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Review

Postharvest biology and technology research and development initiatives for Nigeria

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This paper presents summaries and major recommendations of ten published technical papers by the author in the field of post harvest biology and technology, which answers to developmental challenges that will bring fundamental changes to society, including job creation and poverty reduction through creation of wealth and desirable opportunities. These papers are in the areas of developments in 1-methylcyclopropene (1-MCP) post harvest technology research for fruits, vegetables, fresh-cut produce and ornamental products. The challenges of the Euro-Retailer Produce for Good Agricultural Practice (EUREPGAP®) benchmarks in areas of traceability, records keeping, varieties and rootstocks, site, soils, fertilizer use, irrigation, fertigation, crop protection, harvest, post harvest and Health, Safety and Environment (HSE) issues. The applications of biological control agents in pre- and post-harvest operations and modified atmosphere packaging and related technology in post harvest handling of fresh fruits and vegetables, in addition to the use of hot water treatment as a non-chemical alternative in keeping quality during post harvest handling of citrus fruits. Methods of keeping freshness in fresh-cut horticultural produce, and finally the maturity, quality and marketing of fruits and vegetables. All these publications present unique opportunities for research and development initiatives for Nigeria in particular and Africa in general.

Key words: Post-harvest, biotechnology, research, development, Nigeria.

INTRODUCTION

As the technological world around us grows, so, too are the various professions. Under the present circumstances, we must recognize and respond to each opportunity to accommodate, support, and actively participate in technical and commercial activities where our training and experience provide us a role to play. We must continue to develop and use the best technologies available to us and we will have to do so in a manner that the economics of the business world and society in general, will support. We will have to work much closer with professionals from other fields, both within the agricultural sector and in the broader technical and industrial base. We must recognize that the business world and the professional world are becoming more "action and results" oriented, and less "domain or territory" oriented. We will have to be more interdisciplinary in our development and more cooperative in our approach.

The Agricultural and Environmental Engineering profession has a strong base on which to build its future activities. The broad solid base is the biological sciences and the biological production systems. The profession is well positioned to continue to play a major role in agriculture and agri-business, and also to contribute to the wider range of technical activity and indeed, to provide leadership in these sectors. This involves applying problem solving abilities to all aspects of the design and operation of systems for biological production, from family farm operation to genetically manipulated bio-technological production systems. The horizon of the Agricultural and Environmental Engineering profession has broadened since its early beginnings and will of necessity continue to broaden into the future. Recognizing that the base of agriculture has changed and will continue to change, and that the future of the society will depend on the application of biological sciences to produce products from renewable sources, emphasis has shifted in recent years to "Bio Engineering" (which could mean Biological, Bio-resource, Biosystems, Biomedical, Bioinformatics, Bioimaging, Bioinstrumentation, Biomass, Biorobotics, Biodegradable, etc) as our profession transforms to the betterment of society.

The evolution of new technologies continues to change our working environment. Pressure from such factors as advances in biotechnology, environment technologies, social sciences and the variety of activists groups has greatly diminished the opportunity for compartmentalized or elitist participants. Technology is advancing at an ever-increasing pace; the range of things we can accomplish with new technologies is expanding even faster. Along with this, the demarcation lines between the disciplines and between the professions are rapidly blurring. Development and application of technologies is, of necessity, becoming a multi-disciplinary team activity and the individual tasks involved are being handed to whoever has the ability and interest to do them, regardless of their professional discipline.

This paper therefore presents a modest contribution of an agricultural and environmental engineering professsional to the study of post harvest biology and technology with the view to opening up areas for nationally coordinated research and development efforts.

POSTHARVEST BIOLOGY AND TECHNOLOGY RESEARCH AND DEVELOPMENT INITIATIVES FOR NIGERIA

The challenges of Euro-retailer produce for good agricul-tural practice (EUREPGAP®) benchmarks: advocacy 1 - traceability, records keeping, varieties and rootstocks, site, soils and fertilizer use (Irtwange, 2005a)

This first part of the advocacy paper summarised the EUREPGAP® requirements in the areas of traceability and trackability, record keeping and internal self-inspection, varieties and rootstocks, site history and site management, soil and substrate management and fertilizer use. The EUREPGAP® registered product must be traceable back to and trackable from the registered farm where it has been grown. Farmers must keep up to date records and undertake self-inspection against the EUREPGAP® standard prior to application for EUREPGAP® registration. Cropping techniques and measures adopted in the "mother crops" are such as to minimise inputs such as crop protection products and fertilizers in the registered product crops and guarantees seed quality. The use of seed treatments must be recorded. Purchased propagation material must be accompanied by officially recognised plant health certification. The planting of GMO's must comply with all applicable legislation in the country of production. There must be a risk assessment for new agricultural sites, which shows the site in question to be suitable for food production, with regards to food safety, operator health and the environment. A recording system must be established for each field, orchard or green house. There must be a written justification for the use of soil fumigants. The technically responsible person must demonstrate competence to determine quantity and type of fertilizer (organic and inorganic) to use. Fertilizer application machinery must be kept in good condition. Human sewage sludge must not be used on the farm. EUREPGAP® recommends that purchased inorganic fertilizers be accompanied by documentary evidence of chemical content, the varieties grown have resistance/ tolerance to commercially important pests and diseases, soil maps be prepared for the farm, alternatives to chemical fumigation be explored before resorting to the use of chemical fumigants and the farmer participate in substrate recycling programmes for substrates where available and keeps records with quantities recycled and dates.

The paper recommended as follows:

- There is need for producers to be aware of the standard and similar commercial standards with respect to EUREPGAP® requirements in the areas of traceability and trackability, record keeping and internal self-inspection, varieties and rootstocks, site history and site management, soil and substrate management and fertilizer use.
- There is need to establish a National Technical Working Group to develop a small holder EUREPGAP® interpretation guidelines that will be used in Nigeria and to work out sustainable compliance modalities for small-scale farmers.
- Nigeria as a country must take deliberate efforts to establish the NIGERIAGAP as a national agricultural production document and develop guidelines for implementing EUREPGAP® for crops certified under EUREP.
- The National Economic Empowerment Development Strategy (NEEDS) programme and Nigeria's Millennium Development Goals documents must capture the requirements for EUREPGAP® in its planning and execution with respect to agriculture and food security.
- There is need for farmer education in Nigeria and entrants of educated persons into the farming business.

The challenges of Euro-retailer produce for good agricultural practice (EUREPGAP®) benchmarks: advocacy 2 - irrigation, fertigation and crop Protection (Irtwange, 2005b)

This second part of the advocacy paper summarised the irrigation, fertigation and crop protection requirements for EUREPGAP®. It is recommended that systematic methods of prediction be used to calculate the water requirement of the crop, the most efficient and commercially practical water delivery system be used to ensure the best utilization of water resources and irrigation water be abstracted from sustainable sources. Untreated sewage water must not be used for irrigation/

fertigation. The protection of crops against pests, diseases and weeds must be achieved with the appropriate minimum crop protection product input. The crop protection product applied must be appropriate for the target as recommended on the product label. Chemicals, banned in the European Union, must not be used on crops destined for sale in the European Union. All the crop protection product applications must be recorded including the crop name and variety. The registered pre-harvest intervals must be observed. The application equipment must be kept in good condition. Surplus application mix or tank washings must be disposed of according to national or local law, where it exists. The farmer or any customer of the farmer must be able to provide current evidence either of annual residue testing, or of participation in a third party crop protection product residue monitoring system, which is traceable to the farm, and that covers the crop protection products applied to the crop/produce. Crop protection products must be stored in accordance with local regulations. Empty crop protection product containers must not be re-used. Obsolete crop protection products must be securely maintained and identified and disposed of by authorized or approved channels.

From the study, the following recommendations were drawn:

- There is need for the NEEDS programme and Nigeria Millennium Development Goals documents to sufficiently address the requirements for EUREPGAP® with respect to irrigation, fertigation and crop protection.
- There is need to establish a National Technical Working Group to develop a small holder EUREPGAP® interpretation guidelines that will be used in Nigeria and to work out sustainable compliance modalities for small-scale farmers.
- Nigeria will have to sign on to EUREPGAP® or develop NIGERIAGAP and benchmark against the EUREPGAP® to enable our local farmers take advantage of export opportunities available in the European markets.
- Relevant authorities should ensure that the pesticides banned are not being used in the Nigerian agricultural systems.
- There is need for farmer education in Nigeria and entrants of educated persons into the farming business.
- In the interim, Nigeria may be better off concentrating on export of processed agricultural products than fresh while building capacity for irrigation, fertigation and crop protection in line with EUREPGAP® standards.

The challenges of Euro-retailer produce for good agricultural practice (EUREPGAP®) benchmarks: advocacy 3 - harvest, post harvest and HSE issues (Irtwange, 2005c)

This third part of the advocacy paper summarised the harvesting, produce handling, waste and pollution management, recycling and re-use; worker health, safety and welfare and environmental requirements for production and export of agricultural crops. A hygiene risk analysis must be performed for the harvest and pre-farm gate transport process. Produce containers must be used exclusively for produce. Ice to be used in produce handling at point of harvest should be made with potable water and handled under sanitary conditions to prevent produce contamination. Hygiene risk analysis must be performed for the produce handling process. The source of water used for final product washing must be potable or declared suitable by the competent authorities. All label instructions for chemicals applied to the produce must be observed with clear procedures and documentation available, i.e. post harvest biocides, waxes and crop protection products application records and packaging/delivery dates of treated products. Floors should be designed to allow and ensure drainage, all possible waste products be identified in all areas of the farm business, there be a documented plan to avoid or reduce wastage and pollution and avoid the use of landfill or burning, by waste recycling and a risk assessment for safe and healthy working conditions be carried out. Formal training or instructions must be given to all workers operating dangerous or complex equipment. First Aid boxes must be present in the vicinity of the work. The workers who handle and apply crop protection products must be trained. Workers (including subcontractors) must be equipped with suitable protective clothing in accordance with label instructions. A member of management must be clearly identifiable as responsible for worker health, safety and welfare issues. All subcontractors and visitors must be aware of the relevant demands on personal safety. The farmer should understand and assess the impact his/her farming activities have on the environment. A conservation management plan must be established (either individually or on a regional basis). Consideration should be given to the conversion of unproductive sites into conservation areas. There must be on the farm, and available on request, a clearly identifiable document for complaints relating to issues of compliance with EUREPGAP®.

The following recommendations were drawn from this paper as follows:

- There is need for the NEEDS programme and Nigeria Millennium Development Goals documents to sufficiently address the requirements for EUREPGAP® with respect to harvest, post harvest and HSE issues.
- There is need to establish a National Technical Working Group to develop a small holder EUREPGAP® interpretation guidelines that will be used in Nigeria and to work out sustainable compliance modalities for small-scale farmers.
- Nigeria will have to sign on to EUREPGAP® or develop NIGERIAGAP and benchmark against the EUREPGAP® in line with initiatives already taken by Kenya, Egypt and South Africa.

- There is need for farmer and processor's education in Nigeria and entrants of educated persons into the production, storage and processing business.
- In the interim, Nigeria may be better off concentrating on export of processed agricultural products as it may be easier complying with EUREPGAP® standards.

Developments in 1-methylcyclopropene (1-MCP) post harvest technology research: I-fruits and vegetables (Irtwange, 2005d)

Ethylene is a plant hormone that controls many plant responses, such as growth, senescence, ripening, abscission and seed germination. 1-Methylcyclopropene (1-MCP) has been shown to bind to ethylene receptor for a certain period of time and prevent ethylene action. The potency of the compound to inhibit ethylene action has been tested on a wide scope of systems like fruits (climacteric and non-climacteric) and vegetables. Generally, there were fluctuations in the responses as related to the concentrations of the inhibitors, cultivar or variety, stage of development and time from harvest to treatment. The advantage of using inhibitors of ethylene action over inhibitors of ethylene production lies in the ability of the inhibitors of ethylene action to protect the tissue against both endogenous and exogenous ethylene, thus providing better overall protection. 1-MCP and its structural analogues are potent inhibitors of ethylene action capable of providing good protection against endogenous and exogenous ethylene. The fact that the compounds are in a gas phase and are non-phytotoxic, odorless and effective at minute concentrations, renders them promising candidates for commercial use. However, the development of water-soluble inhibitors will expand the potential use of the inhibitors in agriculture.

The study recommended as follows:

- 1-MCP may not be beneficial for every fruit and vegetable depending on cultivar, duration, type of tissue and maturity.
- The gas may be especially beneficial in slowing ripening and deterioration of some tropical, sub-tropical fruits and vegetables to allow prolonged storage under the higher temperatures required to prevent chilling injury to these commodities.
- In temperate fruit, 1-MCP could improve tolerance of commodities to interruptions in the cold chain or physiological disorders, thus possibly reduce dependency on costly controlled atmospheres.
- 1-MCP treatment may prove useful for protecting ethylene-sensitive members of mixed-load shipments.
- 1-MCP has been approved for commercial use only with apples. As was the case for apples, additional research with other fruits and vegetables will be required to precisely determine the optimum 1-MCP treatment levels, length of exposure, and to establish whether different cultivars will require unique application conditions.
- The development of water-soluble inhibitors will expand the potential use of the inhibitors in agriculture.
- There is need to carry out similar research for our local crops.

Developments in 1-methylcyclopropene (1-MCP) post harvest technology research: II-fresh-cut produce and ornamental products (Irtwange, 2005e)

Ethylene is a natural hormone for the plant and, like other hormones, is involved in a number of physiological processes. Apart from inducing ripening-related changes, ethylene is known to play a role in pigment formation, chlorophyll degradation, decay resistance, phenolic metabolism, and other processes. 1-Methylcyclopropene (1-MCP) has been shown to bind to ethylene receptor for a certain period of time and prevent ethylene action. There is potential to achieve desirable as well as undesirable responses to 1-MCP. While some aspects of ripening and senescence are nearly completely arrested by timely application of 1-MCP, others not under complete control by ethylene may continue to change. This has important implications for quality after storage. The advent of 1-MCP as a commercial tool has tremendous potential to help industries maintain quality. However, because of the long-reaching effects of 1-MCP, cautious adoption of this powerful tool is recommended. It will undoubtedly take a period of commercial experience to fully realize the benefits of 1-MCP for improving the quality in the marketplace. This paper discussed the uses of ethylene, its inhibitors and developments in applications of 1-MCP to fresh-cut produce and ornamental products and predicted its future commercial use in the food industry.

The study recommended as follows:

- 1-MCP may not be beneficial for every fresh-cut produce and ornamental products depending on cultivar, duration, type of tissue and maturity.
- The gas may be especially beneficial in slowing ripening and deterioration of some fresh-cut produce and ornamental products to allow prolonged storage under the higher temperatures required to prevent chilling injury to these commodities.
- 1-MCP treatment may prove useful for protecting ethylene-sensitive members of mixed-load shipments.
- 1-MCP has not been approved for commercial use in any fresh-cut produce or ornamental products. Additional research will be required to precisely determine the optimum 1-MCP treatment levels, length of exposure, and to establish whether different cultivars will require unique application conditions.
- The development of water-soluble inhibitors will expand the potential use of the inhibitors in agriculture.

- There is need to carry out similar research for our local crops.

Application of biological control agents in pre- and post harvest operations (Irtwange, 2006a)

There is increasing concern about the environmental effects and safety of chemical pesticides and fungicides all over the world. Regulatory agencies have reacted to public pressure and introduced comprehensive legislation to reduce pesticide use. The limited number of viable alternatives to synthetic pesticides, however, is currently the major obstacle in reaching that goal. There is also the absence of effective chemicals for the control of many diseases. Some pests have developed resistance to certain pesticides. Biological control of pre- and post harvest diseases has been one of the most extensively studied alternatives and appears to be a viable technology. Research and development of biological control products for pre- and post harvest use has been on a fast track. Several commercial products are already available and others will be available in the near future. However, huge commercial successes in biological control are still rare. Currently, the main hurdle facing widespread use of post harvest bio-control strategies is the decreasing efficacy and lack of consistency found when these methodologies are applied as standalone treatments under commercial conditions. Research into formulation technology might offer a new stimulus to help develop successful biological control agents from the vast number of strains isolated in the past decades. Combining biological, chemical, physiological, and other post harvest practices in an integrated control strategy can give excellent pest control during long term storage and transport of certain fruits. The opportunities of successful implementation of this technology is growing as information regarding various aspects related to formulation technology, application, microbial ecology, and genetics becomes available.

The study recommended that innovative biological control strategies should take into consideration the growing concern over contamination of the produce with human pathogens, as well as plant pathogens. The time is ripe to integrate bio-control agents with one or more physical treatments such as heat treatments, controlled and modified atmospheres, natural biocides, and food-grade preservatives. Such an integrated approach will probably provide adequate control levels comparable to those achieved by chemical fungicides. To achieve this goal, the fruit and vegetable industry should adopt certain changes in packing and sorting lines required for successful implementation of an integrated control strategy. Molecular approaches may prove useful in developing bio-control agents with enhanced bio-control activity and set directions for full exploitation of the genetic potential of these antagonists. Yeast antagonists selected for their bio-control activity appear to be very well adapted to growth and colonizing fruit surface and especially fruit wound sites. This feature suggests that these yeasts provide an excellent means of delivering bioactive compounds, such as fungal cell-wall-degrading enzymes, directly to areas where pathogen propagules are most likely to germinate and infect the tissue. Combining the ability of these yeasts to rapidly colonize wound sites with enhanced constitutive production of antifungal proteins may prove to be a useful strategy for improving bio-control effectiveness.

Application of modified atmosphere packaging and related technology in post harvest handling of fresh fruits and vegetables (Irtwange, 2006b)

Fruits and vegetables are important source of carbo-hydrates, proteins, organic acids, vitamins and minerals for human nutrition. When plants or plant parts are used by humans, whether for food, or for aesthetic purpose, there is always a post harvest component. Post harvest losses in fresh fruits and vegetables may occur anywhere from the point where the food has been harvested or gathered up to the point of consumption. Appropriate post harvest handling can minimize moisture loss, slow down respiration rate and inhibit the development of decay causing pathogens. Temperature is the most important determinant of fresh produce deterioration rate. An important supplement to proper temperature and relative humidity management is the use of controlled (CA) or modified (MA) atmosphere. This paper reviewed the physiological factors affecting shelf life and applications of modified atmosphere packaging (MAP) and related technology in prolonging shelf life of fresh fruits and vegetables. The paper further provided tables of values for permeabilities of films available for packaging fresh produce, classification of horticultural commodities according to respiration and ethylene production rates and MAP potential for benefit for whole and fresh-cut fruits and vegetables. The paper encouraged commercial application of MAP by processors and retailers in addition to further research efforts for local crops under local conditions.

The paper recommended as follows:

- MAP and related technology can be selectively used in post harvest handling of fresh fruits and vegetables with good results.
- There is need for commercial application of the technology by processors and fresh produce retailers.
- There is need for MAP and related technology research for local crops under local conditions in developing countries.

Hot water treatment: a non-chemical alternative in keeping quality during post harvest handling of citrus fruits (Irtwange, 2006c)

Citrus fruits are an essential component of some of the

human nutritional requirements like vitamins, minerals and organic acids. Preservation of these products, however, is one of the central problems encountered by producers worldwide. The post harvest losses of fruit and vegetable stands at 20-40% in the average. The use of synthetic chemicals on harvested fresh produce is becoming more difficult to justify due to the concerns about human health risks associated with the chemical residues particularly in the diets of children, the widespread occurrence of fungicide-resistance isolates, the environmental problems associated with the disposal of water used in packing operations, and a lack of approved fungicides for the control of sour rot. Therefore, the interest in "non-conventional" methods for post harvest decay control of fruits and vegetables has become increasingly important. Hot water treatments to control post harvest diseases of citrus avoid residue and disposal issues associated with chemical treatment. Heat treatment technologies are currently a relatively simple, non-chemical alternative to methyl bromide that can kill quarantine pests in perishable commodities, as well as control some post harvest diseases. Unlike methyl bromide, heat treatments do not pose significant health risks from chemical residues and, as a result, are more appealing to consumers than methyl bromide fumigation. This paper reviewed some of the developments in hot water treatment and its effect on the quality of citrus fruits.

The paper noted that in view of environmental and health concern, a determined effect has been made to reduce the use of chemicals to control diseases of citrus fruits. Regulatory agencies have reacted to public pressure and introduced a comprehensive legislation to reduce the application of chemicals. The hot water dip is viewed as potential visible anti microbial post harvest treats of citrus fruits. All citrus fruits may not respond to heat treatment in same way. Water loss from the hot water treated fruits may be a problem when stored. This may be reduced by wax addition to the hot water or rinse water. Wax is nowadays often applied to reduce water loss and improve the storage life of the citrus fruits. The challenge is for development of simple, low cost hot water treatment facilities as a non-chemical alternative in keeping quality during post harvest handling of citrus fruits

Keeping freshness in fresh-cut horticultural produce (Irtwange, 2006d)

Growth in demand has led to increased marketing of fresh fruits and vegetables in fresh-cut products form. Therefore many firms dedicated to this type of food processing have been established. Fresh-cut produce can help increase the consumption of fresh produce due to its convenience and attractive appearance and flavor. However, cutting results in tissue damage that can stimulate oxidation of cellular components causing tissue browning, microbial development on the wound surface and tissue breakdown. The physical damage or wounding caused by preparation increases respiration and ethylene production, which leads to increase in other biochemical reactions responsible for changes in color, flavor, texture and nutritional quality such as vitamin loss. Development of novel approaches for assuring the quality and safety of fresh-cut produce depends on a better understanding of fresh-cut vegetable and fruit physiology, including nutrients and other functional components as affected by storage and handling. This thus requires integration of quality management techniques like sanitation, color and texture preservation and temperature management. This paper reviewed the different methods and techniques used to keep fresh-cut fresh.

The paper observed that fresh-cut vegetable and fruit products differ from traditional, intact vegetables and fruits in terms of their physiology and their handling requirements. Fresh-cut vegetables deteriorate faster than intact produce usually because of the wounding associated with processing, which leads to a number of physical and physiological changes affecting the viability and quality of the produce. Integration of good sanitation, proper handling, proper packing and proper temperature management techniques along the marketing channel from the harvest point until the consumption point is essential to attain high quality level of fresh-cut produce. The paper recommended that:

- Avoiding desiccation at the cut surface of some fresh-cut products is critical for maintaining acceptable visual appearance.
- Flesh firmness of fresh-cut fruit products can be maintained by application or treatment with calcium compounds. Calcium is thought to stabilize membrane systems and maintain cell wall structure in vegetables and fruits.
- Yellowing or loss of the green pigmentation can be controlled by use of modified atmosphere and packaging.
- Browning in fresh-cut produce can be controlled through physical methods which include heat inactivation, modified atmosphere storage and storage under controlled temperature.

Maturity, quality and marketing of fruits and vegetables (Irtwange, 2006e)

Maturity at harvest is one of the main factors determining the quality of a product. Post harvest technologies deal with separation, sampling, sizing, sorting, grading and marketing operations. These post harvest handling procedures are most important as they may either protect the quality or ruin much that was achieved up to this stage. The fruit and vegetable industry is unique. Dealers

handle a product that is very perishable. A one or two day delay in marketing can mean the difference between profit and loss. This paper examined maturity indices for fruits and vegetables, quality of fresh horticultural commodities and marketing of mature and quality agricultural produce. Developing countries need to develop maturity indices, quality standards and organize on governmental or cooperative levels to penetrate the marketing systems of the rich nations.

The recommendations for developing countries were as follows:

- There is need to develop specific indices of maturity for each commodity in terms of stated parameters.
- Enact a Perishable Agricultural Commodities Act to promote fair trading in the fruit and vegetable industry.
- Act united towards the global markets.
- Develop quality standards for all agricultural produce.
- Operate your own, independent transport logistics.
- Bring your products into European and USA ports and sell from there.
- Keep watch on the worlds markets by linking yourself to the information sources worldwide especially information from gov, .org, .ac and .edu internet addresses.
- Develop few, but commercially attractive new produce and market them in cooperation with the established fruit trade.

CONCLUSION

The current era of globalization is inextricably linked with biotechnology which is in a phase of evolution with endeavours directly linked to development, product and services. This paper has sought to transform and transmit post harvest biology and technology research and development efforts to improve on current knowledge of the subject and expertise for the benefit of present and future generations. These issues have not just intellectual appeal, but the basic research and development discoveries shared can be translated into technology that will impact positively on agriculture, environment, healthcare, pharmaceuticals, diagnostic tools and modern health management technologies and thus benefit researchers and related industries in the areas of improved research and development networking, teaching and learning.

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