FRONTIERS OF TECHNOLOGY FOR NATIONAL FOOD SECURITY – CHALLENGES AND POSSIBILITIES

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1.0 EXPLANATION OF TERMS

Frontier is a term derived from 14th century Anglo-Norman word, ***frounter*** or French word ***frontier.*** It basically means

- The "front part (of an army)" or **limit of knowledge**, i.e. the furthest limit of knowledge in a specific field;
- a yet to be fully developed field of study;
- a study area in need of research and development.

For the purpose of this presentation, the last two meanings of “Frontier” will be applicable.

Technology is a term derived from the early 17th century Greek ***tekhnologia***, which means systematic treatment. The word ***tekhnē,*** a variant of ***tekhnologia***, means art or application of acquired skills. Various other meanings of Technology are as follows:

- **application of tools and methods:** the study, development, and application of devices, machines, and techniques for manufacturing and productive processes
- **method of applying technical knowledge:** a method or methodology that applies technical knowledge or tools
- **application of scientific knowledge:** use of observations previously proven by experiment to provide solutions to problems
- **machines and systems:** machines, equipment, and systems considered as a unit

In Cultural anthropology, Technology is the sum of practical knowledge: i.e. the sum of a society's or culture's practical knowledge, especially with reference to its material culture.

Different expressions are used to describe types of technology such as Traditional, Appropriate, Alternative or Emerging / Advanced / Converging / Frontier Technology.

Technologies are called "Traditional" if, unaffected by modernization, they have been commonly applied over a long period of time. In general, traditional technologies tend to be cheap, easy to produce, apply, maintain, and repair. They are generally labor-intensive, which can be economically beneficial considering the cost incurred in the process.

Appropriate Technology is technology that is designed with special consideration to the environmental, ethical, cultural, social and economical aspects of the community it is intended for. With these goals in mind, Appropriate Technology typically requires fewer resources, is easier to maintain, has a lower overall cost and less of an impact on the environment compared to industrialized practices.

The term is usually used to describe simple technologies suitable for use in developing nations or less developed rural areas of industrialized nations. This form of appropriate technology usually prefers labor-intensive solutions over capital-intensive ones, although labor-saving devices are also used where this does not mean high capital or maintenance cost. In practice, appropriate technology is often described as using the simplest level of technology that can effectively achieve the intended purpose in a particular location. In industrialized nations, the term appropriate technology takes a different meaning, often referring to engineering and applications that take special consideration of its social and environmental ramifications to serve a peculiar purpose.

Alternative technology is a term used by environmental advocates to refer to technologies which are more environmentally friendly than the functionally equivalent technologies dominant in current practice. It is technology that aims to utilize resources sparingly, with minimum damage to the environment, at affordable cost and with a possible degree of control over the processes. The term is sometimes confused with appropriate technology, but while there is significant overlap, the terms have different meanings, particularly related to the importance of low cost and ease of maintenance for developing country applications.

Some "alternative technologies" have in the past or may in the future become widely adopted, after which they might no longer be considered "alternative." For example the use of wind turbines to produce electricity.

Emerging / Advanced / Converging Technology

Emerging technology is a general term used to denote significant technological developments that in effect, broach new territory in some significant way in their field. Examples of currently emerging technologies include nanotechnology, biotechnology, cognitive science, robotics, and artificial intelligence.

Emerging technologies are those technical innovations which represent progressive developments within a field for competitive advantage; while converging technologies represent previously distinct fields which are in some way moving towards stronger inter-connection and similar goals. However, the opinion on the degree of impact, status, and economic viability of several emerging and converging technologies vary.

Food Security refers to the sustained availability and affordability of good quality food. A household is considered food secure when its occupants do not live in hunger at the risk of malnutrition and starvation. Two commonly used definitions of food security come from UN's Food and Agricultural Organization (FAO) and the United States Department of Agriculture (USDA):

- Food security exists when all people, at all times, have access to meet their dietary needs and food preferences for active and healthy life (FAO).
- Food security for a household means access by all members at all times to enough food for an active, healthy life. Food security includes at a minimum: (i) the ready availability of nutritionally adequate and safe foods, and (ii) an assured ability to acquire acceptable foods in socially acceptable ways (that is, without resorting to emergency food supplies, scavenging, stealing, or other coping strategies) (USDA).

2.0 FOOD SUPPLY AND AVAILABILITY IN NIGERIA

The guiding premise of this paper is that without deliberate changes from the normal course of events in agricultural production and food, processing and storage practices many of the food security problems of today will persist and some will become worse. It is imperative, therefore, to first discuss food supply and availability in Nigeria.

2.1 Pre – Independence Era

The Nigerian agriculture, before independence was focused at producing export crops such as cocoa, rubber, groundnuts, palm-oil, cotton, etc. In spite of this focus, Nigeria was self-sufficient in food production. Staple food crops like maize, yam, cassava, cocoyam, beans, sorghum, millet etc and livestock were produced in abundance. The consumption patterns of the two categories of food items (plant and animal products) were found to depend on the location. In the southern parts, the staple food was yam, while little food of animal origin was consumed, except in the coastal and riverine areas where fish and marine products were abundant. Intakes of legumes, nuts, green leafy vegetables and fruits were higher than in other places. In other locations, especially in the northern parts, staple foods were millets and sorghum, supplemented with more meat, fish or dairy products. Furthermore, because of the relatively lower cost of food crops most Nigerians were apparently well-fed.

2.2 Oil Boom Era

The oil boom (1970 – 1980) was an era that witnessed a phenomenal increase in the cost of living and purchasing power of Nigerians with a drastic change in the taste of consumers. The period formed the genesis of the decline in agricultural production – affecting both food and export crops. It is a well established fact that Nigeria manifests the typical symptoms of a peasant agriculture with the farms being dominated by small-scale farmers who are responsible for about 95% of the total production. About 80% of the people live, work or have livelihoods dependent on land.

The oil-boom encouraged a steady drift away from rural to urban areas in search of white collar jobs. These trends led to inadequate food production, which resulted in an increase in food prices, which rose by between 85% and 125%.

Bridging the gap between supply and demand

Between 1970 and 1980, food production increased at a rate of 2% per annum, while the corresponding demand stood at 4.5%. As a means of bridging the gap between supply and demand, part of the export earnings from oil was diverted to food imports rather than encouraging or improving food production. For instance, in the period 1970 – 1977, food imports grew at an estimated rate of 19% per year in real terms. Food import bill stood at ₦1,020.7million in 1978, while by the end of 1981 it had risen to ₦2,115.1million. In 1960, the expenditure was ₦24million while by 1970 it rose to N1,246.1million. It was therefore evident that a country which was 80% agrarian was importing an increasing amount of food.

2.3 Industrial Development and Food Availability

The need for the food and allied industries to source for raw materials within the country has stimulated agricultural production. Prices of food crops such as maize, sorghum and cassava have gone up astronomically due to increasing demands by the relevant industries. The direct consumers of these staple food crops have been edged out in the 'price war' as they could no longer afford these commodities at sufficient quantities needed to meet their nutrient requirements. This trend may continue for some time unless attempts are made to increase food production and make more food available on the consumers' table.

2.4 Future Trends

It is apparent from all indications that Nigeria has not been able to produce enough food to feed her teeming populations and to meet raw material requirements for the industries. This is evidenced by the massive importation of grains and other food items to meet internal demand. In analyzing future prospects for national food supply and demand, Nigeria cannot be isolated or immuned from international or global economic determinant factors for over thirty years, Nigeria has depended heavily on imported food items.

Globally, the four critical factors that would determine food supply are the four "Ps" namely: **Population**, **Prosperity**, **Pollution** or Environmental Quality and **Productivity** in agriculture

Population - More mouths to feed means more demand for food.

Prosperity - Widespread economic prosperity means that more people can afford adequate diets, and that people are more likely to have access to health care, a sanitary water supply and education. Prosperity as measured by income per capita also affects food demand. As people attain higher income levels, they tend to buy more food and to buy a wide variety of food including meat and animal products. So 6 billion relatively affluent people require significantly more agricultural production than do 6 billion relatively poor people.

Pollution (environmental) - The availability of quality land and water resources needed for agricultural production are critical factors in the future of agricultural production. To what extent can we expand the area devoted to agricultural production? Will soil erosion or water pollution leave us with less arable land, or less irrigable land? In addition, global climate change may influence agricultural production.

Productivity - Agricultural productivity measures our ability to increase food production without increasing the amount of agricultural land. No matter what happens to environmental quality and, land and water resources, the future food supply will continue to grow if productivity grows fast enough. Productivity per acre can increase because farmers apply more fertilizer, or use more labour, or use more of other inputs per acre. Productivity per acre can also increase because of new technology, such as new seed varieties.

Interactions of the 4 Factors:

- As population grows, urban and industrial water users compete with agriculture for scarce water.
- Population growth slows as people become more prosperous.
- As agricultural productivity increases, economic prosperity improves for the entire economy.
- Increased use of agricultural chemicals may improve productivity while harming the environment.

The interaction of the above four factors along with the price of food and government policies will determine available food in future.

3.0 FRONTIER TECHNOLOGY IN FOOD PRODUCTION

The world is currently experiencing major revolutions in science and technology, especially through Biotechnology, which is influencing agriculture and industry in a fundamental manner. One of the Frontier Technologies for consideration in this lecture is Biotechnology and is so discussed.

3.1 Biotechnology and Food Security

Biotechnology is defined as the application of science and engineering principles in the direct or indirect use of living organisms or parts or products of living organisms in their natural or modified forms for the production of goods and services. The goods and services include the products of industries concerned with food, beverages, pharmaceuticals and biomedicals. There are other definitions of biotechnology depending on what organism is being manipulated. For example, when used in references to plants, biotechnology refers to a collection of techniques for the propagation of plants through "cloning" or asexual methods and for changing plants genetically through genetic manipulations at the cellular and molecular levels.

Biotechnology Tools

The more recently developed biotechnological tools are based on the use of

i) Recombinant DNA technology
ii) Monoclonal antibodies (MCA) and
iii) Cell and tissue culture techniques including novel bioprocessing techniques.

It is the combination of these three processes that forms the basis of genetic engineering of microbes, plants and animals. Recombinant DNA is the transfer of the genetic material (DNA) from a cell of one species to another unrelated species which is made to express itself in the recipient species cell. Monoclonal antibodies are specific diagnostic tools which allow the rapid detection of individual proteins produced by the cells and can be useful for food safety and disease control protocols, while cell and tissue culture technique allow the rapid propagation of genetically engineered cells.

Genetic Engineering

There is a great deal of excitement both among scientists and agricultural policy makers about the potential of biotechnology, especially genetic engineering, to enhance agricultural productivity and hence national food security. This excitement is not misplaced, given what the application of biotechnology has achieved in other countries especially the advanced nations of the world. However, in order to obtain the full benefits potentially derivable from the application of biotechnology to food production in Nigeria, the focus of biotechnology need to be on the probes that constraint agricultural production and which are amendable to biotechnological intervention and the products and processes needed to solve these problems. Two areas that quickly come to mind as far as food security is concerned are crop and livestock production.

Genetic Engineering and Crop Production

In crop production, the major route for the application of the new technologies is the development of new crop varieties with novel characteristics such as herbicide resistance, resistance to specific pests and disease, high yielding capacity and improved nutritional quality. The key components for the effective use of genetic engineering to develop such varieties are:

- Identification and isolation of suitable genes for transfer
- Delivery systems to introduce the desired genes into the recipient cells and
- Expression of the new genetic information in the recipient cells

Given that the requirements for the three key components are satisfied, the widespread use of the newly available characteristics will be dependent on their further incorporation through conventional plant breeding into varieties with suitable agronomic characteristics and stable yields. Therefore, greatly strengthened plant breeding programmes are a necessary prerequisite for the successful use of modern biotechnology in developing new varieties of crops with novel characteristics.

An indirect application of genetic engineering to increase agricultural production is the development of more accurate and rapid diagnostic tests for plant diseases and the addition of new techniques for plant breeding to increase the efficiency of breeding programmes. Such diagnostic tools include monoclonal and polyclonal antibodies that have utility as specific immune reagents in immune assays and nucleic acid probes developed for detection of all classes of plants pathogens. Techniques that may increase efficiency of breeding programmes include molecular genetic maps that make it possible to carry out quantitative breeding programmes based on qualitative data and also for traits controlled by more than one gene. Agricultural diagnostic techniques may be used in crop research and development and also regulation and crop management. Regulation involves the detection of pathogens in quarantine, mycotoxins in grains and foodstuffs and pesticide residues. Crop management will benefit from accurate disease diagnosis, selection of pathogen-free planting materials and detection and monitoring of pathogens in crops and soil.

Genetic Engineering and Livestock Production

Livestock production can greatly benefit from the application of biotechnology. The major areas of intervention of biotechnology in livestock production include embryo technology and many aspects of the physiology, immunology and nutrition of farm animals. Innovative technical developments now available comprise successful gene transfer techniques, *in vitro* fertilization, cloning of embryos and sexing of semen. Techniques have been perfected for the recovery, storage and implantation of embryos. It is now possible to super-ovulate and to recover many embryos at a time. This will result in ability to produce more calves from a cow than would be possible with normal reproduction. The advantages of embryo transfer cloning to produce multiple copies of an embryo by nuclear transplantation. In addition, through genetic engineering it is possible to:

i) Insert into the animal genome the capacity to synthesize proteins which are not normal to that animal and which may have particular value, for example, the gene for the synthesis of human blood clotting factor in sheep.
ii) Transfer genes for proteins with biological effects such as growth hormones
iii) Locate and transfer genes with important effects, for example, for trypanotolerance in cattle, and to use this technique to make more effective selection for the trait.

It is also possible to apply biotechnology for disease control in livestock. Disease control in livestock has four components: (i) diagnosis (ii) treatment (iii) prevention of recurrence and (iv) eradication of disease from a given population of livestock with suitable precautions to prevent its reintroduction. Two broad areas of biotechnology which offer much improved means of approaching the problem of diagnosis, treatment, prevention and eradication of livestock disease are production of monoclonal antibody and recombinant DNA technology. Novel animal vaccines have been developed and more can still be developed by recombinant DNA technology for the control of animal diseases. For example, coccidiosis and Newcastle disease in poultry, brucellosis in cattle, dysentery in swine etc.

3.2 Information Technology and Agricultural Production

Agriculture constantly experiences advances in technology. Recently, the use of IT tools, such as e-mail and the World Wide Web, has become commonplace and thus afford the agriculture industry the opportunity to increase information flow to all industry participants at a reduced cost. Today information technology makes it possible to create new networks, in which farmers, scientists and other stakeholders in agricultural production can exchange information at minimal cost.

Information technology (IT) doubtlessly contributes much to agriculture and rural development. Firstly, IT helps to initiate new agricultural and rural business such as e-commerce, real estate business for satellite offices, rural tourism, and virtual corporation of small-scale farms. Secondly it supports policy-making and evaluation on optimal farm production, disaster management, agro-environmental resource management etc., using tools such as Geographic Information Systems (GIS). Thirdly, it helps to improve farm management and farming technologies by efficient farm management, risk management, effective information or knowledge transfer etc., realizing competitive and sustainable farming with safe products. For example, farmers must make critical decisions such as what to and when to plant, and how to manage pests, while considering off-farm factors such as environmental impacts, market access, and industry standards. IT-based decision support system (DSS) can surely help their decisions.

Furthermore, IT application has spread to wildlife monitoring, habitat assessment, satellite data processing, tracking of rare species, databases, habitat evaluation and connectivity, sensor development and monitoring, information processing and pests control, application of robotics, maintenance of varieties, storage of seeds and/or genetic information, forming of communities, monitoring of the distribution of rare agricultural varieties and related aspects.

4.0 FRONTIER TECHNOLOGIES IN FOOD PROCESSING AND PRESERVATION

The United Nations World Commission on Environment and Development defined sustainable development as “meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.” A sustainable way of designing and developing food products stands to appeal to consumers, and provides a point of differentiation from competitors and a perfect platform for a range of positive public relations activities. Innovation is vital to maintain progress in technology and engineering. Food safety is now the first priority of the food production and preservation industry, incorporating innovation and sustainability. The industry can compromise with some quantities such as color to some extent, but not with safety.

In the light of the foregoing, one of the major factors reducing available food in Nigeria is Post-harvest losses, which is a fundamental flaw in our agricultural policies (pre – 2002), which has resulted in the near total neglect of the Post-harvest sector. Recognizing the need to reduce Post-Harvest food losses in developing countries of Africa, Asia and Latin America, the United Nations General Assembly in New York in September 1975 resolved as follows: **"The further reduction of Post-harvest losses in developing countries should be undertaken as a matter of priority with a view to reaching a 50% reduction in 1985"**

A number of new preservation techniques are known to satisfy current demands and consumer satisfaction in nutritional and sensory aspects, convenience, safety, absence of chemical preservatives, price, and environmental safety. Understanding the effects of each preservation method on food has therefore become critical in all aspects of preservation and processing of foods.

Obviously, this was not realized in Nigeria and Post-harvest food losses remain unacceptably high. Over 30 years after the United Nations resolution on Post-harvest food loss reduction, high Post-harvest losses are the most important factor responsible for food insecurity in Nigeria.

Mechanical, physical, chemical, and microbial effects are the leading causes of food deterioration and spoilage. Damage can start at the initial point by mishandling of foods during harvesting, processing, and distribution; this may lead to ultimate reduction of shelf life. Other examples of deterioration can be listed as follows:

(i) bruising of fruits and vegetables during harvesting and postharvest handing, leading to the development of rot,
(ii) tuberous and leafy vegetables lose water when kept in atmospheres with low humidity and, subsequently, wilt, and
(iii) dried foods kept in high humidity may pick up moisture and become soggy.

In the light of the above, attention must therefore be paid to the application of conventional and frontier technologies in reducing losses through efficient storage systems and processing methods.

The application of conventional and or traditional food storage, preservation and processing techniques have been well documented. The need for appropriate technologies for national food security has also been established. However, food processing as an integral part of the economic development of any country is a significant component of national food security. While one would canvass appropriate or traditional technologies, it is important to advance the cause of frontier technologies for the Nigerian food industry. This is important as application of these technologies would lead to enhanced food production and processing, and products of improved quality, not only for home consumption but also for export purposes. There is no gainsaying that for such industrial sector (food sector) to compete in the international markets and meet international standards, advanced food processing techniques would have to be adopted.

Increasing rate of urbanization and a trend for men and women to work some distance away from home is leading to consumer demand for 'convenience', ready-to-eat foods. Demand for such time-saving foods is on the increase in Nigeria and other parts of the world. With high and increasing levels of literacy in the developed and developing worlds respectively, coupled with abundance of information on food-related health issues, consumer knowledge on healthy eating habits is growing at a fast rate. Consumer preferences are therefore shifting in favour of natural foods with little or no chemical additives and preservatives

4.1 Case for Frontier Technologies for National Food Security.

Advances in technology have been recognized as the key driving force in economic development, which accounted for the lion's share of economic growth in advanced countries. Recently, countries such as Korea, Taiwan, Singapore and Malaysia have transformed themselves from technologically backward and poor countries to relatively modern and affluent economies. Each now has a significant collection of industrial firms producing technologically complex products and competing effectively against firms based in advanced countries. These nations are now food sufficient through applications of modern technologies in agricultural production and food processing.

4.2 Selected Frontier Technologies in Food Processing

In this presentation, selected frontier technologies in food processing are discussed.

4.2.1 Biotechnology in Food Processing

Apart from the direct application of biotechnology in crop and livestock production highlighted earlier, other potential applications of biotechnology in food processing include:

- Genetics in baking, winemaking and production of microbial polysaccharides, enzymes, sweetners, flavor, colouring, emulsifiers and stabilizers are very crucial in food processing and preservation.
- Genetic engineering is of importance in microbial biomass production. This includes, ability to utilize desired substrate by the cloning of the organism, improvements in recovery and processing of single cell protein after fermentation. Furthermore, computer controlled fermentation systems are being adapted for optimizing production rates. Single cell oil has assumed importance in recent years. Attempts have been made to have tailor-made organisms to produce edible oil with higher quality and yield.
- All food fermentations are mixed culture fermentation comprising of different strains of yeast, fungi and bacteria. Genetic engineering will permit the creation of microorganism with properties especially desirable for food and feed applications.
- Genetic engineering has the potential to slow down the natural senescence processes as well as alleviate the stress responses from harvested tissues especially fruits and vegetables. The mechanisms governing senescence in other edible plant organisms such as tubers, roots, leaves and flowers are different from those in fruits, although there some common themes. Genetic engineering solutions need then to be devised on a case-by-case basis depending on the tissues and species.

4.2.2 Microwave Heating refers to use of electromagnetic waves of 1-3000 MHz to heat through dielectric and ionic mechanism. Microwaves are another method of heating foods. Microwaves are generated by a magnetron tube that converts electrical energy at 60cycles/second into an electro-magnetic field with positive and negative changes that change directions millions of times per second. When food is exposed to microwaves, it absorbs that energy and converts it to heat. Microwave energy is used to heat meals at home and also at processing plants. The latter include baking, concentration, cooking, curing, drying, blanching, sterilizing, etc. Microwave and radio frequency heating for pasteurization and sterilization are preferred to convectional heating because they require less time to come up to the desired process temperature, particularly for solid and semi-solid foods.

4.2.3 High Pressure Processing (HPP), also described as high hydrostatic pressure (HHP) or ultra high pressure (UHP) processing, subjects liquid and solid foods, with or without packaging, to pressure between 100 and 800 MPa. Process temperature during pressure treatment can be specified from below 0 ^{0}C to above 100 ^{0}C. HPP acts instantaneously and uniformly throughout a mass of food independent of size, shape and food composition.

High pressure heating is unlikely to replace conventional thermal processing because the latter is a well-established and relatively cheap food preservation method. Applications in food preservation include pasteurization of fruit and vegetable products, tendering of meat products, texturisation of fish proteins, applications in the dairy industry and high pressure freezing / thawing. Pulsed high pressure treatments combined with high temperature for short times have been proposed for food sterilization because of its effective microbial spore inactivation. However, the stability of nutrients (e.g. Vitamins) and possibly chemical compounds is unlimited under such extreme pressure temperature conditions. It is evident therefore that more research is needed on these aspects under high pressure sterilization conditions.

4.2.4 Pulsed Electric Fields (PEF) is a physical technology based on power electronics, permits operation at low or moderate temperature and therefore represents a promising non-thermal preservation alternative to heat pasteurization. PEF processing involves the application of high voltage (typically 20-80kVcm^{-1}) to foods placed between 2 electrodes. PEF may be applied in the form of exponentially decaying, square wave, bipolar, or oscillatory pulses and at ambient, or slightly above ambient temperature for less than 1s. Energy loss due to heating of foods is minimized, reducing the detrimental changes of the sensory and physical properties of foods. Some important aspects of PEF technology are the generation of high electric field intensities, the design of chambers that impart uniform treatment to foods with minimum increase in temperature and the design of electrodes that minimize the effect of electrolysis.

The strength of the process includes the very rapid inactivation of vegetable micro-organisms, including pathogenic and spoilage strains, at moderate temperatures (<40 or 50^{o}c), and with small to moderate energy requirements (50 – 400J.ml). Food sanitation, reduction of the microbioal load and extension of storage life can therefore be obtained without notable effects on food constituents or quality.

The limitations to the use of pulsed electric fields in food processing and preservation include:

- Only homogeneous fluid foods without gas bubbles or large particles can be effectively processed.
- Bacterial spores are not inactivated and enzymes are only partly inactivated, thus PEF-treated non-acid foods necessitate refrigerated storage and distribution.
- Detrimental chemical changes may take place if dielectric breakdown and electrochemical phenomena are not controlled.

PEF food processing has been found to have potentials in the processing of juices, liquid yoghurt, jams, wines, soft drinks, beer, carbonated drinks, liquid dairy and egg products, syrups, etc.

4.2.5 Membrane Filtration Techniques

The basic principle is to separate a single liquid food into two liquid streams by means of a solid membrane. The membrane is selective, allowing some materials to pass through (the permeate stream), while other materials are retained (the retentate stream). In some cases, it is the permeate stream that is desired, in others, it is the retentate, while sometimes both products are of value. The main criterion for separation is size, although other factors, such as surface change or shape of the molecule or particle, may have an effect. The driving force for the separation is pressure difference across the membrane.

Advantages of the membrane processing technique include:

- It is a purely physical operation and hence there are no chemical changes to the process streams
- The separations are pressure driven and no excessive heating is required, hence there is little risk of heat damage, resulting in flavour or other quality changes to food components, or heat denaturation of enzymes.
- No phase changes are involved, which may lead to reduced energy use compared to operations involving evaporation.

Ultrafiltration applications include: milk for protein standardization, cheese, yoghurt, whey, buttermilk, eggs, gelatin and fruit juice. The process has been found useful to concentrate whey, reduce transportation of milk by removing the water and recover rinsing water by concentrate eggs, blood gelatin and fruit juices. Besides the reduction in water and recovery of valuable food components, ultrafiltration and reverse osmosis discharge water that is low in organic matter, thereby decreasing the potential for pollution from discharge water.

4.2.6 Hurdle Concept

The principle underlying the use of combined techniques is known as the 'Hurdle' concept and includes the use of combinations of temperature, water activity, preservatives, modified atmosphere, acidity and redox potential to inhibit microbial growth. In each minimal processing method, micro-organisms are destroyed, and in some cases enzymes, and there are no substantial increases in product temperature. There is therefore little damage to pigments, flavor compounds, vitamins and, in contrast to heat processing, the sensory characteristics and nutritional value of foods are not degraded to a significant extent. The resulting products have higher quality and consumer appeal in markets where the retention of natural sensory characteristics can command premium prices.

4.2.8 Modified Atmosphere Packaging (MAP)

Modified Atmosphere Packaging has been defined as the packaging of a perishable product in an atmosphere which has been modified so that its composition is other than that of air. The main purpose of MAP technology is to extend shelf life of food products by slowing down their rates of spoilage while maintaining their safety and general quality. Factors of consideration in designing a MAP regime for any product are microbial, physiological, chemical and physical changes.

In general, three major gases are used, singly or in combination, for most MAP products. These include CO_2, N_2, and O_2. Other gases that had been reportedly used are CO, SO_2, N_2O, NO, He, H_2, ethylene oxide and propylene oxide. Another method of providing modified atmosphere in the package is to use atmosphere modifiers, which come in small sachets. These include O_2 absorbers, CO_2 absorbers or generators, ethylene absorbers or generators and ethanol generators.

In the development of MAP product, a suitable packaging film or container must be chosen based on the nature of the product to be packaged. MAP has been found not to adequately prolong shelf life of some fruits for extended marketing periods, especially for export purposes. However, for processed products, which are much less perishable, the technique (MAP) has significantly modified their microbioal chemical and physical characteristics. Such processed products include meat and bakery products, intermediate moisture fruit and vegetable products and high protein foods such as shredded cheese.

While the technique has potentials in the food industry, its successful commercialization would depend on providing solutions to the following, among others:

- Atmosphere modifiers, to produce desired atmospheres accurately ad cheaply
- Packaging materials that are more responsive to the requirements of the products, the packaging technology, the environmental regulations, and are cost-effective.
- Marketing infrastructure needed for MAP products, especially with respect to post-process handling of the products, reliable temperature control system throughout the marketing chain, regulations relating to labelling, marketing and consumer education on proper handling of the products.

4.2.9 Edible Coatings

Major losses in quality and quantity of fresh fruits occur between harvest and consumption. Savings obtained through reduction of post-harvest fruit losses are regarded as “a hidden harvest”. Extension of shelf-life through controlled atmosphere storage and modified atmosphere storage have been used for preserving fruits by reducing their quality changes and quantity losses during storage. Edible coatings on fresh fruit can provide an alternative to modified atmosphere storage by reducing quality changes and quantity losses through modification and control of the internal atmosphere of the individual fruits.

Edible coatings reported to be effective include wax, chitin and chitosam (deacylated chitin) from marine invertebtates, a mixture of sucrose fatty acid esters (SFAE), sodium carboxymethyl cellulose and mono and diglycerides and zein. A shortcoming of edible coatings is the possibility of the modifications of the internal atmosphere of fruits, which can increase disorders associated with high carbon dioxide or low oxygen concentration. Furthermore, consumers tend to be wary of waxy coatings.

4.2.10 Food Freezing

Ice crystallization is one of the key issues in maintaining the shelf-life and other quality attributes of frozen foods. During freezing and frozen storage, water contributes to cell rupture and a food provides a medium for accelerating and spreading deterioration reactions. The use of pre-freeze treatments has been indicated to help, either by inactivation reactions directly or by reducing the water content in the material, which facilitates the reactions. Partial dehydration is therefore achieved by air drying before freezing; a process termed dehydrofreezing. The advantages include;

- Energy saving, since the water load to the freezer is reduced, as well as transport, storage and packaging costs.
- Better quality and stability (colour, flavor), as well as thawing behavior (i.e. lower drip loss).

Conventional air drying can be substituted by (or combined with) osmotic dehydration as a pre-freeze treatment.

5.0 CHALLENGES FACING APPLICATION OF FRONTIER TECHNOLOGIES FOR NATIONAL FOOD SECURITY.

The possibilities are enormous but the challenges are daunting but not insuperable. Some of the challenges are:

i) **Political will**: this is associated with good governance, foresight, good planning and adequate funding

ii) **Poor infrastructural** base including uninterrupted power and water supply, without which research and applications are impossible

iii) **Inadequate manpower**
- Plant breeders
- Animal breeders
- Molecular biologists
- Technologists

iv) **Potential Hazards:** Hazards that have been associated with genetically modified foods are as follows;

- The product of the introduced gene, that is, the coded protein for the novel gene, may be harmful. The main concern is about allergic reactions and, to a lesser extent, toxicity.
- There is a need for intensive testing of the novel food in people who are known to be allergic to the donor organism.
- Transfer of an antibiotic resistance marker gene from genetically modified crop to intestinal bacteria is a potential worry, but is unlikely to occur.
- There is a greater possibility of transfer of herbicide resistance from one plant to another, especially among closely related species that can cross-pollinate leading to widespread resistance of weeds to the herbicide, which may become ineffective.
- If a gene for production of an insecticide spreads into mild plant, there could be serious effects on a wide range of insects, including loss of some beneficial species.

v) **Product Acceptability**

Consumers may perceive new food technologies as more risky than traditional food technologies. Results of a Swiss survey showed that respondents perceived food irradiation, GM plants and GM animals as unknown and dreadful food hazards. In general, products or food technologies with tangible benefits were viewed as less dreadful than products or food technologies without obvious consumer benefits. Perceived risk is negatively correlated with willingness to buy a product. People tend to have confidence in natural food and the way it is produced, but they are suspicious of new foods and new food technologies. Perceived naturalness seems to be a factor that influences acceptance of new food technologies. The more a product is seen as natural, the less acceptable will be a genetic engineered version of that product.

vi) **Scientific Challenges**

- Yield potentials and responsiveness to available chemical fertilizers and pesticides
- Adaptation to the growing period and drought tolerance

- Disease and pest resistance
- Improvements in quality, palatability, and consumer acceptance
- Storage, transport, and other handling qualities (including processing) with available technology
- Changes in labour requirements in production to the available mechanical technology, in view of other requirements for household labour and incentives for labour use
- Compatibility with other social, cultural, and economic norms
- Lack of adequate data or information on some physical (including rheological) and chemical parameters of new food materials

6.0 APPROPRIATE APPROACHES TOWARDS FRONTIER TECHNOLOGIES

6.1 Blending of traditional and frontier technologies

Traditional technologies are environment specific, less risky, eco-friendly and sustainable under low levels of production with respect to time and resource-use. Studies have shown that the involvement of landless labourers and small-scale producers and processors could enable change to take place through a blend of traditional and frontier technologies (ecotechnologies).

6.2 Participatory research and training

Participatory research and training is a fundamental requirement for resource-based and people-focused development. New patterns of research organization, with scientists and farm families and processors becoming partners in the development and dissemination of new technologies need to be evolved while the existing systems are reoriented.

6.3 Inauguration of Bio safety Protocol

It is very imperative to develop bio safety protocol that will be responsible for the assessing of risks of new technology and possibility of managing the risks before it can be adopted in the nation. Members should cut across all the disciplines that are vital to such technological investment Professional bodies such as the Nigerian Institute of Food Science and Technology (NIFST)and those in social fields are relevant to this.

6.4 The role of Information and Communication Technologies (ICT)

A decisive role can be played by information and communication technologies in promoting human capacity development for food security. Investments in scientific and material resources for agricultural production bear little fruit without parallel investments in human resources. To this end, information and communication technologies are powerful resources for informing people and providing them with the knowledge and skills they need to put agricultural science and technology inputs to effective use. The use of information and communication technologies can also help experts and people in general to exchange experiences, find common ground for decisions and actively participate in and guide development activities. Substantial investment in information technology will have to be made while strong networking among African scientists and with those in the Western world will need to be facilitated and subsequently enhanced.

Public Enlightenment

It is imperative to put in place and execute public enlightenment programmes to educate potential beneficiaries and end users of emerging technologies. This may involve strong extension activities at rural levels to ensure adoption of newly introduced technologies.

7.0 CONCLUDING REMARKS

One of the major indices of classification into developing (less industrialized) and developed (industrialized) countries is the stage of technology and the application of such technologies to provide goods and services. Developing countries are less industrialized due to inability to develop either their own technologies or apply advanced technologies for developmental purposes. However, the economies of developing countries are usually affected by industrial applications of frontier or emerging technologies. This is evident by the replacement of copper by optic fibre in telecommunications.

Developing countries not only serve as sources of raw materials for the industries in the developed countries, but also rely on goods and services (market outlets) for developed countries. It is imperative therefore to put in place "Advanced Technology Alert Systems (ATAS)" to monitor changes in technology and their likely effects on our corporate existence in developing countries. This would enable us prepare for the future consequences of frontier technologies.

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