COMMENTARY

Essential oils: a traditionally realized natural resource for food preservation

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Since the beginning of the food industry, synthetic preservatives have been used to prevent food spoilage caused by microbial and oxidative deterioration. In view of the recent consumer awareness towards green consumerism, some of the prevalent synthetic preservatives are not reliable in the present day. In this context, essential oils of aromatic plants often having strong antimicrobial and antioxidant potential may be used as natural preservatives to realize the consumer demand for safe, healthy and nutritious food. The current existing limitations of essential oil-based preservatives such as low water solubility, strong organoleptic characteristics (flavour and aroma), low stability, etc. could be addressed by the modern advanced technologies such as nanoencapsulation, edible coatings and controlled release systems. This commentary provides an overview on the prospects, existing limitations and future research direction towards the development of essential oil-based preservatives.

Background

In spite of all available means of food protection, microbial spoilage (bacteria, moulds and yeast) and oxidative deterioration (lipid peroxidation, nutritional and colour impairment) are still the major challenges for food industries. A range of synthetic preservatives are currently being used to extend the shelf-life of food items. However, based on recent reports on resistance development, adverse effect to the health and environment, some of the prevalent synthetic preservatives have been restricted for their continuous use in food preservation. The recent strict regulatory approval policies for new synthetic preservatives and consumer preference towards green consumerism provide an expanding opportunity for traditionally used natural products to be a complementary alternative to synthetic ones. In this context, essential oils (EOs) traditionally realized as a volatile cocktail of several bioactive compounds (terpenes, terpenoids, phenylpropenes and phenolics) often having strong antimicrobial and antioxidant potential could play a significant role in the development of eco-friendly plant-based food preservatives. Approximately 3000 different EOs are already known, among which 300 are used as flavour and fragrance agent in the world market[1]. The diversified use of EOs could be helpful in retardation of food spoilage, and also to enhance organoleptic properties such as taste, texture and nutritional value of foods items. This commentary presents an overview of the potential use of EOs as food preservatives. In addition, some perspectives and remarks on the role of scientific and technological advancements in the development of the EO-based preservatives are discussed.

Essential oils as food preservatives

Since antiquity, EOs have been used for their pesticidal potential against a wide variety of agricultural pests by the ethnic people as part of traditional practices. However, their application as an antimicrobial and antioxidant agent is a recent growing trend reflecting the interest towards 'green consumerism'. According to the recent European regulation EC/1334/2008; Code of Federal Regulation 21CFR part 182.20 (USA), natural substances that were found to have minimum quantity requirement to produce their intended effect in food system, either alone or as co-adjuvants with flavouring substances are generally recognized as safe (GRAS) food additives[2,3]. In this perspective, EOs could play a promising role either individually or as co-adjuvants in the development of biorational food preservatives. In general, EOs act as a fumigant with no/less residual effect on applicable products and exhibit superiority over other food preservatives. Eco-SMART is one of the world's leading EO-based industries, that has developed several commercial EO-based products. DMC Base Natural, Protecta One and Protecta Two, Eugenol-Tween® and Eugenol ethoxylate, Acti Vin™, Pycnogenol® and Herbalox® are some plant based formulations that show potent inhibitory effects against food-borne pathogens[4–6]. Till now, there is no report on any residual toxicity effect of EO-based formulations on the health of consumer. Some of the EOs, oleoresins and their bioactive compounds such as angelica, basil, citrus peels, lemongrass, thyme, ylang-ylang, carvone, cinnamaldehyde, citral, *p*-cymene, eugenol, limonene, menthol, linalool, are GRAS by the Food and Drug Administration (FDA) in the United States[3].

A plethora of research articles have revealed that EOs and their bioactive compounds exhibit strong antimicrobial effects against food-borne pathogenic bacteria (*Salmonella*, *Staphylococcus aureus*, *Escherichia coli*, *Listeria monocytogenes*, *Yersinia enterocolitica*), moulds (*Aspergillus flavus*, *Fusarium* spp., *Penicillium* spp.) and their associated mycotoxins contamination (aflatoxins, fumonisins, patulin)[1,7–11]. However, the molecular mechanisms of synergism between EOs and their bioactive compounds, which target different cellular sites (cell wall, plasma membrane, mitochondria, intracellular proteins, enzymes) at a time is lacking[12]. This challenge has to be addressed by the scientific community, which could facilitate the development of an *in vitro* synergistic formulation of EO-based compounds to overcome the resistance challenges.

Apart from microbial spoilage, food items are prone to oxidative deterioration during storage condition, and the cumulative effect of these two events results in significant changes to food quality. Oxidative deterioration imposes undesirable changes in food items such as lipid peroxidation, nutritional loss, off-flavour, and colour impairment. Further, reports on the carcinogenic potential of currently used synthetic antioxidants like BHT and BHA constrain their continuous application as food preservatives. Therefore, a new source of antioxidant compounds for the shielding of food matrices against oxidative deterioration is needed. A number of plant EOs and their bioactive compounds exhibit strong antioxidant potential, which can be exploited as a natural alternative[9–11,13]. *Piper betle* (betel leaf), *Rosmarinus officinales* (rosemary), *Syzygium aromaticum* (clove), *Cananga odorata* (ylang ylang), *Curcuma longa* (turmeric) and *Zingiber officinale* (ginger), are some of the traditionally used plants exhibiting strong antioxidant potential.

Hence, diversified use of EO-based formulations having strong antimicrobial and antioxidant efficacy could play a major role in food preservation by retarding microbial growth and oxidative deterioration, with enhanced flavour properties.

Existing constraints of essential oils as food preservatives

Although EOs exhibit promising preservative potential in terms of strong antimicrobial and antioxidant activity with enhanced nutritional quality of food items, they have some technological drawbacks such as high volatility, reactivity and poor water solubility. In addition, availability of raw material, lack of quality control, phytochemical variation, inconsistent efficacy, range of target organisms, unknown mode of action, adverse effect on food matrix components (lipid, starch, proteins and their organoleptic property) and cost efficiency, are some of the major issues that need to be addressed before their possible application as a food preservative.

Focus of research – the way forward

In light of the above discussions, it is imperative to focus on multidisciplinary approaches to resolve the foregoing limitations of EO-based preservatives and in the development of cost effective natural preservatives to enhance the shelf-life of food items.

Role of modern science and technological innovations

EOs often have strong efficacy as preservative agents, their high cost compared to available synthetic pesticides and threat of biodiversity losses of aromatic plants demand diversified use for sustainable food preservation. Therefore, trans-disciplinary approaches using multi-level collaboration between science, technology and innovation at local, national and global levels are needed. The use of recent biotechnology approaches co-adjuvant with combinatorial chemistry, nanotechnology, active packaging system, and edible coating significantly expand the application domain of EO-based preservatives in food industries.

Biotechnological and combinatorial chemistry

In the past decade, biotechnological and combinatorial chemistry approach has become a major focus of research activity for accelerating the development of novel bioactive compounds. Elucidation of the metabolic pathways and precursors of volatile organic chemicals can play a significant role in the generation of commercial aroma chemicals which could reduce the requirement of raw materials from traditional agricultural sources. The recent innovation in biotechnological approaches could provide a metabolic map for the genetic engineering of essential oil formation[14]. Lange *et al.*[15] have reported the potential utility of metabolic engineering and functional genomics for the sustainable production of cost-effective, high-quality peppermint EO. According to Berger[16], more than 100 commercial aroma chemicals have been successfully derived using biotechnology approaches. In addition, application of recent combinatorial chemistry could be used to design newer, desired semi-synthetic analogue of the natural compound by changing the stereochemistry profile. Several synthetic antimicrobial, antioxidative, aflatoxin-binding peptides, flavour compounds, enzyme inhibitors, unnatural polyketides and carotenoids with desirable and useful properties have been synthesized by combinatorial chemistry approaches[17].

Nanotechnology

Application of nanotechnology in the food industry is one of the fastest growing fields in food science and technology. Nanotechnology has pronounced efficacy to transform the academic research output to industrial applications in the real food system. Nanomaterials (size <100 nm) can be used as a carrier to mask the undesirable aroma effect of EO-based preservatives with enhanced bioefficacy, bioavailability, stability and functionality. Abdollahi *et al.*[18] have reported that nanoencapsulated *Rosmarinus officinales* EO exhibits strong antimicrobial and antioxidant activity with improved physical and mechanical properties. Gomes *et al.*[19] studied the efficacy of spherical poly (lactide-co-glycolide; PLGA) nanoparticles with entrapped eugenol and trans-cinnamaldehyde using controlled release experiments and reported formulations efficiently inhibiting the growth of *Salmonella* spp. and *Listeria* spp. Although some preliminary research has already begun for the nanoencapsulation of EOs and their bioactive compounds, more efforts are needed to achieve sustainability in food safety.

Active packaging and bioactive edible coating

Nowadays, active packaging and edible coating has gained significant attention by the food industries as an alternative method for controlling food spoilage. Recent literature has revealed that EOs and their bioactive components have pronounced efficacy in food packaging materials as a source of antioxidant or antimicrobial agents[20,21]. Wasapower™ is a well-known commercialized example of antimicrobial packaging using wasabi extract (roots of *Wasabia japonica*) developed by Sekisui Plastics Co, Japan[21]. Edible coatings containing EOs can extend the shelf life of applicable foods at an effective lower concentration than that applied directly to product surfaces. Ponce *et al.*[22] have reported that the edible coating of chitosan enriched with rosemary and olive oil improves the antioxidant protection of the minimally processed butternut squash without affecting its sensorial properties.

Regulatory issues

It is imperative for any new preservative that regulatory authorities should recognize its potential, including the prioritized actions in terms of toxicology, environmental fate, exposure, and product chemistry to assure its safety and quality. Therefore, a healthy collaboration among the scientific community, industries and regulatory authorities is required for the development of the natural/EO-based preservatives and their commercialization. Indeed, in this direction some effective steps have already been taken by FDA, Flavor and Extract Manufacturers Association, and Environment Protection Agency to facilitate the natural food preservatives. Based on these many EOs and their bioactive compounds are maintained under the GRAS category, which could be used in the formulation of food preservatives under the limit of prescribed doses.

Conclusion

Essential oils and their bioactive compounds can be exploited as natural food preservatives. The recent innovations in science and technology such as combinatorial chemistry, biotechnological advances, nanoencapsulation, edible coatings, and controlled release system could successfully address the existing limitation of EOs as food preservatives. Therefore, collaborative studies between R&D institutions and food industries are needed to optimize the application procedure and effective doses of EO-based preservatives to achieve both antimicrobial and antioxidant fortification without affecting organoleptic properties of applicable food items. We hope that the diversified use of EOs could play a major role in the development of biorational food preservatives in the near future.

1. Burt, S., *Int. J. Food Microbiol.*, 2004, **94**, 223–253.
2. Ayala-Zavala, J. F., Rosas-Dominguez, C., Vega-Vega, V. and González-Aguilar, G. A., *J. Food Sci.*, 2010, **75**, 175–181.
3. US Code of Federal Regulations, 2013, Title 21, Part 182, Section 182.20.
4. Ahn, J., Grun, I. U. and Mustapha, A., *Food Microbiol.*, 2007, **24**, 7–14.
5. Kamatou, G. P., Vermaak, I. and Viljoen, A. M., *Molecules*, 2012, **17**, 6953–6981.
6. Dubey, N. K., Shukla, R., Kumar, A., Singh, P. and Prakash, B., *Curr. Sci.*, 2010, **98**, 479–480.
7. Bakkali, F., Averbeck, S., Averbeck, D. and Idaomar, M., *Food Chem. Toxicol.*, 2008, **46**, 446–475.
8. Bhat, R., Rai, R. V. and Karim, A. A., *Comp. Rev. Food Sci. Food Saf.*, 2010, **9**, 57–81.
9. Prakash, B., Shukla, R., Singh, P., Kumar, A., Mishra, P. K. and Dubey, N. K., *Int. J. Food Microbiol.*, 2010, **142**, 114–119.
10. Prakash, B., Shukla, R., Singh, P., Mishra, P. K., Dubey, N. K. and Kharwar, R. N., *Food Res. Int.*, 2011, **44**, 385.
11. Prakash, B., Mishra, P. K., Kedia, A. and Dubey, N. K., *LWT – Food Sci. Technol.*, 2014, **56**, 240–247.
12. Carson, C. F., Mee, B. J. and Riley, T. V., *Antimicrob. Agents Chemother.*, 2002, **46**, 1914–1920.
13. Ruberto, G. and Baratta, M. T., *Food Chem.*, 2000, **69**, 167–174.
14. Lange, B. M., Wildung, M. R., Stauber, E. J., Sanchez, C., Pouchnik, D. and Croteau, R., *Proc. Natl. Acad. Sci. USA*, 2000, **97**, 2934–2939.
15. Lange, B. M., Mahmoud, S. S., Wildung, M. R., Turner, G. W., Davis, E. M., Lange, I. and Croteau, R. B., *Proc. Natl. Acad. Sci. USA*, 2011, **108**, 16944–16949.
16. Berger, R. G., *Biotechnol. Lett.*, 2009, **31**, 1651–1659.
17. Wong, D. and George Robertson, G., *J. Agric. Food Chem.*, 2004, **52**, 7187–7198.
18. Abdollahi, M., Rezaei, M. and Farzi, G., *Int. J. Food Sci. Technol.*, 2012, **47**, 847–853.
19. Gomes, C., Moreira, R. G. and Castell-Perez, E., *J. Food Sci.*, 2011, **76**, 16–24.
20. Licciardello, F., Muratore, G., Mercea, P., Tosa, V. and Nerin, C., *Packag. Technol. Sci.*, 2013, **26**, 173–185.
21. Sung, S. Y., Sin, L. T., Tee, T. T., Bee, S. T., Rahmat, A. R., Rahman, W. A. W. A. and Vikhraman, M., *Trends Food Sci. Technol.*, 2013, **33**, 110–123.
22. Ponce, A. G., Roura, S. I., del Valle, C. E. and Moreira, M. R., *Postharvest Biol. Technol.*, 2008, **49**, 294–300.

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