Use of Plant Antimicrobials for Food Preservation

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***Abstract*—**Spoilage occurs in plant produce due to the action of field and storage microorganisms. The conditions of storage can also cause physiological spoilage. Various methods exist to ensure that these food substances maintain their quality long after harvesting. However, many of these methods either fail to keep the plant for the required period or predispose the plant to other spoilage risks. The major shortcoming posed by the use of many antimicrobials is the chemical residues it deposits in the food substance. The use of plants in preservation has been in use for a long period, though little understood then, it served its purposes. A better understanding of the roles of these plant parts in increasing the shelf life of farm produce has helped in the creation of more effective and safer means of pest and microbial control. This can be extended to plants that have not been used for these purposes initially. Microbial sources should also be investigated as these have provided cheaper sources of secondary metabolites.

***Keywords*—**Antimicrobials, Food preservation, Phytochemicals.

I. Introduction

THE availability of farm produce during off-season has been plagued majorly by problems associated with preservation and storage. Of the many hazards that plague food handling and storage, spoilage caused by microbial contamination or physiological activities occurring in the food product itself [1] contribute significantly to food loss. A large portion, (30% - 50%) of these products is lost in postharvest processes leading to an inability to access enough of these products at all times despite the annual increase in production. Humidity alone or in combination with temperature also plays substantial role in the physical hazards that pose threat to food security. The presence of some amount of moisture or water activity in some food substances, especially dried raw food materials and processed foods will favor the growth of bacteria and enhance fungal infestation. The presence of these organisms usually leads to rotting, discolouration and formation of off-flavors in the food products depending on the types of microorganisms and their corresponding physiological activities.

Mechanical hazards arising from bruises, compression and impact force during harvesting, transportation from the farm and storage methods are implicated in the initiation of physical hazard due to exposure to atmospheric milieu; chemical and biochemical hazards resulting from interplay between oxygen and activities of endogeneous enzymes. Approaches to ensure prolonged storage hence availability of farm produce by reduction of microbial spoilage are reviewed accordingly.

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II. Food Preservation

A. Traditional Approaches to Preservation

Long before the advent of technology and its attendant applications, man has devised numerous means of preserving his food for availability during off-season and for preservation of quality of the food substances during long storage. One notable preservation method is fermentation. Traditionally, fermentation was carried out spontaneously and besides preservation assisted in food processing. Fermentation procedures enhanced flavor, aroma, digestibility as well as reducing cooking times in food substances. Lactic acid bacteria and yeasts were the major microorganisms involved in these fermentations and the production of acids made the food unbearable for the growth of many spoilage and pathogenic microorganisms. This was applied to the preservation of vegetables where sugars in the leaves were converted to lactic acid [2].

Drying has been applied successfully to many food substances to prolong their shelf life. This seeks to reduce the moisture content which makes the food substances unfavorable for growth of many spoilage bacteria. Smoking is an adaptation of drying since many of the methods used in its adaptation to preserve foods also seek to reduce the water activity in food substances (such as fish) before they are eventually dried. This is in addition to the production of antimicrobial substances from the wood smoke and ash. Drying, however, predisposes the products to mould and insect infestation [3]. Storage of maize husks in cribs and silos is a method that ensured that they remained dry even during the rainy seasons as well as protection from insect infestation [1]. Other methods that also help in longer storage by reducing the microbial population of food substances include subjecting them to high temperatures. This helps in reducing enzyme activity that could cause physiological spoilage [2]. Grains are stored among neem leaves and with capsicum peppers to ensure they are preserved till the next season. Tubers are stored under dried mulches of maize and millet left under a shade, while others are preserved under plant materials mixed with soil [1].

B. Modern Approach to Preservation

Proper postharvest handling is being employed in the control of plant losses. This has an effect on the shelf life as well as ensuring the security of plant products in terms of quality and quantity round the year. An important factor that has been identified in ensuring food security is the proper postharvest storage of food crops. The design, construction and maintenance of storage facilities and power supply in some developing countries are factors considered in postharvest storage. Refrigeration to a temperature of about -

1^0C to 13^0C has been used in increasing the shelf life of perishables such as fruits which have a high water activity and soft tissues. A misuse of this technique can also lead to chilling injury in the fruits. Poor infrastructure in developing countries has however constrained the use of such technologies [4].

Moreover, the storage atmosphere can be designed to reduce the respiration rate, ripening, ageing, decay, oxygen and or carbon dioxide levels. Methods used in this direction are modified atmosphere storage and controlled atmosphere storage respectively. These methods have been applied to only a few commercial fruits such as apples where others will react adversely to this kind of atmosphere. While the environment is created to prevent spoilage by intrinsic factors, it could also however favor the growth and metabolism of other microorganisms that have the ability to cause spoilage.

Postharvest pathogens have been controlled to a certain level of efficiency by chemical fungicides [5], [6]. However, the use of fungicides is increasingly becoming unacceptable due to factors such as restrictions on authorized active ingredients available for pest control, increased resistance of some postharvest fungal pathogens against the few authorized fungicides, health risks involving presence of chemical residues in the food as well as growing consumer demand for both high quality and safe fruits and vegetables, have increased efforts to develop control methods other than the chemicals [7]-[10], [6]).

C. The Use of Plants and Their Products as Antimicrobials

Essential oils also called volatile or ethereal oils have been the active principle of many important herbal remedies since ancient times [11], [12]. This has also been applied to food preservation where the presence of naturally occurring antimicrobial agents in plants have been used against the spoilage microorganisms found in food in order to increase the storage properties of food [13], [14]. The suitability of a plant as an antimicrobial agent is dependent largely on the active components present in the plant part being used as an antimicrobial. The presence of an active component at a particular time is determined by factors such as environmental conditions, the period during which the plant part was collected, method of drying the plant part, storage condition and isolation methods [13].

III. Activities of Phytochemicals as Antimicrobials

The antimicrobial activity of plants is as a result of certain compounds regarded as active compounds. These substances are naturally produced in plants as defense mechanisms against pathogenic microorganisms and insect pests [15]. Plant phytochemicals are classified broadly as Terpenoids, Phenolics and Alkaloids [16].

A. Phenols

Phenols and their derivatives which possess oxygen molecules [17] are secondary metabolites. They generally include phenols, phenolic acids, quinones, flavones, flavonoids, flavonols, tannins and coumarins [18].

Phenols and phenolic acids are bioactive phytochemicals consisting of a single substituted phenolic ring. They contain varying number of hydroxyl groups and this determines the level of toxicity to microorganisms [19], [20]. Flavones, flavonoids and flavonols have the phenolic structure with one carbonyl group. They are synthesized by plants in response to microbial infection [21]. They have been found to be effective in vitro as antimicrobial substance against a wide array of microorganisms [22] due to their ability to form complexes with nucleophilic amino acids in proteins and bacterial cell wall. These lead to enzyme inactivation [23]. Flavonoids are described as phenolic compounds and they include pigments such as luteolin-7-glucoside, quercetin-3-glucoside, apigenin-7-glucoside and kaempferol 3-glucoside which confer antimicrobial activity on the plants from which they are extracted [24]-[26], [6]. Active components of plants extracts also include phenolic compounds classified as caffeic acid derivatives. The caffeic acid derivatives include chlorogenic acid, chicoric acid, verbascoside and isoverbascoside [6]. Tannins are polymeric phenolic substances possessing the astringent property. These compounds are soluble in water, alcohol and acetone and give precipitates with proteins [27]. Tannins succeed in their antimicrobial activity by making substrates required for growth unavailable, directly inhibiting oxidative phosphorylation and in some cases inhibition of extracellular enzymes in microorganisms [19]. Coumarins are phenolic substances made of fused benzene and pyrone rings [28]. They have a characteristic odor and several of them have antimicrobial properties.

Phenolics inhibit adhesion in some pathogens as well as disintegrating the outer membrane of bacteria leading to the cell becoming permeable hence affecting cell integrity. This disintegration is achieved by chelating divalent cations from the membrane. Moreover, the cations responsible for stability of the outer membrane can be replaced during the process of intercalation of the phenolic extract into the bacterial membrane. The partially hydrophobic nature of the extracts also contributes to the antimicrobial activity [18].

B. Terpenes

Essential oils contain many substances including isoprene structure based substances called terpenes and terpenoids. Terpenes are known to disrupt membranes in microorganisms, alter their permeability and affect their ability to effectively carry out osmoregulation. Moreover, the ability to remove toxic substances through the microbial cell membrane is also greatly impaired [29], [30]. The 1,8 cineole is a terpenoid with the ability to reduce growth, inhibit the spore production in fungi and germination of wide range of microbes [13], [31] [32]. Since fungi absorb nutrients from their environment, they have been found to absorb terpenoids which lead to hyphae malformations, disorganization of cell wall, and leakage of cytoplasmatic material.

C. Alkaloids

The diversity of alkaloids is an indication of their efficiency in antimicrobial activities of plant extracts. These compounds occur in varying concentrations in different plants and plant parts as well as having derivatives themselves that are all efficient against microbes [26], [6]. Some of these substances are lipohilic and hydrophobic in nature thereby altering the integrity of the cell wall and mitochondria while affecting the transport system and causing cell content leakages [33]-[37]. They have also been found to be able to intercalate with DNA [38].

IV. Conclusion

Literature is inundated on the use of plant extract and essential oils in the control of microorganisms and the scope has successfully covered fungi and bacteria. Activities have been recorded with very high inhibitory concentrations against both Gram positive and Gram negative bacteria. This success has also included the control of many field and storage microbes. *In vitro* tests have been positive for the control of identified storage and field pests of plants such as *Ganoderma boninense* [39], *Aspergillus flavus* [24], [31], [40], *Mucor* spp. and *Rhizopus* spp. [40], *Penicillium* spp. [31]. The success with these microorganisms and many more recorded in the laboratory can be translated to the field where actual pesticides and microbicides containing specific active ingredients extracted from plant sources are used. Positive results have been obtained with *Bacillus thuringensis* in similar tests in the control of Lepidoptera insects.

Many obstacles will challenge this giant stride, however, they are not insurmountable. One of which is the correlation between quantity of the active component that can be produced and plant mass used. However, this can be overcome using biotechnological approaches involving the use of plant genes.

Moreover, due to the fact that only a small fraction of the metabolite profile of the approximately 5% fungi and 0.1% bacteria have been identified [41], other sources of antimicrobial phytochemicals such as fungi [42], bacteria and actinomycetes must be further studied and their inhibitory activities better understood [43]. The renewed interest in metabolites from marine bacteria and actinomycetes is a justified solution to the search for new substances for the control of microorganisms due to the large expanse water bodies cover on the surface of the earth [43]. Reference [41] has observed a possibility where due to convergent development, some plant metabolites will eventually be produced by microorganisms. Since the phytochemicals are produced as a result of an external stimulus, it is suggested that a similar response can be expected in microorganisms that are exposed to the same stimulus. Other yet-to-be discovered microbial sources will prove invaluable in the production of these antimicrobial phytochemicals for commercial production and large-scale uses in field and storage pest control.

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