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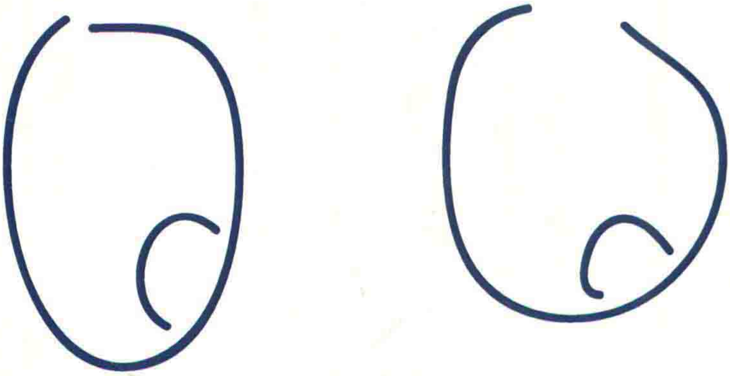
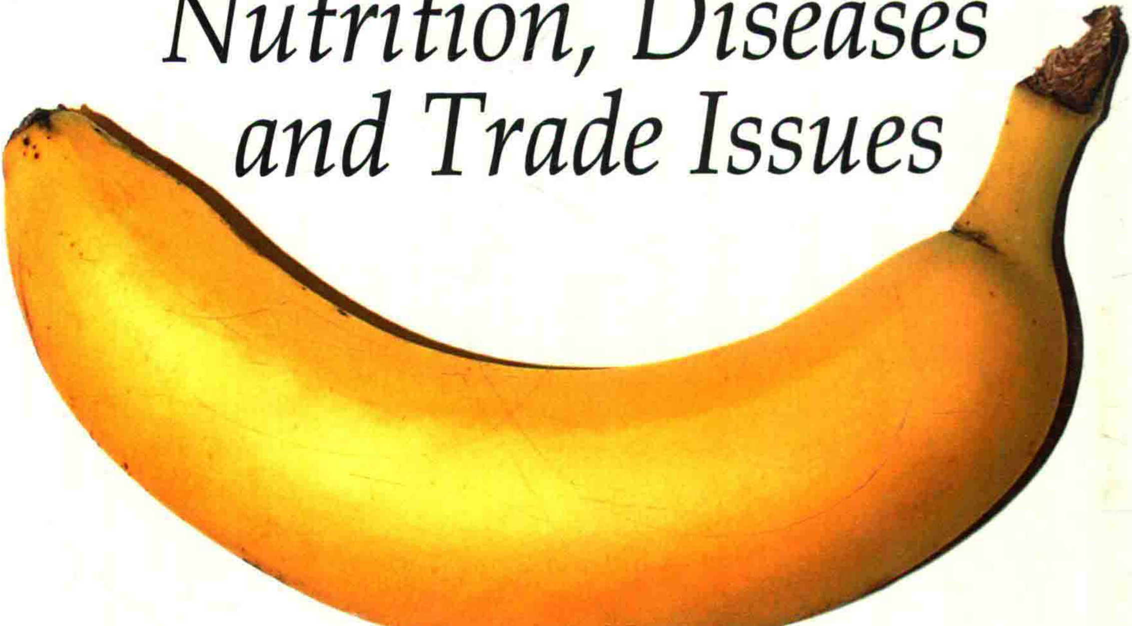


BANANAS

Nutrition, Diseases and Trade Issues



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Editor

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FOOD SCIENCE AND TECHNOLOGY

BANANAS: NUTRITION, DISEASES AND TRADE ISSUES

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FOOD SCIENCE AND TECHNOLOGY

BANANAS: NUTRITION, DISEASES AND TRADE ISSUES

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PREFACE

Bananas are a major staple food for millions of people in the world, especially in tropical regions. In 2006, estimated world production of bananas was 80.6 million tons while 16.8 million tons of fruit were traded. Bananas are a valuable nutrition source of vitamin A, B6, and C. They are rich in carbohydrates, fibers and potassium. Banana plants can also be used in the making of papers, handicrafts, baskets, carpets, as animal feed and inter-cropping. They also have important medicinal uses in the treatment of gastric ulcers and diarrhea and to reduce stress and anxiety. This book presents current research data in the study of bananas compiled from authors across the globe and including agrochemical free treatments to improve the shelf-life of bananas; pesticide residues in bananas; green banana pulp usage; enzymes and bioactive proteins in bananas; and banana lectin interactions with the immune system.

Chapter 1 - Bananas have become popular fruits and over the years, the consumers seem to look for more exotic cultivars. The limited availability of such cultivars in countries where they do not grow, has been due to their inability to withstand rough handling during long distance transport. While handling methods to reduce bruises and damage have been worked out, by determining optimal ambient conditions for fresh produce, this alone would not be sufficient to prevent postharvest disease. Agrochemical usage has been the preferred method of treating fresh produce to control postharvest pathogens and thereby extend shelf-life. With no exception bananas too had to undergo the changes of treatments that the other fresh commodities underwent. Before agrochemicals became available freely, various non-chemical methods have been tried out to keep produce longer. Such knowledge was confined to local growers and handlers, unless their effects were tried out scientifically. Some of these methods were perfected to use for quarantine purposes. While agrochemical usage became more widespread and popular, during the late 70s pesticide resistance became a problem and agrochemicals were noted to have adverse health effects. Thereafter some of the methods tried out earlier were looked at afresh as a pressing need to replace the efficient but potentially dangerous agrochemicals. Some of these alternatives ranged from high temperature exposure of fruits for a defined time period and use of plant derived natural pesticides, of which essential oils played a major role. Furthermore, some of the methods used in the food industry, such as use of food additives and use of irradiation were investigated. Additionally when biocontrol of pathogens became a popular topic, some researchers commenced work on biocontrol of postharvest pathogens. When the above methods were scientifically investigated some of the results were unforeseen. These observations seem to have lead to investigations on challenge inoculations to boost up natural resistance of produce, which has developed as an entirely new branch of research. As most of the agrochemical free methods (with the exception of irradiation) were not as efficient, combining different methods as a multi-hurdle approach, or even combining lower doses of agrochemicals with the agrochemical free methods have been tried out.

Chapter 2 - Bananas are one of the most popular fruits in international trade. Their cultivars, as well as for other fruits and vegetables, are commonly treated with pesticides to control weeds, nematodes, fungal pathogens and insect pests, which have been regulated by several legislative authorities around the world because of their concern about the safety and efficiency of the use of these compounds. In an attempt to facilitate the worldwide trade, maximum residue limits (MRLs) of pesticides have been established. However, most countries set their own MRLs or even authorize the use of certain pesticides which are forbidden or not used in other countries. Hence, strong barriers are created in the international trade, which makes necessary the development of suitable analytical methods able to feasibly identify and quantify authorized and non authorized pesticides in bananas at the required MRL level. The present chapter pretends to show the current situation of the analysis of pesticides residues in bananas and to synthesize the literature concerning pesticide occurrence in these fruits and its relation with trade issues.

Chapter 3 - Fungal diseases of banana can be classed into diseases of the foliage, diseases of the root, corm and pseudostem and diseases of the fruit, including those at post harvest, such as anthracnose. Of these, the most important are the fungal disease of the foliage caused by black sigatoka (*Mycosphaerella fijiensis*) and the wilt disease of the pseudostem caused by the four races of Panama disease (*Fusarium oxysporum* fm sp *cubense*). The monoculture of dessert bananas for urban consumption and the export trade has facilitated the spread of black sigatoka, such that serial applications of fungicides are obligatory in most production areas of the world. In addition, the production of susceptible plantains by smallholders has become unsustainable in many areas due to high costs and difficulty in applying fungicides without the use of airplanes. After the advent of Panama disease in the 20th century, wilt resistant Cavendish dessert bananas replaced the susceptible banana 'Gros Michel' as the principal bananas in the export trade; however, these plantations are now threatened by a new race of Panama disease (Tropical race 1V) which is now present and spreading in S.E. Asia. Here we review the most significant advances in both basic and applied scientific understanding of these two disease complexes which have been made in the last two decades.

A full review of fungal diseases (of which there are more than 40) which affect bananas and plantains has been given in Jones [2000]. The present review deals with advances in research into the two most important diseases, black sigatoka (causal agent *Mycosphaerella fijiensis*) and *Fusarium* wilt tropical race 4 (*Fusarium oxysporum* f sp *cubense*)

Chapter 4 - Banana (*Musa sapientum*) is a major staple food for millions of people in the world, especially in tropical regions. In 2006, estimated world production of banana was 80.6 million tones while 16.8 million tones of fruit were traded (FAO). However, owing to the significance of the different importers in the consuming countries, the world trade of banana has a clear regional character. At the end of 20th century, the export sector of banana has shown a great dynamism and has undergone important structural changes because of the challenges associated with successive reforms of the European Union (EU), Banana Regime and World Trade Organization (WTO). Bananas are grown in tropical regions where the average temperature is 27° C and the annual rainfall is 78-98 inches. It is believed there are nearly 1000 varieties of bananas in the world. Bananas are a valuable nutritional source of vitamin A, B_6 and C. They are rich in carbohydrates, fibers and potassium but short in proteins. Bananas are mostly consumed as a fresh fruit. However, there are other applications of banana plants like in making of banana papers, handicrafts, baskets, carpets, as animal feed and in intercropping. Bananas have important medicinal uses. They are used to treat gastric ulcer and diarrhea and help to reduce stress and anxiety. Moreover, they are reckoned useful for cancer prevention and heart diseases. Bananas are a good source of energy and their high potassium content assist brain for better functioning. Bananas provide several advantages including their accessibility in tropical and subtropical countries where so much of future control of vaccine-preventable diseases will be focused, their palatability and digestibility by infants, and because they do not need cooking that destroy antigens.

Chapter 5 - The banana is one of the most important energy sources for people living in many tropical and subtropical countries, including Brazil, which is the second largest world producer. Bananas are a highly perishable fruit and areoften consumed when the fruit is ripe; for this reason, high quantities of unripe fruit are wasted and rejected for commercialization. These losses can be reduced by the application of the discarded fruit as low-cost raw material in the food industry.

Green banana pulp contains high starch concentration (over 70–80% of dry weight), a percentage comparable to corn grain endosperm, which turns the green banana processing into starch and flour an important resource for many industrial purposes, especially since the banana starch has peculiar characteristics compared with other starches from different botanical sources.

Several products have been studied with green banana pulp and starch applications, such as pastas, cake, bread, juices, porridges and mayonnaise. Furthermore, banana starch has been widely studied in the nutrition area since the introduction of the resistant starch concept (a portion of starch that resists digestion in the small intestine). Also, another study showed that banana is the main polyphenols source in the Brazilian people's diet, which improves its functionality. Examination of starches' rheological properties is an important step in the characterization and understanding of their functional properties.

A recent research study in Brazil presented the development of emulsions, like mayonnaise, with green banana pulp as a stabilizing agent. The study evaluated the green banana pulp influence on the nutritional profile, sensory evaluation and on the rheological behavior of the emulsions. Several formulations were developed and analyzed by means of response surface methodology. Related to nutritional characteristics, the results showed high carbohydrate content, low lipid amounts and low caloric values in all formulations; moreover, the product presented high mineral salt content as potassium, iron, magnesium, calcium and phosphorous. These findings show these emulsions are nutritionally enriched, and increase still more the product's value. The emulsions showed pseudoplastic behavior at 10 and 25°C and rheological data were well described by the Herschel-Bulkley model. The emulsions purchase intent by the consumers showed that 75% of the consumers would buy the product.

The banana availability in Brazil makes the use of unripe fruit a promising alternative, owing to its digestion and functional properties, high nutritional value and high applicability as raw material in the food industry. Use of culls for starch production would provide a product that might be competitive in the starch market, would improve banana economics and reduce a large environmental problem. Therefore, this represents possibilities for diversifying and broadening the market for banana producers.

Chapter 6 - This study was conducted to investigate the effect of a high temperature and short time (HTST) drying pulse at 150 °C, combined with a hot air-drying (AD) process stage at 70°C, on phase transitions, structure and porosity of bananas. In order to obtain a crispy and stable product, the air-drying stage at 70 °C was performed to water activity values below 0.3. Desultory samples were collected during different drying times to be analyzed. For structure and porosity analyses, samples were analyzed as a whole (entire shape). For the analyses of phase transitions, samples were divided into two groups: the internal part formed during drying (middle samples); and a crust formed on the external surface during drying (surface samples). Changes of structure during drying were analyzed using a stereomicroscope, since porosity is calculated from the bulk volume and particle volume. The glass transition temperature was determined by differential scanning calorimetry. Finally, sorption isotherms were determined by the gravimetric method for samples collected at the last time of drying (the dryer samples). According to the results of the structural observations of the banana samples, the drying treatment led to structural changes in the samples, affecting porosity, which reached higher values in the end of drying. The loss in the structure of the surface samples was directly related to glass transition temperatures determined during the same drying times. The middle samples presented only a melting peak, as we looked at glass transition temperature in all surface samples studied, which decreased as water content increased, confirming the water plasticization effect. The Guggenheim-Anderson-de Boer (GAB) model was found to be the best-fitted equation, providing information on samples shelf-stability.

Chapter 7 - In this article enzymes and other biologically active proteins of the banana are reviewed. The bulk of the literature is on the banana fruit. Polyphenol oxidase isolated from roots may be associated with resistance against the parasitic nematode *Radolpholus similis*. Lipoxygenase purified from leaves may be involved in leaf aroma production. Key enzymes of carbohydrate metabolism including ATP-dependent and pyrophosphate-dependent phosphofructokinase have been isolated from banana fruits. Acid phosphatase, pectate lyase and β-1, 3-glucanase from fruits are associated with fruit ripening. Starch phosphorlases, polygalacturonase and pectin methylesterase have been reported from fruits. The allergen present in bananas have been indentified to be a class I chitinase. Banana fruit lectin displays unique carbohydrate binding properties. It stimulates nitric oxide production by macrophages, [methyl-^{3}H] thymidine uptake and cytokine production by splenocytes, inhibits tumor cell proliferation, and reduces the activity of HIV-1 reverse transcriptase. Thaumatin-like protein from banana fruits exhibits antifungal and HIV-1 reverse transcriptase inhibitory activities but is devoid of mitogenic activity toward splenocytes and inhibitory activity toward tumor cells. Banana fruit chitinases demonstrate antifungal activity. Other than the proteins mentioned above, fructooligosaccharides and small molecules with biological activity have also been reported.

Chapter 8 - Isoamyl acetate is one of the most important flavor compounds used in food industries because of its characteristic banana flavor. The ester is used as a flavoring compound in many foods and drinks, such as honey, butterscotch, artificial coffee, beverages and perfumes. Also it is one of the major flavor components of fermented alcoholic beverages, such as sake, beer and wines. The isoamyl acetate production is traditionally carried out *via* chemical synthesis by Fischer esterification mechanism. However, because consumers are moving to foods containing natural flavors due to environmental and health issues, biotechnology is emerging as a competitive alternative to traditional chemical synthesis for the production of isoamyl acetate. Enzyme and whole-cell biocatalysis and fermentation were recently proposed for isoamyl acetate production that can be considered close to 'natural'. These new bioprocesses are in development stages, and most of them limited only to laboratory scale, however, they have high potential to be industrially useful and could offer an alternative way to obtain natural banana flavor. The current review discusses the myriad of reaction systems developed for isoamyl acetate production.

Chapter 9 - Physical, chemical and functional analyses were done of square banana *Musa balbisiana*. Immature fruit were pealed, cut, dried, ground and sifted through 80-mesh screen to produce a flour. Particle size was determined by granulometry: 65.41% of the flour was <53μm diameter. Standard AOAC (1997) methods were used to determine moisture (4.92%), ash (3.74%), protein (4.15%), fiber (2.46%) and crude fat (1.29%) contents. Total carbohydrates (88.40%) were estimated as nitrogen free extract by difference at 100%, and apparent amylose content (18.8%) was determined by the colorimetric method of Morrison and Laignelet (1983). Initial (*To*=73.34 °C), peak (*Tp*=80.41 °C) and final temperature (*Tf*=89.87 °C), as well as gelatinization enthalpy (ΔH=16.31j/g) results indicated this flour to have potential applications in food products submitted to high processing temperatures for complete gelatinization and to ensure thickening. Solubility, thickening power and water absorption capacity were directly correlated to the applied temperature increases. These were caused by breaking of intermolecular hydrogen bridges in amorphous zones, which allowed progressive water absorption. Starch granules resisted swelling at temperatures below 70 °C. Banana flour gels formulated at 6 and 8% had deformation (57.125; 57.1%) and maximum load (0.101; 0.114 kgf) values indicating their possible use in pudding and cream type products. Gel stability under refrigeration, quantified as syneresis, showed them to lose water over time, an undesirable trait in the food industry since it limits use in refrigerated products. Square banana flour is an unconventional, alternative functional ingredient with potential applications in food system formulations.

Chapter 10 - In nature, plants are subject to attack by a wide variety of pathogenic microorganisms. However, as a consequence of the co-evolution of plants with these microorganisms, plants have developed physical, physiological and chemical defensive barriers to resist the attack of pathogens or to limit the infection (Agrios 2005; Baker *et al.* 1997; Glazebrook 2005; Hammond-Kosack & Jones 2000; Rausher 2001). Chemical barriers are collectively known as phytoprotectants and include phytoalexins and phytoanticipins. While production of phytoalexins occurs in response to both biotic and abiotic stress, phytoanticipins are preformed secondary metabolites with antimicrobial activity (VanEtten 1994). At the same time, phytopathogens have developed diverse mechanisms to infect plants; these mechanisms include the synthesis and secretion of cell wall degradation enzymes, the formation of specialized structures, the detoxification of phytoprotectants, and the production of phytotoxic metabolites, commonly known as phytotoxins. Due to their structural variety and different mode action, phytotoxins are considered to be the specialized weapons of fungal pathogens which produce them during the infectious process (Knoche & Duvick 1987; Knogge 1996; Jeng-Sheng 2001). The present chapter describes the role of natural products, particularly phytoprotectants and phytotoxins, during the infectious process between *Musa* spp. and *Mycosphaerella fijiensis*.

Chapter 11 - This article focuses on how the decline of banana production symbolizes socio-cultural transition in Buhaya, the region inhabited by the Bahaya banana agriculturalists of northwestern Tanzania. Bananas have held a prominent meaning in this region and in the

Bahaya cultural way of life for centuries, serving as concrete and symbolic mediums of existence. Bananas are essentially what make the people in this region distinctly "Bahaya," forming the cultural core and staple food. In addition, cultural and symbolic meanings and everyday purposes of the banana emanate through Bahaya socio-culture. However in (at least) the three past decades, invasive and lethal pathogens have increased, causing widespread destruction of banana plants on the kibanja— the banana homegarden which represents the origin and temporal and spatial essence of bananas and the Bahaya socio-culture. Ethnographic data gathered from socio-cultural anthropological research conducted in Nsisha, a rural village in Buhaya, supplements relevant literature on this region to show that the destruction of banana plants has led to shifts in meaning and reality in the Bahaya socio-culture. For many Bahaya, the onslaught of banana pathogens, combined with a matrix of diseases affecting animals, humans and other agricultural crops have increased household poverty and food and nutrition insecurity in Buhaya. This article briefly sheds light on the cultural significance of the banana in Bahaya society, with an emphasis on the decline in production in recent decades. In addition, this article acknowledges other challenges facing the Bahaya society to illustrate the socio-cultural shift that the traditional banana cultivators are currently undergoing.

Chapter 12 - Banana is known as a dopamine-rich and potassium-rich food, however no previous data regarding biochemical or psychological alteration induced by excess intake of banana has been reported. We encountered a female adolescent patient with anorexia nervosa, who was obsessed by an extremely restricted eating habit. As a result of ingesting nothing but maximum 20 bananas and less than 500 ml mineral water per day for more than two years, she exhibited biochemical and metabolic disorders such as hyperkalemia, hyperdopaminemia, and pseudoaldosteronism. The patient also showed a drastic change in her psychological state, represented by decreased anxiety and increase in inner-impulse. Based on the biochemical changes seen in the patient, the accumulation of free dopamine due to obsessive banana ingestion was the most likely cause of her altered psychological state. When the patient resumed eating other food items after 26 months of obsessive and restricted banana ingestion, the abnormalities in her blood values and her psychological state were corrected to that of pre-obsessive eating period. We conclude that in this case, an obsessive and restricted eating habit of banana ingestion modulated her biological and psychological homeostasis.

Chapter 13 - Lectins are a highly diverse group of proteins whose biological functions have been associated with the carbohydrate binding activities. Banana lectin is a member of the jacalin-related family of lectins, and belongs to the glucose/mannose specific subgroup. However, it shows a unique specificity for internal α1,3 linkages as well as β1,3 linkages at the reducing termini in branched mannose oligosaccharides, which are components of the "core" region of N-linked glycoproteins. As some other plant lectins, banana lectin is stable to the harsh conditions of the human gastrointestinal tract. As a small protein it seems to be able to pass the mucosal barrier and to reach the immune system inducing specific IgG4 antibodies. Banana lectin also displays T cell proliferation in CD3+, CD4+ and CD8+ populations of human PBMCs. It has been recently shown that *in vitro* stimulation of Balb/c and C57 BL/6 splenocytes by the recombinantly produced banana lectin resulted in the proliferation of T cells and an increased secretion of interferon-gamma. Due to its notable immunomodulatory potential, it has been proposed for the treatment of some Th2-related disorders. This work will discuss banana lectin interactions with the immune system and consider implications for future therapeutic applications.

CONTENTS

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Chapter 1

AGROCHEMICAL FREE TREATMENTS TO IMPROVE POSTHARVEST SHELF-LIFE OF BANANAS

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ABSTRACT

Bananas have become popular fruits and over the years, the consumers seem to look for more exotic cultivars. The limited availability of such cultivars in countries where they do not grow, has been due to their inability to withstand rough handling during long distance transport. While handling methods to reduce bruises and damage have been worked out, by determining optimal ambient conditions for fresh produce, this alone would not be sufficient to prevent postharvest disease. Agrochemical usage has been the preferred method of treating fresh produce to control postharvest pathogens and thereby extend shelf-life. With no exception bananas too had to undergo the changes of treatments that the other fresh commodities underwent. Before agrochemicals became available freely, various non-chemical methods have been tried out to keep produce longer. Such knowledge was confined to local growers and handlers, unless their effects were tried out scientifically. Some of these methods were perfected to use for quarantine purposes. While agrochemical usage became more widespread and popular, during the late 70s pesticide resistance became a problem and agrochemicals were noted to have adverse health effects. Thereafter some of the methods tried out earlier were looked at afresh as a pressing need to replace the efficient but potentially dangerous agrochemicals. Some of these alternatives ranged from high temperature exposure of fruits for a defined time period and use of plant derived natural pesticides, of which essential oils played a major role. Furthermore, some of the methods used in the food industry, such as use of food additives and use of irradiation were investigated. Additionally when biocontrol of

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pathogens became a popular topic, some researchers commenced work on biocontrol of postharvest pathogens. When the above methods were scientifically investigated some of the results were unforeseen. These observations seem to have lead to investigations on challenge inoculations to boost up natural resistance of produce, which has developed as an entirely new branch of research. As most of the agrochemical free methods (with the exception of irradiation) were not as efficient, combining different methods as a multi-hurdle approach, or even combining lower doses of agrochemicals with the agrochemical free methods have been tried out.

INTRODUCTION

Loss of harvested commodities occur in high quantities world wide and losses in under developed countries are known to be higher than those in developed countries mainly due to poor storage and food handling technologies. Postharvest losses have been quantified in different countries for a variety of commodities, and the references cited even in a recent review by Korsten (2006) are more than 10 years old. Agrochemical usage has been the principal means of controlling such losses in the past (Eckert, 1967; Eckert and Ogawa, 1985). A pressing need to search for alternatives to replace agrochemicals arose in the 1980s when pests showed resistance to agrochemicals (NAS, 1986) and a report of US National Academy of Sciences indicated the presence of oncogenic compounds in pesticides (NAS 1987). The impact created by the above scenario has been so significant to attract the interest of many researchers all over the world within the last two decades to find effective and safe means of extending postharvest shelf-life. Cutting down agrochemical usage has taken a multitude of approaches such as careful handling to prevent bruises and wounds, sanitation to reduce surface microflora of pathogens, use of inorganic chemicals known to have fungistatic effects and looking at novel approaches for traditional methods with a modern viewpoint. Additionally looking for biocontrol agents against postharvest pathogens has also become a popular research topic. Thus, alternatives to agrochemicals have been diverse, concentrating on different aspects of postharvest life. While acknowledging the fact that postharvest managing strategies to suit the changing fruit trading patterns have evolved over the years and with that, it could be assumed that the countrywide policies on importation and exportation of fresh produce and the acceptable agrochemicals on them too have evolved all over the world, posing a complex picture to the entire state of affairs.

It may be timely to revisit the basic facts governing postharvest shelf-life. The key factors restricting postharvest shelf-life are mainly physiological status of commodity and attack by pathogens. Timing of harvest to achieve physiological maturity and thereafter careful handling to avoid damage of produce play a major role in this regard. Storage at optimum conditions, thereby maintaining the physiological status at an ideal level to permit a smooth continuation of metabolic processes after harvest, at the slowest pace possible avoiding stress are the key concerns in keeping fresh produce longer. While the above precautions would help in combating pathogen attack, an additional protective treatment to suppress pathogens is also required. This need has been fulfilled over the years, by the use of agrochemicals, and even today there is considerable usage of agrochemicals in postharvest handling of fresh produce in spite of all the restrictions.

Postharvest treatments have been aimed at not only suppressing pathogens, but also at slowing down senescence, strengthening cell walls exposed to the pathogens and the environment and harnessing natural compounds capable of augmenting natural defense. The climacteric fruits depend on ethylene to undergo ripening associated changes which include softening of the fruit pulp and peel, conversion of starch to sugar in the pulp while there is an increased rate of respiration called the climacteric peak. It is well known that high rates of ripening lead to faster senescence and therefore, increased vulnerability to mechanical and microbial deteriorations. Additionally any stress condition, including bruising or damaging could trigger ethylene production, leading to faster senescence. The increased sugar levels in ripe fruits also help the establishment of pathogens by offering them a ready supply of nutrients. Hence any treatment that could delay respiration and ethylene production is anticipated to have a positive impact on the shelf-life of the commodity.

UNIQUE ISSUES OF BANANA

Bananas are tropical, and unlike most other tropical fruits they are not seasonal. Banana is recorded to be native to Southeast Asia, and countries in Asian region including Sri Lanka have great potential to introduce exotic banana cultivars to the rest of the world. Among the key potential cultivars are `Embul' and `Kolikuttu' from Sri Lanka, as well as several described by Hassan and Pantastico (1990) in the ASEAN region. Banana is eaten as a fruit when ripe, or may be harvested when green, and cooked as a starchy staple. In fact in Africa, bananas are considered to be an important starchy food and the African continent has been recorded to have a high acreage of banana for this purpose (Khader *et al.* 1990). The cooking varieties are generally called plantains, although it is possible to cook some of the green mature bananas which are regularly eaten as fruits as well. The present discussion is on bananas consumed as fruits after they ripen.

One of the earliest books written on bananas is by Simmonds, of which the first edition has been published in 1959 (Simmonds, 1966). The references cited therein date back to the 19th century with articles written to scientific journals mainly focusing on Indian banana cultivars. Now bananas are considered one of the most important fruit crops in the world. Unlike other tropical fruits bananas are unique, as a sucker produces only one bunch and then the stump has to be removed for the next sucker to grow and bear fruit. The bunch itself consists of several hands of bananas, each hand bearing about 15-20 fruits (depending on the cultivar) on a crown which is attached to the main stem of the banana bunch. As each successive hand from a sucker unfurls sequentially, each hand on a bunch will be in a successively decreasing maturity level. The curved shape of the fruit, and the arrangement of fruits on a hand makes it even more challenging for handlers and packers to avoid bruises and excessive pressure on certain areas. Depending on the cultivar and the handler's choice, they may be transported after dehanding on the crown or as bunches. Although there are no toxicities recorded on the peel, it is generally not eaten. This is an advantage as postharvest treatments could be directly applied to the peel, as the peel is sufficiently thick and spongy in most cultivars it has a buffering effect to protect the pulp getting infiltrated with foreign substances. This appears to be true of the spread of diseases as well. In fact it has been noted that thicker the peel, lesser the spread of anthracnose lesions (Perera *et al.* 1999). In spite of a choice of a wide variety of cultivars of banana all over the world (Simmonds, 1966; Hassan and Pantastico 1990) the most commonly found bananas in areas of the world where banana is not cultivated, has been the large fruited Gros Michel and Cavendish group, which have thicker peels, and consequently to longer postharvest shelf-life.

The banana trade appears to have depended on agrochemicals from an early age (Burden, 1969; Long, 1971; Locher and Hambel, 1973; Griffee and Pinegar, 1974). Agrochemical application may take the form of dipping, spraying or even injecting to the bunch (Beattie *et al.* 1995). Among the agrochemicals used on bananas are fumigants such as sulfur-dioxide and methyl-bromide, systemic fungicides, such as thiabendazole and carbendazim), sterol inhibitors such as prochloraz and propiconazile, and phenyl amides such as matalaxyl and benzimidazole (Gowen, 1995; Kraus and Johanson, 2000). Postharvest diseases of bananas have been efficiently controlled by dip or spray treatments of the detached hands with suspensions of 200-1000 mg/L thiabendazole, or 100-500 mg/L benomyl. Additionally, carbendazim, thiophanate-methyl and imazalil have been used to control specific postharvest diseases (Eckert and Ogawa, 1985). Even as early as the 70s, various environmental issues such pathogen resistance (Kuramoto, 1976; McDonald et al. 1979) including resistance of banana pathogen *Colletotrichum musae* (Griffee, 1973) to agrochemicals were noted. Benomyl has been the most popular agrochemical used to increase shelf-life of bananas. Subsequently with increasing records of pathogen resistance and other related issues, and as it was noted to be a possible human carcinogen by the US Environment Protection Authority (http://www.pesticideinfo.org/Detail_Chemical.jsp?Rec_Id=PC32865) the production of benomyl was halted in 2001. Currently thiabendazole and Thirem along with a few other agrochemicals, have replaced the role of benomyl until an equally effective agrochemical-free alternatives could be found.

Lately there has been a niche market for organic bananas (UNCTAD, 2008). Agrochemical usage on traditionally grown fruits (both pre and postharvest) such as banana is negligible or absent in Sri Lanka, and perhaps this is true in other neighbouring countries as well. Banana is grown in the home gardens and is a small farmer based industry in most of the agriculture based countries of low technology. However, to develop a lucrative market overseas, innovative techniques are needed to replace the function of agrochemicals.

The total number of banana cultivars worldwide is not known exactly but has been estimated to be around 100-300 (Samson, 1982). A fraction of this would be dessert bananas. It is known that about 22 cultivars of dessert bananas are available in Sri Lanka (Chandraratna and Nanayakkara, 1951; Fonseka and Vinasithamby, 1971) indicating the rich diversity of bananas in the region. Much ground work has been done for the popularization of these bananas (Hewage 1996; Abayasekara, 1998; Perera, 2000; Daundasekara, 2003; Gunasinghe, 2004; Indrakeerthi, 2006; Ikiriwatte 2008; Weerakoon, 2009; Wanigasekara, 2009).

SPECIFIC CONCERNS ON THE POSTHARVEST LIFE OF BANANA

Bananas are cited as a classical example of postharvest management of fruits transported long distances from tropical countries (mainly South and Central American countries known