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Review Paper

Application of phytochemical extracts and essential oils in food products: A review

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Abstract. Plant extracts and essential oils are increasingly becoming important in the food industry. Their antimicrobial and antioxidant abilities coupled with the increasingly negative consumer-led views on artificial preservatives have strengthened the argument for the incorporation of extracts in foods. This study seeks to reveal the critical factors that have favoured the adoption of extracts by the food industry and also shed more light on the hitherto grey area in the world of plant extracts and oils. The study also reveals the positive organoleptic effects these extracts have on foods and also the possibility of exploring possible synergies derived from extract combinations. It is recommended that more work is done in the area of antimicrobial synergies and ensuring balance between food safety and quality concerns.

Keywords: Artificial preservatives, essential oils, foods, plant extracts, organoleptic effects, synergies.

INTRODUCTION

Plant extracts and oils have been of immense help for thousands of years for the various purposes they have been used for (Jones, 1996). In fact, Reynolds (1996) reported that the antimicrobial activity of plant extracts and oils has been the cornerstone of various scientific applications in the food processing industries, pharmaceutics, alternative medicine and some natural health therapies.

Plant extracts are usually collections of crude mixtures obtained from plant parts and are attested to have inhibitory effects on micro-organism especially the pathogenic activity, the plant parts could be leaves, stems, flowers, fruits, roots, barks, etc. Essential oils are aromatic oil liquids gotten from plant parts or (sometimes animals) and are proven to have anti- pathogenic and anti-spoilage properties useful in inhibiting viruses, bacteria, fungi and some insect parasites (United States Food and Drug Administration, 2009). According to Dorman (1999), plant volatile essential oils can be extracted by various distillation methods either through steam or hydro distillation. The antimicrobial properties of various plant oils and extracts have been assessed and reviewed (Deans and Svoboda, 1988).

Burt (2004) stated that essential oils are now legal food preservatives in the United States and the European Union. He also reported the presence of more than 60 individual compounds present in a typical essential oil with the major compound usually called active compounds accounting for close to 85% of the oil. Despite the availability of useful alternatives including chemical additives and salts, the use of plant extracts and essential oils are on the increase in the food industry. Also, the factors favouring their use, mechanism of action and synergistic combinations are the important foci in this study. The objective of the study is to therefore synthesize the recent research advances in the use of extracts and oils and to critically examine the underlying factors behind the increasing importance.

Health issues

In recent years, there has been observed increased scepticism in the use of artificial additives and chemicals

like organic acid salts and nitrites in food. This also indicated an increasing demand for “naturally” cured products and organic foods, health reasons were usually overwhelming concerns for these. It has also been observed that food industries are now in search of clean–label alternative additives (Sullivan et al., 2012).

According to the United States Department of Agriculture regulations for producing and labelling natural foods (2005), the use of artificial flavourings, chemical and synthetic preservatives have now been banned in the United States. This could be due to possible fear of carcinogenic contamination. By carcinogenic contamination, the possible presence of cancer-causing chemicals in additives which has been a relevant issue in the western world is meant. A recent survey done by the Organic Trade Association (2009) brought up interesting outcomes; it stated that 73% of U.S homes often procured organic food and also stated health benefits as essential reasons, 47% asserted that they avoided artificial ingredients and preservatives in food. These emergent issues have led to an increasing focus on the use of natural antimicrobials in preserving food and inhibiting pathogen growth and infection instead of continued use of chemical ingredients (Theron et al., 2007).

Phenolics

Phenolics and phenolics-based compounds have been implicated to be the major active compounds in various plant extracts: oregano, cranberry, citrus, rosemary, etc (Lin et al., 2004). Phenolic compounds possess strong antioxidant and antimicrobial properties, hence helping to prevent rancidity and spoilage in high fat and lipid-based foods and reducing microbial loads in foods (Lin et al., 2004). The antimicrobial properties of various plant extracts (and oils) have been assessed and reviewed (Deans and Svoboda, 1988).

The work done by Bevilacqua et al. (2010) revealed the presence of eugenol and limonene which are the two active phenolics-based components present in appreciable portions in citrus oils. According to Lin et al. (2004), phenolics and phenolics-based compounds are major determinants of inhibitory potency and antimicrobial actions of plant extracts and oils. Rosmarinic acid was discovered to be the major phenolic based in oregano and cranberry extracts. However, it still must be emphasized that there is still very little work done on phenolic-based antimicrobial and inhibitory synergy in foods. Acidification by fermentation or direct addition has been found out to significantly increase inhibitory potency of phenolics (Lin et al., 2004)

The method of ascertaining the total phenolic contents was developed by Chandler and Dodds (1983), they reported that total phenolic content of a plant extract were usually determined as Gallic acid equivalent by plotting an absorbance versus a Gallic acid standard curve. The synergism of combined plant extracts increase diversity of phenolics and it has been stated that this could significantly aid or hinder inhibitory potency (Lin et al., 2004). This ensures the need to know the optimum concentration of phenolics needed to optimize antimicrobial efficacy and potency.

MECHANISM OF ACTION AND INTRINSIC FACTORS

Mode of action

Understanding the dynamics of how antimicrobials work through the active compounds is important in determining what pathogen it should be used against. Active compounds of antimicrobials work in different and diverse ways to stop microbial growth improve shelf-life of food products or cause cell lysis.

Wendakoon and Sakaguchi (1995) suggested that the hydroxyl (OH) group of eugenol (an active compound of essential oils) has the ability to adhere strongly to proteins, making them inert and thus preventing enzymatic functions and reactions and also contributed about the possible occurrence of cell-wall breakdown and cytolysis in pathogen due to antimicrobials.

While this could be true, it is also important to know that pathogens are increasingly finding ways to counteract and resist antimicrobial effects which is coming more to the fore in the case of *Listeria monocytogenes;* a psychrotolerant gram-positive bacteria which are well-evolved organisms with the ability to withstand several stress conditions including low pH (Swaminathan, 2001)

In another view, Yen and Chang (2008) stated that eugenol speed up fungal death by taking up free radicals manufactured by the pathogen also greatly altering the composition of the fungal cell wall. In other words, active compounds are able to absorb high energy molecules and ions produced by pathogens and deny them the nutrients needed for growth and multiplication. Mycelia growth of fungus was usually stagnated by the presence of inhibitory volatiles (Pimenta et al., 2012).

Practical examples of antimicrobial use in foods

It was discovered that strong microbial inhibitory properties of vinegar, sugar and lemon against several strains of both gram positive and negative bacteria and some fungi like yeast and moulds existed and also that they were safer health-wise compared to chemical additives (Theron et al., 2007). It is also interesting to note that the use of natural antimicrobials do not significantly alter the taste and perception of treated food substances by consumers. Sullivan et al. (2012) worked on curing systems in ham processing and preparation and discovered that the combination of traditional curing with some antimicrobials produced hams with strong anti-

Listeria properties and stated that any possibility of pathogen growth is drastically reduced by use of antimicrobials and taste of consumers wasn't significantly affected. The importance attached to antimicrobials can't be overemphasized, Food Standards Australia and New Zealand guidelines (2008) stated that "foods are considered satisfactory when total aerobic bacteria counts are less than or equal to 6 log CFU per gram and pathogenic bacteria are undetectable". Hence antimicrobials have inhibitory properties that can be harnessed to a great extent without fear of health repercussions and are also relatively cheap to get.

Research on human noroviruses revealed that cranberry and pomegranate juice showed the ability to adhere strongly to viral P particles and consequently stagnating viral multiplication and metastasis (Dan-Li et al., 2012). It is important to note that noroviruses are notorious groups of enteroviruses implicated in the occurrence of food borne illnesses and gastroenteritis. Cherry powder extracts have been discovered to be effective as cure accelerators in curing systems, the importance of which means the shelf life of such food product be it fish or meat can be extended (Terns et al., 2011). The antibacterial activity of rosemary extracts were positive against *Penicillium* roquefortii and Botrytis cinerea but no effect were recorded for gram negative bacteria like Salmonella and Escherichia coli showing that rosemary extracts may not be ideal for inhibiting such pathogens (Del campo et al., 2000). It has also been reported that lipids, surface active agents and some proteins had the ability to reduce the potency of anti pathogenic activity (Del campo et al., 2000), this agrees with the work of Larson et al. (1996) who discovered that *L. monocytogenes* were less sensitive to phytochemical extracts in meat systems to broth media which was said to be due to high lipid content and lower acidity. Inhibitory activity of rosemary and citrus extracts have implicated to be effective against *Lactobacillus* spp. and *L. monocytogenes* in cooked meatballs and also consumer perception in terms of taste and acceptability were not significantly affected (Fernandez-Lopez et al., 2005). It must also be noted that it is important that antimicrobials are dissolved in the right solvent for it to be effective (Allen et al., 2012). As observed in culture media or broth systems, by increasing lag phase and reducing maximum growth rate (Stasiewicz et al., 2010), antimicrobials create clear inhibition zones on the media and gradually phase out the pathogen spread (Lin et al., 2004).

Intrinsic factors

The importance of pH in the use of suitable solvent for dissolving antimicrobials cannot be swept away, depending on the nature of plant extracts in use, acidic or basic medium may be required for greater antimicrobial potency. According to Lin et al. (2004), the effect of phenolic-based plant extracts: oregano and cranberry extracts on *L. monocytogenes* in meat and fish systems are significantly influenced by degree of acidity or alkalinity of the buffer. It was reported that the pH value of 6.0 to be the best with lactic acid being the buffer if antimicrobial efficacy is to be significantly stronger when the phytochemical synergies of oregano and cranberry extracts are used against *L. monocytogenes* in food and meat systems.

In the culture media, oregano and cranberry extracts produced clear inhibition zone against the pathogen. The lactic acid was useful in bringing down the acidity to a lower level to significantly increase antimicrobial efficacy in broth and meat systems. Pathogens like *L. monocytogenes* are remarkably psychrotolerant, having the ability to grow at subzero temperatures (Swaminathan, 2001). It thus mean that while antimicrobial extracts can be able to effectively inhibit pathogen on culture media, its usually a different matter in refrigerated circumstances (Lin et al., 2004).

Seafoods like shrimps and oysters which are usually at high risk of *Listeria* contamination have been observed to tend to grow to astronomic levels during refrigeration thus necessitating the use of healthfriendly and relatively cheap antimicrobial extracts (Yoon et al., 2004). The use of essential oils like thyme, oregano and carvacrol oils have been found to be significantly effective against *L. monocytogenes* biofilms though cinnamon, bay, eugenol oils had only moderately inhibitive effects when used on stainless steel and polystyrene surfaces (Desai et al., 2012).

ANTIMICROBIAL SYNERGIES AND THE HURDLE CONCEPT

Synergistic effect of extract combinations

Research on possible synergies derived from combining two or more antimicrobial substances have generated interesting results; synergies of spice and herb extracts have been discovered to be double effective in stagnating microbial and pathogenic activity in ready-to-eat (R-T-E) foods with spoilage bacteria (Weerakody et al., 2011). They also discovered that galangal leaves which is a spice and rosemary bark extracts which is a herb had significantly stronger inhibitory effect on lactic acid bacterium *Lactococcus lactis* than just using one extract and this helped increase shelf life and viability of cooked RTE shrimps to 12 days or more at 4°C and more than 8 days at 8°C.

This becomes more remarkable when its noted that the use of this antimicrobials do not significantly alter the taste and public acceptance of the products (Sullivan et al., 2012) and is thought to pose little or no health hazards (Organic Trade Association, 2009). The extension of shelf life for days ensures the elongation of the product viability and health (Weerakody et al., 2011). Phytochemical synergies of oregano and cranberry

extracts were able to effectively control *Listeria* growth in refrigerated fish and meat systems as compared to one individual extract alone when the fish and meat slices were kept at 4°C in refrigerated systems (Lin et al., 2004).

While oregano and cranberry extracts were able to control *Listeria* growth and increase lag phase, the photochemical synergies of their combination in the presence of lactic acid was significantly stronger than that of an individual extract. The antimicrobial efficacy or potency of the synergy was more felt at pH of 6.0 compared to 7.0. Lactic acid was used as the acidifying agent in the experiment.

While the synergies of combined antimicrobials are significantly stronger, it is important to know the effect of the antimicrobial extracts at different concentrations and identify ideal solvents that will help dissolve the active compounds efficiently (Weerakody et al., 2011). Another issue had to do with combining these extracts in what proportion to produce optimum concentration of optimized phenolics or other active compounds that will adequately inhibit pathogen and spoilage bacteria growth in food samples and culture media.

It was discovered that in the use of oregano and cranberry extracts to control *Listeria* in meat and fish system, by combining oregano and cranberry extracts in weight per weight basis of 75:25 to produce 0.1 mg/ml gave the optimum amount of phenolics needed. Tryptic soy agar (T.S.A) was the culture medium of choice used in the experiment (Lin et al., 2004).

Synergistic combinations are fascinating areas in the study of antimicrobial extracts and more research light is being thrown into it by scientist and researchers. While there are lots of commercial available extracts, there is the question mark of optimum concentration hanging on their use.

The hurdle concept

The hurdle concept has to do with increasing the preservative factors or barriers that a pathogen has to overcome to infect or intoxicate foods and food products. The use of antimicrobial extracts becomes more important in the hurdle concept because it increases the number of hurdles or barriers the pathogen or spoilage bacteria must scale through thereby prolonging the shelf life or viability of the food (Weerakody et al., 2011).

CONCLUSION

Based on the study done and research light thrown into antimicrobial extracts, it is sufficient to say that antimicrobials are effective means of controlling food borne pathogen and spoilage bacteria (Weerakody et al., 2011; Dan-Li et al., 2012).

Methods to control pathogen growth in culture media or broth do not necessarily apply to that of refrigerated systems due to obvious temperature differences and special cases of psychotropic pathogens like *L. monocytogenes* (Lin et al., 2004). Antimicrobial extracts are proven and also do not significantly alter the taste, acceptability and perception of consumer public (Sullivan et al., 2012). While food safety is of overall importance, food quality demands by consumers mean that concentration of extracts to be applied to food systems is important from the organoleptic viewpoint as sensory qualities of food products as perceived by consumers are critical commercial factors.

It is recommended that more work should be done on use of antimicrobial and their synergies in the control of food borne viruses, an area that needs more research insight.

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