Loss from rotting/decay of tissues.
4. Loss from weight-loss.
5. Loss from mechanical damage or serve cuts
6. Loss from poorly constructed storage houses or barns which result in poor ventilation.
7. Loss from poor sanitation
8. Loss from tissues breakdown
9. Loss from sprouting.

SPROUTING

With the exception of loss from sprouting which was briefly mentioned in connection with onion bulbs, all the other storage losses had been considered under fruits and vegetables. The same principles of storage loss occur in both group of crops. With the exception of cassava roots which are not organs of perennation nor propagation, sprouting is an important attribute of the roots with adventitious buds and tubers because of the high level of food reserves, principally starch in these crops. Tubers are normally dormant at maturity and the period of dormancy usually varies from species to species and with the cultivar and depends on the conditions under which the tubers are stored.

At the break in dormancy and consequent sprouting during storage, the stored *starch gets converted to sugar* which supports the development of the new plant and is utilized for the *increased respiration which occurs during sprouting.* There is thus loss of food reserves as well as increased moisture loss resulting from sprouting. Sprouting is known to increase with increase in storage temperature up to a certain maximum. Studies conducted on yams (Coursey, 1961) potato (Burton, 1966), sweet potato (Kushman and Wright, 1961) and on the cocoyams (Gollifer and Booth, 1973) show the amount of losses that can occur in these crops as a result of sprouting. *Indeed all the food reserve in the stored tubers can be lost in a matter of days if sprouting is not checked.*

Market Losses

A visit to a typical yam market in one of the big cities in Southern Nigeria will show the very poor market conditions under which the yam tubers are sold. In these markets, the yams suffer from losses similar to those enumerated under storage. This is because the yams on display are in a way also in storage since they may remain "stored" in those markets for several months waiting for buyers. Specifically the following storage losses are aggravated by the market situation.

1. **High temperature cooking:**

The yams are piled up and exposed to the direct heat of the sun. This results in rapid loss of water and the attendant shriveling.

2. **Poor Ventilation:**

Because of the huge heaps of the tubers several tubers at the bottom of the pile will suffer from poor ventilation. The result is poor respiration giving rise to *respirational disorders* enumerated earlier.

3. **Rotting/Decay:**

Depending on the length of time the tubers are exposed in these markets the harvesting, transporting and storage infections by microorganisms can be aggravated in the markets. The non-removal of decayed tubers form the immediate vicinity of the healthy ones provide ready source of inoculums for infection and re-infection.

SUMMARY

From the above account on the *handling causes* of loss of postharvest food crops what clearly emerges is that anybody involved with postharvest handing of food crops should take every possible precaution to

(a) Understand the requirements of the crop one is handing.

(b) Appreciate that *all fresh produce are living* and should be treated as living organisms.

(c) Evaluate the situations which can possibly result in the loss of the produce

(d) Correct these situations capable of causing loss.

B. ENVIRONMENTAL FACTORS

The tropical environment is perhaps the most powerful force responsible for the rapid loss of food especially the perishable fruits, vegetables and tubers. We had earlier indicated that the tropical climate with its high temperature and relative humidity is conductive for rapid deterioration of harvested crops. We shall here examine more closely the effects of these and other environmental factors on the loss of harvest crops.

TEMPERATURE AND POSTHARVEST LOSS

The effect of temperature on perishable crop is two-fold.

(a) its effect on the post harvest physiology of the crops and

(b) its effect on the rate at which rot-causing microorganisms bring about the decay of the crops.

It is now clear that the deterioration of harvested fruits and vegetable crops is directly related to temperature. Indeed for many fruits and vegetables *deterioration rate* more than doubled for every 10^0C rise between temperatures of 10^0C to 30^0C. This means therefore that a crop stored at 30^0C will deteriorate eight time more than that stored at 0^0C. The main reason for this is the *high respiration rate* and *increased enzyme activity* at these high temperatures. Temperature affects the life of the crops through its effect on enzyme activities. These enzyme are specialized biological catalysts differing from the chemical catalysts by their very specific nature of action. They are the mediators for change in the storage process and their activities are temperature and moisture dependent. At low temperatures below a critical value, the activity of the enzymes are arrested or slowed down considerably and at higher temperature (within limits) the activities are faster. This is the basis for reduction of temperature of perishables by refrigeration.

Owing to the importance of temperature in the life of these perishables, facilities are provided in the developed countries for continuously keeping these crops at the appropriate low temperature for optimal storability. It is thus possible to keep the harvest throughout the handing steps from the producer to the consumer at these temperatures. These low temperature facilities are referred to as the COLD CHAIN. In these developed countries the links in the cold chain are sometimes broken temporarily and the crop is returned to the chain again. *In the tropics, however, the cold chain is virtually non-existent.* The cooling devices are only afforded by the affluent at the consumer level handling operations. In many crops there is no cooling device at all and the harvests are simply left at the mercy of the environmental temperature.

It is pertinent to record here that not all crops can be subjected to freezing temperatures. This is because many tropical fruits, vegetables and tuber are damaged by temperatures below 100C. this damage is referred to as CHILLING INJURY. For example, such fruits as bananas, mango, orange, tomato, pawpaw, peppers, tubers such as yams, cassava, sweet potato, cocoyam, cannot be stored at temperatures below 100C otherwise chilling injury results giving rise to *discolorations*, failure to ripen, development of pits, changes in flavor and *outright breakdown of tissue.* Each crop has its critical temperature for storage below which chilling injury results. These critical temperatures for the different crops are listed in Tables 3.

TABLE 3: Fruits and Vegetables Susceptible to Chilling Injury

Commodity	**Critical temperature**	**Symptom**
Avocados	10^0C (500F)	Pitting brown or black Discolouring, taste bitter, rancid
Bananas	13^0C	Darkened vascular system, poor ripening
Sweet Potatoes	13^0C	Incresed decay Hard pitting.
Grapefruit	10^0C	Pitting, brown stain, watery breakdown, decay
Mangoes	10^0C	Pitting, grayish, scald uneven ripening, poor flavor
Tomatoes	13^0C	Poor ripening increased decay.

EFFECT OF TEMPERATURE ON DISEASE DEVELOPMENT

Temperature also affects the rate at which disease causing microorganisms damaged the harvested crops. The effect of the temperature could be directly on the rate of growth of the pathogen or on the rate of decay of the tissue. It is known for example that whereas most pathogens cannot grow at temperatures as low as 0^0C a few fungal pathogens e.g. *Botrytis cinerea,* and *Alternaria sp.,* can grow at this temperature. It is important while considering the use of low temperatures to prevent the rot of produce to remember the effect of the low temperature on the life of the crop itself.

Temperatures above 30^0C have two uses:

(1) preventing decay of crops by microorganisms

(2) promoting healing of wounds of tuber

Such high temperatures have also their disadvantages. For example, unripe tomatoes stored above 30^0C will develop yellow colour and fail to develop the normal red pigment and certain banana varieties would fail to ripen at high temperatures in addition to a change in flavor. Already as indicated, such high temperatures promote excessive low so water resulting in weight loss and wilting. It is important that temperatures manipulations whether high or low should be so reconciled to favour minimizing loss of harvested crop.

Moisture and Postharvest loss

Moisture loss is particularly important in perishable produce especially tubers which need to be stored for a fairly long period of time and those perishables which because of their nature readily wilt or shrivel. It is pertinent to observe that although high relative humidity favours the growth of spoilage microorganisms they do not in some cases result in increased decay of fruits and vegetables. Arinze (1986) showed that the effect of RH was more pronounced on the keeping quality of the tomato fruits than on the rate of decay caused by the spoilage organisms.

In discussing the special problems of postharvest storage in the tropics, we had stated that the combined factors of high temperature and high relative humidity shortened the storage life of stored crops especially cereals owing to the increased activity of storage moulds at these storage conditions. We find that in many situations these two factors, rel. humidity and temperature, are difficult to separate since the amount of water vapour in the postharvest environment depends on the temperature of the environment. A rise in temperature of the environment. A rise in temperature of the surrounding air means ability of that environment to accept more moisture!

To understand the role of humidity in postharvest loss it is necessary to examine the role of water in the life of the plant. As already stated while cereals and seeds have a low content of 10-20% the perishable crops are mainly composed of water (70-75%). A shift in the amount of water in these crops can result in loss in quality. Indeed of the perishable crops, loss in water can result in the very serious consequences of wilting and weight loss. And of course many crops are sold in the market on the basis of weight so that a loss in weight resulting from loss water means economic loss.

The water vapour in air is usually expressed as relative humidity. This may be defined as the *ratio* of water vapour pressure in air to water vapour pressure of *saturated air* at a given temperature. A principle of relative humidity is that water vapour moves from areas of high relative humidity to areas of low relative humidity until an equilibrium is reached. This principle is critical for the life of stored products which have an established relative humidity. For example, many fruits and vegetables have relative humidity of97 – 100%. To remain fresh, these perishables have to be placed in environments which have relative humidities of 97-100%. If the relative humidity is lower than 97% water will move out from the fruits and vegetables to the surrounding air resulting in wilting and weight loss. Also, cereals with relative humidity of 16% cannot be stored in an environment of high relative humidity of say, 30%, because at this relative humidity the seeds will absorb water from the environment, and this has consequences for increased enzyme activities which can give rise to higher respirational loss, high germination, high heat generation and of course increased activity of decay organisms.

Practically it is difficult to completely prevent water loss from fresh tissues. This is because respiration within the tissue causes a *rise in internal temperature.* This rise consequently *creates a higher water vapour pressure* than the surrounding postharvest environment, and movement of water out of the tissues. The result is, according to the vapour pressure law, loss of water from the tissues. In practice however to maintain the quality of fruits and vegetables generally, relative humidity of 90% of the storage environment is adequate.

An important consideration in fixing the relative humidity of the storage environment is the temperature of the store. As stated earlier warm air holds more water vapour than cold air. However the ideal situation is to maintain the high relative humidity by use of a refrigeration system so as reduce the respiration of the tissue as well as the action of spoilage organisms. In the low technology developing countries, high humidity around the produce may be accomplished by *wetting the floors of storage rooms or covering the produce with appropriate materials-leaves* and tarpaulins to avoid direct exposure to surrounding dry air.

SOLAR RADIATION AND POSTHARVEST LOSS

The danger posed by exposure of fresh fruits and vegetables to direct sunlight was highlighted in our discussion of the postharvest handling steps. This is being re-emphasized here since this type of loss is directly resulting from the effect of the environment. When exposed to direct sunlight harvested crops absorb light energy from the sun. This energy is converted into heat in the crop *and the temperature of the crop is raised.* The temperature in some harvested crops could be more than 30^0C, resulting in heat injury, sun-burn, sun-scald, etc. Since such high temperatures are unhealthy to most produce, direct exposure of crops to sunlight should be avoided.

ATMOSPHERIC GASES AND POSTHARVEST LOSS

The atmospheric is composed of 78% nitrogen, 21% oxygen, 1% argon, 0.03% carbon dioxide and some water vapour. Thus, in addition to water vapour these other variables exist in the storage environment and their presence, absence and concentration can have diverse effects on the storage life of different crops. *It has been shown that the concentration of N2 and argon do not affect the quality of the crops but the amounts of* 0_2*, carbon dioxide and ethylene in the storage environment have tremendous effect on the quality of the crops.*

For the purpose of respiration, 0_2 is always utilized and $C0_2$ released. If the 0_2 concentration in the environment is increased this will lead to respiratory increase and the attendant dry matter loss of the crop. If however the storage environment is not tampered with, the concentration of 0_2 will fall below the 21% and the concentration of

$C0_2$ will rise far above the 0.03% if the 0_2 level is reduced to 10% respiration of the produce will be checked. If it falls further to 5%, the situation becomes harmful as fermentation sets in. Fermentation will give rise to harmful metabolites which are injurious to the crops. The $C0_2$ level will continue to build up around the crops as the oxygen level continues to fall. This situation may be desirable in order to check increase in respiration. However, for any crop the $C0_2$ level cannot rise beyond a critical value. Indeed $C0_2$ content of the atmosphere is often used commercially to prolong the life of specific crops. For example, levels of $C0_2$ greater than 5% has been shown to be harmful to tomatoes, potato and onion whereas the same levels may be beneficial in reducing the deterioration of okro fruits. In promoting ventilation of the storage environment care should be taken to know the 02 and C02 requirements of the crops for although ventilation may be desirable, the composition of the air being passed should be known, quantified and controlled for the particular crop. *This is the basis of the so called controlled or modified atmospheres around stored crops. In developed countries where there is difficulty in obtaining the optimum temperature to keep respiration low the practice is to supplement with modified atmospheres.* For example a temperate crop like lettuce which requires 0^0C for best keeping can be kept at temperature of 4-50C and the oxygen level reduced from 21% to 2%.

Two other gases which play an important role in postharvest losses are *carbon monoxide and ethylene.* Depending on the concentration ethylene can be beneficial as well as harmful.

Ethylene is used commercially to stimulate ripening of fruits such as *tomatoes and bananas and at* same time the gas *is given off by these crops during ripening and decay.* These gases can however be quite harmful for a number of *crops such as okro, onions and potato* which do not produce the gas. *Such produce must, therefore, never be stored, nor transported along side tomatoes and bananas.* The gas caused harm to crops at concentrations as low as 0.1 ppm and the harm is caused mainly by speeding up process of deterioration in the produce, increased respiration, ripening, browning and tissue softening.

C. PARASITIC DISEASE FACTORS

By strict definition, disease (pathological) factors of loss would include all the factors previously enumerated which would in one way or the other cause any defect, blemish or spoilage that will consequently reduce the quality of the produce. Since disease is any condition resulting in the *alteration of either structure or physiological of a given crop, all the factors discussed so far are pathological in nature.* We are however concern here *with parasitic diseases.* These are the defects (diseases) *caused by parasitic organisms.* All the other defects caused by all the other enumerated factors *are non-parasitic.* Thus, the handling, mechanical, environmental and physiological factors are all non-parasitic. As will be shown shortly, virtually all the non-parasitic factors make it possible for the parasitic factors to be effective. *Hence in our consideration of the postharvest handling steps for vegetables, fruits, roots and tubers, the rotting and decay caused* *by parasitic microorganisms might have resulted from poor handling by either the producer, wholesaler, retailer or consumer.* Indeed any mishandling of the produce predisposes the crop to attack by parasitic factors of loss.

The parasitic disease common in postharvest crops can be listed as follows.

Details of this discussion may be found elsewhere (Arinze, 1986, 1987).

1. **Fruits and Leaf Spots**

These are well-defined necrotic lesions occurring of fruits and vegetables. The spots are mostly of preharvest origin but persist during storage and marketing. These spots are caused by fungi and becteria. The most common leaf spots of vegetables are caused by species of *Alternaria, Cercospora, Curvularia* and *Gloeosporium*

2. **Rots**

The rots are achieved primarily as a result of the action of enzymes on the pectic substance of the middle lamella and the cellulose of the cell walls. The result of the action is that host cells separate and the protoplasts die. Such fruits as bananas, citrus, peppers, plantains, mangoes, tomatoes, and the leafy vegetables can be reduced to leaky, sometimes mummified masses in a few days.

(a) **Fruit and Leaf Rots**

As a result of mechanical injury arising from poor handling during harvesting and marketing operations in many cases, and storage under high temperature and humidity, fruits and vegetables are attacked by rot-causing bacteria and fungi, causing bacterial and fungal soft rots. Several genera of fungi and bacteria are responsible, notably – *Alternaia, Aspergillus, Botryodiplodia, Fusarium, Penicillium, Rhizopus,* Among the bacteria are *Corynebacterium, Erwinia, Pseudomonas and Xanthomonas.*

(b) **Rot of Tubers**

Poor handling of tubers and activities of pest and nematodes cause wounds through which fungi enter the produce. The rots are most severe when tubers are stored at high reperature without adequate ventilation. The rots could be soft, watery or slimy depending on the crop, the rot-causing organism and the environmental conditions. The usual soft rot pathogens of tubers are *Botryodiplodia theobromae, Fusarium sp. Penicillium, sclerotigenum, Aspergillus niger,* and *Corynebacterium sp.* Dry rots of yam tubers are usually associated with the nematode, Scutellonema *bradys.* Also *Sclerotim rolfsii* is commonly associated with the rot cocoyams Arinze, 1987).

Bacterial rots of tubers are not as common as the fungal rots. They are seen however where the tubers are stored under humid conditions specially reslting from poor ventilation. It has been observed that bacterial rot in the storage are often a carryover from the field. For example the bacterium *Corynebacterium sp.* and *Erwinia sp.* observed on stored yams (Ogundana, Naqvi and Ekundayo, 1974) were observed before harvest (Ekundayo & Naqvi 1972).

3. **Mildews, Blemishes:**

Mildews and other such unsightly blemishes which cover the surface of vegetables are common occurrence on leafy vegetables.

Although these diseases do not appear very destructive (since the deposits on the leaf surface can be wiped out by cleaning) the surface symptoms are unattractive and hence can lead to a reduction of the market value of such vegetables. It is observed that even after successfully wiping away these blemishes they soon reappear because in many cases these blemishes have their origin inside the host plant. These diseases are generally caused by fungi.

4. **Root Knot of Tubers**

The nematode, *Meloidogyne incognita* is the common root knot nematode of tubers especially yams. The nematodes, cause the tubers to develop gall-like pustles on the surface of the tuber. This makes the tubers very unsightly and seriously reduces their market value.

5. **Deterioration of Cereals and Seeds**

Several spp. of *Aspergillus* and *Fusarium* are involved in the deterioration of stored grains and seeds. Sometimes they invade the produce and either kill the embryo (thus making the seeds valueless) or simply discolour the grain (thus lowering the market value). The may also change the seed biochemically thus making the grain unpalatable. Some fungi (especially the *Aspergillus sp.* cause fungal toxins in the seeds (Mycotoxicoses) e.g. Aflatoxins which are capable of killing animals.

TABLE 4: List of some decay-causing (spoilage) Microorganisms of selected perishables

Cocoyam	*Sclerotum rolfsii Fusarium sp* *Fuserium solani Erwinia sp*	*Fusarium moniliforme Botryodiplodia theobromae Rhizopus stolonifer*
Pepper	*Verticillium psalliotae, Fusarium monilliforme. Fusarium sp. Rhizopus stolonifer, Aspergillus niger Yeasts*	*Alternaria alternate Monilinia sp. Fusarium oxysporum Pseudomonas sp. Erwinia sp.*
Pineapples	*Ceratocystis paradoxa Rhizopus stolonifer Rhizopus oryzae Curvularia verruculosa*	*Penicillium claviforme Aspergillus flavus*
Plantain	*Alternaria sp. Aspergillus niger Botryodiploidia theobromae Fusarium semitectum*	*Cercospora sp. Pscudomonas sp.* *Penicillium sp. Gloeosporium musarum*
Sweet potato	*B. theobromae Rhizopus stolonifer*	*Rhizopus sp.*
Yams	*Botryodiplodia Theobromae Aspergillus niger Penicillum claviforme Fusarium sp. Penicillum Sclerotigenum Fusarium solani*	*Fusarium monilliforme* *Corynbacterium sp. Scutellonema bradys*

Tomatoes	*Rhizpus stolonifer* *Fusarium solani* *Fusarium oxysporum* *Pseudomonas sp.* *Yeasts*	*Aspergillus niger* *Penicillum sp.* *Xanthomonas sp.* *Erwinia sp.*

REDUCTION & PREVENTION OF LOSS

In must be consistently borne in mind that no two crops have exactly the same method of treatment and that there is no generalized way of handling any group crops satisfactorily. Every produce must have its peculiar requirement and must be treated individually in all pre-and postharvest operations. We can only provide here basic principles on which reduction or prevention of loss generally are based.

GENERAL PRINCIPLE

The question of how to reduce or prevent loss of post harvest crops is perhaps most critical in our discussion so far. Since we have identified the three principal causes of low viz. *poor handling factors, the environmental factors and the parasitic disease factors,* its will be neater if we also approach the reduction and prevention of losses by looking at how the factors causing loss can be eliminated or checked. The specific requirements of some of the individual crops shall be treated later.

1. REDUCTION LOSS BY CHECKING THE POOR HANDLING FACTORS

(i) PRE-HARVESTING OPERATIONS

(a) Crop Variety

We agreed earlier that some of the loss which is manifest as post harvest had origin in the preharvest stage. For example, the storability of the produce might be heritable and as such a farmer would be best advised to seek advice before cultivating certain varieties of crops. Several varieties of tomatoes and pepper have flooded the market today and a number of them have been shown to be more susceptible to preharvest diseases than others while *some have tougher textures to withstand more stress than others.* A modern farmer should be aware of these characteristics before planting.

(b) **Healthy Produce**

Secondly a conscientious farmer should ensure that every effort has been made to produce a healthy produce. *A healthy well formed produce will store better than a sick, malformed one.* A producer is therefore expected to be conversant with the principles of fertilizer application, proper spacing, crop protection to ensure a sound produce which will not easily fall prey to the vagaries of the environment.

(ii) **HARVESTING PRACTICES**

(a) Harvesting Implements

The type of tools which are used for harvesting are important in ensuring that minimum damage is done to the produce. We observed earlier that during harvest a lot of cuts, some shallow, other deep, are inadvertently inflicted on the produce especially the tuber crops. It is advisable to avoid sharp pointed metal or iron implements for uprooting such tubers as yams and sweet potato. If metal or iron implements must be used these must be blunt. Long tubers should be carefully lifted to avoid breaking them. The soil around them should be well loosened before an attempts is made to lift them up. For such produce as pepper, tomatoes and all low shrubs, hand picking should be used to harvest them. Harvesting of tree crops as oranges, and mangoes should be done with picking poles combined with hand catching or for medium sized trees, hand picking on ladders is advisable. The essence in these precautions is to prevent the fruits from falling to the ground and getting bruised. The advantage of cultivating medium sized or short stem plants is obvious here, if their yield is the same as tall-stem varieties.

(b) **Maturity Indices**

As already discussed some produce as okro are best harvested while the fruits are immature while for most crops harvesting is best when the crops are just mature. Criteria such as colour, size, shape, general appearance are used to determine when a produce is mature. A crop harvested prematurely is lost and so, timing to determine maturity is essential. Sometimes, a producer harvests before maturity, because of market situations at the time! (i.e. to attract more price) or because of incidence of diseases of climatic conditions.

(c) **Time of Harvesting**

For a producer of fruits, vegetables and all produce of short storage life the time of harvesting is important. It is often the practice in most areas in West Africa for farmers to harvest early in the morning in order to meet the market holding on the same morning. This is to ensure that the vegetables and fruits remain fresh and attract better price. If harvested a day of two before the market day the produce might lose their freshness and the market value would fall. Also for such crops as yams and sweet potato which respond to curing, it is often advisable to leave the harvested tubers on the site of production after they have been lifted for the hot sun to hasten would healing.

(iii) POSTHARVESTING OPERATIONS

(a) Curing Operations

Curing is one of the simplest and most effective ways of bringing about healing of root and tuber wounds. As a result of wound healing, wound pathogens cannot gain entry into the tissues and water loss is also minimized. Healing of wound involves suberization and formation of wound periderm, which forms effective barrier against water and pathogens. Conditions which favour curing are high temperatures of 20 – 400C and high humidities. Table 5 shows the temp and humidity requirements for curing of the major root tubers.

TABLES 5: Curing Treatment for Different Tubers

Crop	Temperature (^{0}C)	Relative Humidity (%)	Time * (days)
Aroids	Curing with smoke has been recorded		
Cassava	30-4-	High	-
Potatoes	15 – 20	85 – 90	5 -10
Sweet Potatoes	30 – 32	85 -90	2 -4
Yam	32 – 40	90 -100	1- 4

**Length of time for proper curing cannot be definitely stated as it depends on many factors, such as condition of the crop at harvest, type of wound, season, storage temperature and relative humidity. In practice the curing period general rangers from 5 to 20 days.*

TABLE 6: Loss of Water from Cured and Uncured Tubers of Three Crop Plants in Storage

For farmers who may not be able to provide the ideal conditions for curing, short periods of sundrying for the stated number of days soon after harvesting should be practiced. Care should be taken not to exceed the number of days to avoid sun scalding.

(b) **Sorting of Produce**

In order to avoid problems during storage, it is necessary soon after harvest to sort the harvests according to their grades. The produce should be separated according to colour, size, maturity, shape, presence or absence of injuries, presence or absence of diseases and degree of ripening. These characters have their consequences on the storability of even the most healthy produce if they are not separated. As already indicated a number of fruits e.g. tomatoes release ethylene is known to stimulate ripening in some fruits. If some fruits are not required ripe, these should never be stored in the same place as the ripe ones. Furthermore, all diseased produce must be removed from the lot. Rather than attempt to deceive the consumers by mixing rejected grades with the high grade produce, the rejected grade could be immediately consumed, processed, used for animal feed or simply thrown away. These measures are more beneficial than losing the whole produce through attempts to conceal unsound produce among sound ones.

(c) **Packaging**

Packaging or non-packaging, the type of package and how the packaging is done are important considerations in preventing loss. We had noted that these factors are mostly relevant in transporting the produce over long distances. Packaging therefore is of relevance at every level of the handling chain-the producers, the sellers and the consumers. *Poor packaging can result or bruising the produce.* Depending on the produce, the following types are available:- wooden crates, card-board boxes, jute bags, bamboo basket, plastic containers. These containers may or may not be provided with covers and may or may not be perforated. Different sizes of the perforations will permit different degrees of aeration. Furthermore, some produce are packed in containers without lining materials. Depending on the crop, different materials are used to line the containers – banana leaves (fresh or dried), newsprints, plastic sheets, wrapping paper, rice straw.

It is recommended that proper packaging materials with adequate ventilation should be used to convey produce from place to place. The materials should be strong enough to withstand wear and tear and should be properly lined with paper or straw, to avoid damage by the body of the container. Also the practice of agitating the package vigorously after filling up in order to create more room is damaging to perishables and must be avoided. A common practice in transferring commodity from one package to another is by "pouring". The pouring practice is adopted in order to save time but this is done at the expense of the health of the produce. Furthermore packaging material must be shallow to avoid pressure of produce (crushing damage) on the bottom layers by those on top.

(d) Transporting:

Packaging transporting, loading and unloading are important operations which ensure that the produce reaches the market or indeed leaves the site of production. Along the production and marketing line, it is essential that vehicles which carry produce especially perishables are well ventilated, have wooden body and not metal ones to avoid overheating. Some transport vehicles have padded walls to provide a cushion which will act as shock-absorber. Where economy permits, potholes on the roads should be filled up to avoid rocking movement of vehicles carrying perishable goods. Furthermore, the vehicles should be roofed to prevent heating by direct sun rays.

(c) Storage

There are a number of reasons why produce need to be stored.

1. Speculations for high prices at the appropriate time
2. Absence of market for the produce at the material time
3. To spread supply from one harvest to the next
4. Lack of transport

A number of precautions must be taken before storage is embarked on. The produce must be packaged in proper containers as discussed earlier to ensure minimum damage to produce. Also precautions must be taken to ensure that only clean healthy ones are stored. Storage floors and walls should be adequately clean. Preferably they should be made of cement or tiled.

The losses suffered as a result improper storage have been itemized earlier. And as earlier highlighted the reasons for storage and for how long will depend of the produce being stored and the availability of storage materials. To ensure that the produce lasts in storage in as fresh condition as possible, a number of dos and don’ts must be observed.

Generally speaking, fresh fruits and vegetables do not have a long storage life (it ranges from a few days to a few weeks) but this can be extended by a number of ways.

i) **Avoiding mechanical injury:** Packaging material must be shallow to avoid excessive pressure on produce (crushing) at the bottom.

ii) **Practice of cold temperature storage:** This perhaps is the only effective way of storing fresh fruits and vegetables. We must remember that every single fruit or leafy vegetable has a critical temperature above it must be kept to avoid chilling injury. Generally the fruits and vegetables should not kept above 150C. Such low temperatures cannot be afforded for the large quantity of produce by the producers, wholesalers and retailers. This is a serious handicap to the storage of tropical produce. Only a few affluent consumers have refrigerating systems to store their produce. The feasible recommended practice in the tropics is to store fruits and vegetables in as cool a condition as can be improvised in the environment. *Since the main aim is to prevent moisture loss and maintain the structural integrity of the fruits and vegetable retailers often dip their produce (e.g orange, leafy vegetables) in water occasionally to keep them cool i.e hydrocooling.*

iii) **Maintenance of high relative humidity:** Occasionally water is splashed on the floor of the storage chamber to achieve RUs high enough to prevent excessive moisture loss.

(iv) **Removal of Sprouts:** in stored tubers which are organs of propagation. Sprouts in stored yams, cocoyams, sweet potato and potato must be removed as soon as they form. Where they are mot removed, the tissue suffers increased moisture and weight loss and seriously alters the taste of the tubers. In the developed countries sprout suppressants have been introduced but this use is not always recommended in the developing countries because of economic considerations and for the fact that the storage facilities available are not suitable for the application of such chemicals.

(v) **Retention of mature tubers in the soil:** This is possible so far only in the case of cassava which can be stored conveniently in the soil for several months after maturity without suffering any appreciable loss, as there is no other satisfactory way of storing the tubers.

f) **Control of Ripening**: this has included here being one important postharvest handling operation for certain fruits. It is necessary to control ripening of produce for a number of reason. Firstly, premature and uncontrolled ripening could lead to loss of the produce if there is no immediate market to quickly dispose of the produce cannot be disposed of when it is time to do so. Thirdly, uncontrolled ripening can lead to uneven ripening of produce of uneven blotchy appearance of individual fruits which can reduce the market value. As stated earlier ripening can take the form of change in colour as in mango or tomato or increased softening of the fruit as in avocado pear.

Using the locally available technology, ripening can be hastened in fruits by:

(i) Mixing ripe and unripe fruit. Ripening fruits release ethylene which will induce ripening in adjacent fruits in a compartment.

(ii) Covering fruits with known leaves. A number of leave, e.g. banana leaves, are used to wrap fruits to quicken ripening.

(iii) Covering fruits in jute bags. This is commonly used to quicken the ripening of plantains and bananas locally.

On the other hand ripening can be retarded or inhibited by:

(i) Storing fruit in the refrigerator

(ii) Dipping fruits in ash

(iii) Harvesting fairly immature fruits. This is common in banana and plantain

(iv) Delaying harvesting. This is done when it is known that harvesting will quicken the ripening process in storage.

In more advanced countries, the use of controlled atmospheres (CA) is very common in delaying ripening. This practice was originally developed for apples in the UK and is now practiced world wide. It consists essentially of controlling CO_2 and O_2 levels in the storage atmosphere. The storage room is of course a cold room specially constructed to give a gas-tight environment to contain the required atmospheres. A circulations system is usually provided within the room to ensure uniform temperature distribution.

When fruits are harvested mature but unripe and left to ripen in storage, what happens is the *fruit only ripens when the internal ethylene reaches a certain critical level. Measures taken to quicken ripening only help to quicken the rate at which this internal critical level is reached.* We can delay ripening by extracting C_2H_4 from the fruits using ethylene absorbents such as potassium permanganate. In practice, the chemical is packed with the fruit during storage or during transit. By so doing, the internal ethylene is not allowed to accumulate to the critical level which will induce ripening.

2. REDUCING LOSS BY CONTROLLING ENVIRONMENTAL FACTORS

The critical environmental factors already identified are temperature, relative humidity, solar radiation and atmospheric gases. The precautions to be taken in storing produce under artificial and ambient environmental conditions have been stated.

As already indicated the high ambient temperature of the tropical environment alone constitutes the greatest impediment to proper storage of produce. Any effort made to reduce the temperature of the storage environment is therefore worthwhile. *A number of cultural practices as well as introduced low technology devices are today in use aimed at reducing the internal temperature of the produce and the storage environment.*

1. Temp and Harvesting Time:

Experience has shown that the temperature of freshly harvested fruits, vegetables and tubers is usually close to the temperature of the surrounding air. It has been the practice in many places for farmers to harvest their produce during the cool early hours of the morning so that the harvested produce can at least go into storage with the *possible minimum amount of internal heat.*

2. Underground Storage:

Temperatures are lower underground than on ground surface. Most tropical tubers have their storage life prolonged by storing them underground. Various degrees of sophistication of underground storage to permit adequate ventilation and removal of excess heat are now available depending on the nature of produce.

3. Evaporative Cooling:

This involves passing air over a moist object resulting in loss of heat i.e. heat of vaporization. If air is circulated around freshly harvested fruits and vegetable which usually have high water content, evaporative cooling takes place and the temperature of these crops is reduced. However this practice would result in loss of water and consequent shriveling of the reduce the temperature of the air. It is evident that this “mechanical refrigeration” as Huysmans (1981) would call it, will increase the humidity of the storage environment and that in fact the degree of the cooling will depend on the relative humidity of the storage environment. If the humidity is low, cooling will be possible but if the air is already saturated the air cannot be cooled. Evaporative cooling has the added advantage that in addition to cooling the storage air, the humidity of the environment is also raised and as earlier indicated, high relative humidity is recommended for the storage of most perishables.

4. Hydrocooling:

It is common practice to remove heat from surfaces by simply pouring water over the surfaces. Water may be sprinkled, sprayed on the produce or the produce may be simply immersed in water for sometime. Sometimes, to bring about rapid hydrocooling, traders use iced-water. In addition to cooling, the produce is prevented from shriveling.

5. Protection from Direct Heat of the Sun (Shading)

Harvested crops must not be left under the direct heat of the sun. Produce should be protected with leaves or transferred soon after harvest to shades.

6. Waxing:

Coating the surface of fruits and vegetables with wax is an excelling method of preservation by slowing down life processes within *the produce. Furthermore the produce is kept fresh since the closed pores will not* permit water loss. The produce therefore does not shrivel. Chemicals are sometimes incorporated to give fungicidal wax emulsion.

3. REDUCING LOSS BY CHECKING PARASITIC DISEASE FACTORS

The simplest way to prevent losses caused by microorganisms is to prevent the microorganisms from coming into contact with the produce. Put differently, conditions which will make it possible for the microorganism to come in contact with the tissue must be avoided. What it therefore means is that human practices which make it possible for disease-causing microorganisms to cause problems for the producer must be checked. Proper handling techniques can reduce the incidence of post harvest diseases.

1) Avoid Wounds on Produce:

As earlier discussed under factors which enhance disease spread, wounds on produce provide ready openings for microorganisms to enter and cause rot in harvested crops. All pre- and post-harvest handling operations must therefore ensure that wounds are as much as possible avoided on the produce. Delicate handling of delicate perishables must be practiced.

2) Ensure proper Sanitation

All harvesting and storage materials must be kept free of disease causing organisms by proper cleaning and application of disinfectants.

3) Practice Curing

This is applicable to bulbs such as onions and the tubers: sweet potato, potato, yams and cocoyams. The practice will heal wounds and this excludes the parasitic microorganisms.

4) Reduce Temperature

High storage temperatures favour rapid growth of microorganisms as well as their decay processes. Storage temperatures can be reduced by methods listed earlier.

5) Application of Chemicals

Postharvest treatment of produce by means by chemicals is an effective way of keeping off decay organisms. It must only be used by someone who is properly informed to avoid the side effects.

Reducing Parasitic Diseases by Means of Chemicals

All through the discussion so far the use of chemicals on produce has not received any significant attention. This has been deliberate. I intended to discuss the subject specially because consumers in the developing world are quite emotional when the question of treating their food with chemicals is discussed. I have therefore emphasized the cultural and physical methods of reducing loss with the hope that these should form the bedrock of our loss control strategy. Specifically the use of chemicals has suffered from a number of setbacks especially in the developing countries for various reasons:

(a) The public is very conscious of the risks involved in use of chemicals

(b) The emphasis today is on non-chemical disease control strategies

(c) The postharvest chemicals being recommend do not appear to produce the "magic effect" expected of them.

(d) The potential of phytotoxicity

This is however not meant to under-rate or undermine the important of chemicals in food production or indeed in postharvest technology today, for, in the developed world without chemicals much of what is produced would never reach the consumer. What is needed in the developing world is proper education and orientation of the consumers towards accepting that chemical now occupy an integral part of disease management programs both pre-and postharvest. It needs to be emphasized that when properly applied chemicals can be effective, economical and safe and that the quality of the food not only remains at maximum level but that the life of the produce can be extended.

Which Chemical?

In recommending chemicals for postharvest treatment certain information are critical.

a) The decay causing organism must be known- the pathogen/disease life cycle and possibility of recontamination of produce.

b) The part of tissue being attacked must be known whether surface of internal tissues.

c) Whether pathogen is wound pathogen or not.

d) The type of tissue infected – perishable or non-perishable.

There are hundreds of postharvest chemicals, some of wide spectrum, others designed for specific pathogens on specific crops and these chemicals (fungicides, bactericides and nematicides) have different properties and special methods of application.

The final choice of chemical to be applied along the postharvest handing processes would depend on the function the chemical is expected to perform. Chemicals are commonly used to perform one of the following functions:-

(a) Sanitation

(b) Protection

(c) Suppression, and

(d) Therapy.

6. Hot Water Treatment

Treatment of diseased produce with hot water (heat) is based on the concept that the temperature of the water would be hot enough to stop further growth of the pathogen inside the produce without causing any harm to the produce itself. The pathogen in the host would presumable be killed by the hot water denaturing the enzymes or the proteins. Because of differences in their compositions different pathogens would of course differ in their sensitivity to heat.

It is therefore not surprising that results obtained from hot water treatments depend on the temperature of the water and the length of time of exposure of the produce to the treatment. Instead of direct dipping in hot water it is sometimes desirable to use steam as a heating medium. This is practiced where wetting of the produce might be objectionable.

Hot water has been successfully used to treat a number of fresh fruits (see Table 7).

TABLE 7: Examples as Hot-water Treatment for Postharvest Decay Control.

Crop	**Water temp. (^{0}C)**	**Tim (min.)**	**Pathogens Controlled**
Lemon	46.19	1.0.10	*Phytophthora sp. Penicillim sp.*
Mango	5.1.1.56	5.0	*Colletotrichum*
Orange	5.3.5	5.0	*Penicillium sp*
Pawpaw	43.19	20	*Phytophthora, Rhizopus sp. Colletorichum sp.*
Pepper	53.5	1.5	*Erwinia sp.*
Tomato	60	1.5.2.0	*Alternarian sp.* *Botrytis sp.* *Penicillium sp* *Rhizopus sp.*

7. Use of Radiation

Ionising radiation, especially gamma rays, has been used to kill pathogens inside tissues. Radiations have particularly excellent quality of ability to penetrate tissues. However, not many fruits and vegetables are able to tolerate high levels of irradiation which are necessary to kill the pathogens inside them for indeed many of them suffer physiological damage as a result of exposure to ioninsing radiation. Furthermore, since radiations are particularly damaging to meristemmatic tissues, tissues so irradiated cannot be used as organs of propagation.

Studies have shown that tomato rot caused by *Alernaria tenuis and Rhizopus stolonifer* can be controlled by irradiation also citrus fruits *rotted* by *Penicillium sp.* Can be controlled although the fruits tend to suffer from injury which increases its susceptibility to another pathogen, *Alternaria citri.*

Ionising radiation has been used on tubers especially potato to inhibit dormancy and recently attempts have been made to inhibit dormancy in yam by radiation (Adesuyi 1975).

NEED FOR INTERATIED CONTROL

No one method of disease control provides the answer to all the problems. Postharvest disease control is not an exception. It is necessary in all cases to approach the control strategy by bringing into play our knowledge of cultural, physical and chemical methods of disease control. The approach is more urgent considering for example the development of new and different strains in disease situation and the successful attack by different species of a pathogen which had earlier been successfully controlled. An example is the case of *Phytophthora* rot of pawpaw cited earlier. Even the popularly acclaimed biphenyl, a chemical impregnant checking the decay of citrus fruit cannot control citrus decays caused by any of the following fungi *Alternaria citri, Geotrichum candidum, Colletotrichum* *gloesporiades* and *Trichoderma liguorum* (Eckert and Kolbergen, 1963). Duran (1962) even showed that certain strains of *Penicillium sp.* are resistant to the chemical.

What is or should be recommended is combined treatments of postharvest diseases which can produce synergistic effects rather than additive ones. Eckert and Summer (1967) stated that considerable effort is being made to increase radiation effectiveness and decrease host damage by application of chemicals known to sensitize postharvest pathogens to irradiation. More research along this and similar line is required in developing a comprehensive integrated control programme for different disease problems.

8. REDUCING LOSS BY PROCESSING

Processing of food is one way of preserving it and so one way of reducing loss. Processing as a means of preservation is often resorted to when (1) a produce cannot be eaten fresh because of certain unwholesome characteristics of the fresh form (2) a produce has been overproduced; that is the production has exceeded immediate demand. Cassava tubers of the bitter variety cannot be eaten raw and so need to be processed. Processing therefore not only renders edible an otherwise inedible produce but also serves as a means of preservation. One sure way therefore of reducing the loss of produce is to process it.

Processing for preservation involves transforming the food into a more stable form which will be free from spoilage and deterioration for a reasonable period of time. When processed, food which otherwise last for a couple of days or weeks can remain

Stable for years! Undoubtedly when a fresh produce is processed, some of the food value is lost. In processing therefore, effort should be made to minimize this loss. Processing aimed at preservation and not at just meeting consumers taste, demands and preferences, should therefore aim at conserving as much as possible the essential natural food quality of the produce.

The following methods of processing for food preservation are practiced.

(a) **Drying:**

Drying of food involves dehydration which is the removal of water. When water is removed from a produce the solid material in the food is concentrated. The result of this is that water is not available for endogenous biochemical activity in the tissue and hence all internal enzyme reactions in the inability of the spoilage microorganisms to grow in or on the food. The age-long method of preservation is possible in many vegetables and tuber crops. Drying can be accomplished by direct sundrying or smoking depending on the produce (Table 8).

TABLE 8: Methods Used to Process our Produce.

Crop	**Methods of Preservation**	**Common Products**
Grapes	Dehydration Dehydration, Freezing Thermal Fermentation	Raisins Jelly, Jams Juice concentrate Juice, Drinks Wine
Okro	Thermal Freezing	Canned Okro Frozen Pkro
Onions	Dehydration Fermentation (Pickling)	Dried onions Pickled onions

Potatoes Yams Cassava Sweet potato Cocoyams	Dehydration Thermal	Flakes, flour Canned potatoes Chips, Sticks, Crips, Fries, Shredded potatoes
Tomatoes	Thermal Fermentation	Whole canned tomatoes Juice, Sauce, Purce Pickled green tomatoes

(b) Heating:

This involve raising the temperature of the produce sufficiently high to inactivate the enzymes in the food (thereby stopping biochemical activities) as well as to destroy all spoilage microorganisms which are present on or in the food. Sometimes it is essential to dry the food after heating. In the absence of drying, the heated food material must be properly packages or canned (sealed under anaerobic conditions) to prevent the attack of spoilage organisms.

(c) Freezing

Keeping produce under frozen condition ensures that no microorganism will grow on it and that no biodegradation can occur. Sometimes vegetables are mildly heated to inactivate the enzymes and then frozen to keep the vegetables stable. It is essential that any produce preserved by freezing must be consumed immediately it is removed from the fridge. This is because bacteria rapidly invade such food it not utilized immediately.

(d) **Fermentation**

The principle of preservation by fermentation involves reducing the pH of the food material to such a level (usually less than 4.5) that spoilage bacteria cannot grow on them. In other words the fermented food is acidified or transformed to other stable acidified form. This is usually achieved by adding organisms which are known to produce the pH level. Tomatoes and onions for examples are sold in such forms as pickled tomatoes and onions. The acid is responsible for the usual sour taste the preserved produce.

Fermentation may also result in formation of alcohols. This is another method of preservation. Yeasts under anaerobic conditions convert sugars to alcohol. It can thus be seen that wine preparation is one form of preserving food, e.g. grapes, by fermentation!

TIPS FOR HANDLING AND STORING SOME TROPICAL PERISHABLES

Tropical produce generally can be classified according to their storability. Under the best storage conditions the shelf life of produce can be as follows:

1. 0 – 4 weeks highly perishable produce
2. 4 -16 weeks moderately perishable produce
3. 14 – 36 weeks perishable produce
4. > 36 weeks non-perishable produce

Grouping some of our tropical crops according to the categories we have:

Category 1. - Cassava, banana, plantain, mangoes, pawpaw, okro, tomatoes, peppers, pineapples, leafy vegetable, etc.

Category 2. - The citrus fruits (lime, sweet orange, grapes, lemons) etc.

Category 3. - Yam, sweet potato, cocoyam, carrots, potato, onions, etc.

Category 4. - The cereals and seeds

TABLE 9: Best Temperature and Relative Humidity for Maximum Storage Period and Processing Methods for Various Produce

Category Shelf life (in weeks)	Produce	Best Temp. C	Best RII.	Shelf life (wks)	Processing methods
1	Bananas	12.5	90-95	2-3	T
	Plantain	13		4	D
	Mangoes	10 12		2-3	T
1 (contd)	Pawpaw	7		2-3	T
	Okro	-	-	-	T.F.D
	Cassava	*	*	*	F_M.D
0 4	Tomato (ripe)	7-10	90-95	1-2	T.D
		7		2-3	D
	Pepper	10		-	T
	Pineapple	12		3.6	T.FM
	Tomatoes (green)	5-7		1-2	D
	Leafy Vegetables				

**Processing methods*

T = Thermal: D = Dehydration: F = Freezing: FM = Fermentation

We shall examine how these crops may be handled and stored to minimize loss, but firstly let us look at some general rules which must be borne in mind each time we think of storage, especially the perishable crops which have the most critical storage problems.

SOME GENERAL RULES

1. Among the perishables there is a wide range of perishability some produce inherently keep better than

others, some can keep only for a few days, others a few weeks and yet others several months.

2. All perishables must be handled with care to avoid any of bruises, abrasions or cuts on the skin.
3. All perishables are best stored at low temperatures to slow down metabolic activity as well as keep off spoilage microorganisms.
4. Some perishables are sensitive to low temperature and so do suffer from chilling injury if stored below the critical temperature for prolonged periods.
5. High humidity should be combined with low temperature to minimize shriveling and weight loss.
6. Certain fruits, e.g. the citrus fruits and pepper, will keep longer if waxed.
7. Cereals and seeds should be sufficiently dried before storage to prevent attack by moulds.
8. Perishable should be stored only if absolutely necessary otherwise they should be consumed early to get the best out of them.
9. Produce should be regularly inspected to remove decaying ones. It is easy to forget stored produce especially if tucked away in containers.
10. Maintain proper sanitation in all storage environment. In addition to these general requirements individual crops have their special requirements for handling and storage.

These will now be looked at briefly.

Bananas/Plantains

1. Harvest fruit while still green but mature
2. Best quality is obtained if the fruit is left to ripen naturally or for commercial purposes ripen artificially for uniform ripening.
3. Avoid wounds during harvesting.
4. Ripening is best achieved at temperature of 1 8-25^{0}C. above 25^{0}C ripening is poor.
5. Bananas and plantains are very sensitive to chilly temperature (see Table 3). If green, ripening is prevented in the fridge and if already ripe the fruit turns black in colour owing to chilling injury.
6. Unripe but mature fruits should be stored in sealed plastic bags and stored at 12-16^{0}C.
7. Fruits may be treated with some recommended fungicides to avoid the dark spots usually observed on banana skin. These sports though are minor infections caused by collectorichum sp. Contribute to lowering of the market value of fruits.
8. It should be noted that unlike other fruits immature bananas can be harvested and ripened artificially to an accepted quality.

Pawpaw:

1. Avoid wounds during harvesting.
2. Do not allow fruit to ripen fully on the tree, deterioration by spoilage organisms sets in Harvest fruits when ripening

(some **yellowing) just** commences and allow to fully ripen in store at ordinary temperature.

3. Unripe fruits should be put in refrigerator not below 70C fruits can keep for up to 3 weeks in this condition.
4. Ripe fruits can store for 7 days in a refrigerator.

Pineapple

1. Harvest only mature fruits
2. Fruits should ripen in field before harvest.
3. Keep fruits in refrigerator but not below 100C to avoid chilling injury. Injury affects flavor.
4. Cup up fruits and store in fridge at 10-150C.
5. Over – ripe fruits easily get diseased by spoilage organisms.

Tomatoes

1. Harvest only mature green fruits.
2. Do not wait for fruits to ripen in the field.
3. Immature fruits must not be harvested. If harvested ripen slowly and produce ripe fruits of inferior quality.
4. Fruits should be ripened at 18 – 25^0C. Fruits which are ripened at temperature below 10^0C possess pate colour rather than bright *red* colour. When ripened at temperature above 25^0C, the fruit will be bright yellow and of poor flavor.
5. Store mature green tomatoes in fridge at 10 – 120C. At this temperature, ripening will be slow and the fruit can keep up to 6 weeks. If the fruits are purchased already fully ripe,

they may be stored for a maximum period of about 2 weeks at 7-100C.

Citrus Fruits

1. Members of the citrus family (sweet orange, lemons, lines and grape fruits) should be harvested ripe on the tree but mot over-ripe.
2. Fruits should be waxed to prevent evaporation and to keep down metabolic activities.
3. Waxing should be done thinly to reduce loss of water respiration which will result in suffocation.
4. Fruits should be removed from room temperature and stored at 5 – 70C. (for oranges) and 10 – 120C (for grapes).
5. The longer the fruits remain on the tree after maturity the more palatable the fruits become. The fruits do not necessary ripen more. Beyond the palatable stage however the fruit begins to deteriorate.
6. Citrus fruits should be wrapped in thin plastic films or newspapers to reduce wilting.

Leafy Vegetables

1. These have large surface areas compared to their volume and so lose water readily. They should therefore promptly be protected by storing in the refrigerator.
2. Leafy vegetable are usually not cold sensitive and so can store at 5- 70C. in the refrigerator.
3. Once collected these vegetables should be place in moistened plastic bags and transferred to could storage.

Yams

1. Harvest only mature tubers.
2. Avoid wounding during harvesting, transportation and all handling operations.
3. Cure tubers to heal wounds by exposure to temperature of 30 – 32^0C at 85 – 90% relative humidity for 3 days.
4. Remove sprouts as soon as they show up. Use hand removal unless for commercial quantities when chemical sprout inhibitors may be applied.
5. Ideally store tubers at 13 – 15^0C and 85 – 95% relative humidity.

Cocoyams

1. Same as above for yams.

Sweet Potatoes

1. Same as above for yams.

Onions

1. Harvest mature.
2. Cure to heal wounds.
3. Onions are not sensitive to chilling and are best stores at 0^0C.
4. They require low relative humidity of about 60 – 70%
5. If fully matured and properly cured, onions can store at ordinary temperature for several weeks.
6. Sprouting in onions can be discouraged by keeping off moisture in storage environment – store in cool dry area.

Cassava

Cassava tubers present a special problem hence its discussion has been deliberately left till now. Owing to inherent properties of the crops, the roots deteriorate fast after harvest. Processes referred to as "vascular streaking" take place in the tissue which make it unfit for consumption or even processing two or three days after harvest. The vascular streaking is a physiological process which results in the bluish colouration of the vascular bundles.

Whichever is the possible mechanism, the result of streaking is a loss in the quality of the roots. Thus unlike the other tropical tubers which can store fresh for up to 6 months or more, cassava has a shelf life of one or two days! Presently cassava tubers once harvested are not stored but are rather processed immediately into forms which can be stored. If a farmer is not ready to process he does not harvest and so the practice is to leave the crop in the field and harvest only when he is ready to consume or process.

Intensive research is currently being undertaken in various cassava growing regions of the world and interested laboratories in other places to fashion new technologies for storing harvested cassava root tubers. A number of claims of limited success have been reported.

HOST/PARASITE PRELATIONSHIP

Mr. Vice-Chancellor, Sir, permit me at this stage to introduce listeners to an area of our discourse which has occupied a greater part of my attention in my academic soujourn. And that is an attempt to understand *how* microorganisms, bring about deterioration of tissues.

Put simple how does *rot* or *decay* of a tissue by microorganisms come about? By what means do pathogens cause decay of tissues? What factors exist in the plant tissue which can slow down or prevent decay? We have been occupied with finding answers to these questions in the last *two decades* or so and I wish to share with you some of our findings.

How Does Decay Come About?

In almost all plant diseases, parasites sooner or later come in contact with *CELL WALLS* of higher plants and alter them in one way or another. In many plants the cell wall is covered by an outer *CUTICLE* so that to get to the cytoplasm the parasite has to overcome both the cuticle and the cell-wall. The physico-chemical properties of the cuticle and the cell-wall are important factors to be considered.

THE CUTICLE

This is a non-cellular membrance made of *CUTIN* which is mostly hydrophobic on the outside. The cutin frame-work has waxes embedded in it. Basically cutin consist of esters which on hydrolysis yield fatty acids and hydroxyl fatty acids. The waxes on the outside consist typicall of complex mixtures of long chain paraffins, alcohols, ketones, esters and acids.

THE CELL-WALL

Below the cuticle is the cell wall which *protects* the cytoplasm below. Traditionally the cell wall is divided into 3 structural/functional regions: *the middle lamella,* the 1^0 *cell wall* and the 2^0*cell wall.* The differences between these wall regions relate to *chemical composition* a the degree of organization. The wall polysaccharides are mainly:

(a) Pectic substances — Pectin / Pectic acid

(b) Hemicelluloses

(c) Celluloses

(d) Lignin

- The middle lamella consist essentially of pectic substances
- The 1^{0} cell wall consists 1^{only} of pectic substances and hemicelluloses.
- The 2^{0} cell wall consists of cellulose, hemicelluloses, lignin all forming a complex – matrix.

Enzymes Acting on Cell-Wall Components

We now know that plant cell wall is a complex structure constituting a barrier to microbial attack. We do know also that some pathogen have evolved purely mechanical means of breaking down this structure but far the most studied are those pathogens which have evolved enzymes capable of dealing which the various wall components.

CUTINASE ENZYME: This degrades cutin making up the cuticle

CELLULOLYTIC ENZYMES: The cellulose complex converts native cellulose to glucose. The complex consists of 4 components, -cellulose, CM-cellulase (C_x), C_2, and C_1. The four components act together synergistically resulting in breaking down cellulose to glucose.

PECTIC ENZYMES: These are the enzymes that attack and disintegrate the pectic substances contained in the middle lamella and the 10 cell wall of the plants. The enzymes are:

(1) Pectinmethylesterases or pectin esterase (PME or PE)

(2) Polygalacturonases (PG)

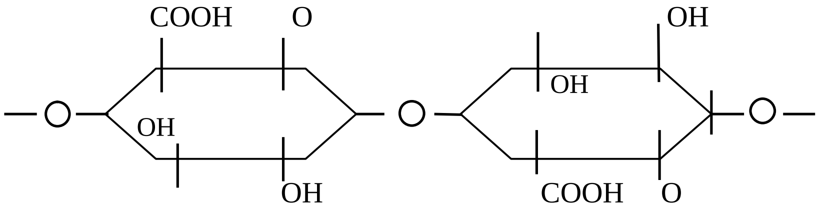
(3) Pectin methylgalacturonase (PMG)

(4) Pectin – transeliminase

There are highly *specific* enzymes attacking different components of the pectic substance in one manner or the other. The resultant effect o these action are *tissue maceration and cell death i.e what we know as ROT or DECAY of tissue*

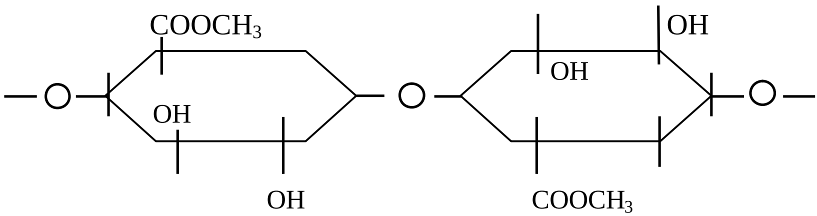
TISSUE MACERATION: The term “maceration” is used to describe the loss in coherence of parenchyma cells when treated with extracts of rot-causing organisms. The macerating or cell-separating enzymes ere those which degrade *the substances* that hold together cells of tissues so that the cells separate from one another. These cells after separation retain their identity for sometime because the cell-walls are disintegrated by continued action of the enzymes. We now know that endo pectic enzymes which split the & 1,4 bonds between the galacturonic acid noieties is responsible for tissue maceration. (Arinze & Smith 1979; Ohazuike Arinze 1992, 1998a & b, Yubedee & Arinze 1994.

Pectic Acid



Pectin or

Pectinic Acid



CELL DEATH

It has long been established that cell separation in *parenchyma* caused by parasites is followed by death of the *protoplasts* in the separated cells. Indeed Brown (1915) showed that in addition to the cell wall dissolving ability, the culture filtrate of *B. cinerea* possessed *toxic* properties. For long it was difficultu to understand how pectic enzyme pectic substances or the products released as a result of enzyme action are themselves injurious. We found recently that the death of the cells is apurely physical effect that proto-plasts ruptured under turgor or pressure (Arinze, 1985a, 1985b).

PLANT DEFENCE MECHANISMS

Mr. Vice-Chancellor, Sir, having established the *mechanisms* by which these pathogens destroy our food crops, we have been intrigued by another phenomenon – how these food crops try to defend themselves against these attacks. Indeed Sir, this phenomenon has been of vital interest to the pbytopathologists because by identifying the factors that confer resistance, it is possible for the plant geneticist to collaborate with the pathologist in order to breed disease-resistant species. Indeed this it what has happened recently in this country and elsewhere. What are these defence mechanism: They are

a) the *physical* barriers that retard growth of pathogens
b) the absence of suitable nutrients in the resistant host
c) the pre-existing chemical substances, which inactivate toxins and enzymes of pathogens.
d) the chemical substances which are *actively* produced by the host as a result of stimulation by the pathogens.

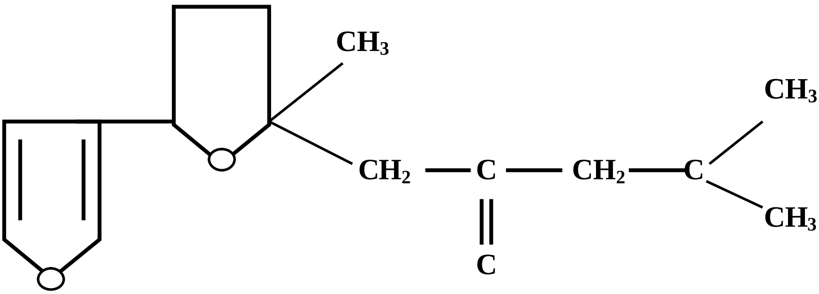
For long, the pathologists contended with studies on factors (a) to (c) dwelling essentially on the role of such chemicals asphenols chlorogenic acid, caffeic acid and catechol as inhibitors of enzymes. Later such chemicals as cuomarins and the derivatives fucocuomarins, isocuomarins were isolated from carrots and their roles in preventing attack highlighted (Condon and Kuc 1962). Earlier Byrde (1957) had demonstrated that the oxidation products of ployphenols inhibited the activity of macerating enzymes. To this array of chemicals were added the saponins e.g the tomatins an & -solanines which we isolated from tomatoes and potatoes *Specifically* Walker et al (1957) showed that resistance of union to *colletotrichum circinans* was due to the presence of catechol and protocatechuic acid which are released by the dead pigmented scales of onion. It is advisable not to remove the dead onion scales from the pink-coloured variety. The scales serve as protective defence. Compare the shelf life of white variety with the pigmented one.

THE SEARCH FOR PHYTOALEXINS: Phytoalexins in its simplest definition, are the chemical substances which are *actively* produced by the host as a result of stimulation by the pathogen. The phenomenon of acquired immunity is relatively new in plants. That phenomenon is not questionable in animals, for its forms the basis of preventive medicine in animals.

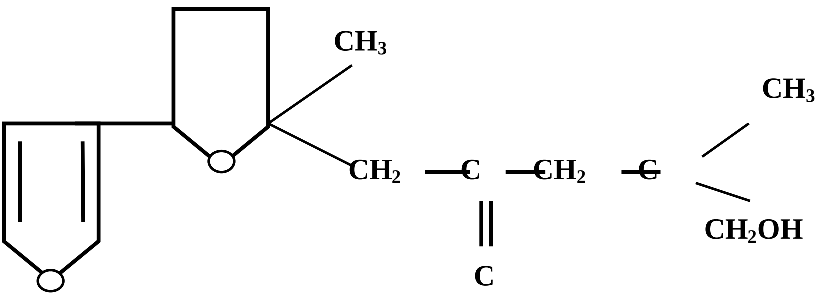
In plants this phenomenon was first reported by Muller and Borger in 1940. They found that potato tubers developed localized resistance to a pathogenic race. This observation led to the development of the "phytoalexin theory".

Mr. Vice-Chancellor Sir, because of the importance of preventive medicine in plants to the survival of humans, and the controversy generated by the discovery of Phytoalexins, a NATO CONFERENCE ON "Active Defence Mechanisms" was held in Germany in 1980. Since then tremendous interest has been shown and physiological plant pathologist have been busy "searching for phytoalexins". The search yielded *pisatin* from pea; *phaseolin* and phaseollidin from green bean, *rhishitin* from potato, *capsidiol* from pepper, the furanoterpenoid *ipomeamarone* and *sesquiterpenoid Ipomeamaronol* from sweet potato. (Arinze & Smith 1980; Kato *et al* 1971; Bailey & Deveral 1971; Sato & Tomiyama, 1969).

Antifungal terpenoid compounds isolated from sweet potato



Ipomeanarone



Ipomeanaronol

Preliminary investigation on the production of antifungal compounds in Nigerian root tubers has yielded some results. (Arinze, 2000, 2001). The search goes on.

INDUCTION OF ANTIFUNGAL COMPOUNDS BY DIFFERENT PATHOGENS IN NIGERIAN ROOT TUBERS

Root and Tubers	***Botryodiplodia Theobromae***	***Fusarium moniliforme***	***Cladosporium Cucumerinum***
Water yam (D.a)	0*	4.5	4.5
White yam (D.r)	3.5	7.5	15.5
Yellow yam (D.c)	3.7	8.8	12.8
Sweet potato (Pink)	3.5	9.0	15.8
Sweet potato (White)	3.9	9.5	15.8
Cassava (sweet)	0	0	0
Cassava (Bitter)	0	0	0
Cocoyam (C.e)	0	0	0
Cocoyam (X.s)	0	0	0

Arinze (2000).

***Total area of inhibitory zones on chromatogram cm^2**

NEED FOR ANATIONAL POLICY FOR REDUCTION OF POST HARVEST LOSS

1. There is need for a NATIONAL POLICY to be developed. The policy should emphasize a serious commitment to reduce post harvest los in all crops. It must be emphasized that the need for this reduction is immediate and no effort should be spared to set in motion urgently this policy.
2. It is envisaged that a NATIONAL COMMITTEE should be set up to comprise the ministries of Agriculture, Commerce and Industries and Education. Education, to take care of research and training, Agriculture to cater for harvesting and processing aspects and Commerce and Industries to cater for marketing and distribution of the finished products.
3. Mode of operation of the NATIONAL COMMITTEE

(i) It is suggested that firstly, the Committee should conduct a National loss assessment survey to determine the nature, causes and extent of post-harvest losses of all the crops produced in the country. The survey should provide reliable data on quantitative and qualitative aspects of the loss.

(ii) Vital information should be provided on the existing methods for the following categories.

(a) Harvesting

(b) Handling/drying

(c) Storage of crops- seeds and grains: Roots and tubers; Fruits and vegetable.

(iii) Suggestions should be proffered on how to reduce loss by improving on the existing local techniques.

(iv) It is expected that the Committee will recommend means to shorten the traditional production, marketing chains which the various crops pass through before reaching the consumer. The role of the various agricultural co-operative is significant here.

(v) While recongnizing the important role of the "new technologies" in improving storage of crops, the committee will be expected to recommend adaptation of local techniques which can be easily applied by the local farmers bearing in mind the absence of electricity and the relevant sophisticated infrastructure in the rural communities.

4. While also recognizing the roles seminars and workshops hitherto play in the dissemination of information, it is observed that more often than not these seminars and workshops end up with beautiful recommendation which neither reach the decision makers for implementation nor the local farmers who are the direct targets of these recommendations. It is therefore envisage that the recommendations of the National Committee shall be treated with dispatch considering the urgency of the matter involved.

5. Following from (4) above, it is expected that specially designated post-harvest extension service workers will be

trained to liase with the local farmers and all consumers generally.

6. It is recommended finally that government should as a matter of urgency designate *centers of excellence for Research and Training in post-harvest Technology* in a number of the Universities and Research Institute: such centers should be specially funded.

The mandate of these centres would be:

(i) to conduct research which should involve genetic control of storage life of crops. We know that to a large extent, the shelf life of a crop is genetically determined and therefore through genetic manipulations, it is possible to extend the shelf life of crops.

(ii) to train extension workers to ensure that they keep abreast with developments in post-harvest loss management.

CONCLUSION

The basis of any agriculture is the healthy productive green plant. We should be concerned about the health of these plants. If we are not, it is to our peril; indeed our extinction as human beings. All life depends on the photosynthetic factory of green plants. It behoves on man to do everything possible to keep these plants healthy. It is saddening that after harvesting the God-given natural products of these plants we allow these harvests to waste and people go hungry. There is hunger, not because farmers do not produce enough but because we allow what is produced to be lost. We have the technology to check this loss. Let us apply it. Isn’t it ironical that there is food every where and yet no food to eat. Let us protect the plant, pre and post harvest. We have no choice.

I salute and thank you for listening so patiently.

Tony ARINZE

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