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CAROTENOID CONTENT OF TOMATO AND EFFICIENT MANAGEMENT OF WASTES FROM TOMATO PROCESSING

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ABSTRACT

The cultivation, packaging and processing of tomatoes into various usable forms result in the generation of millions of tons of wastes around the world annually, and these wastes typically end up as landfills or water contaminants thus constituting an environmental concern. These residues, if properly harnessed, are efficient sources of nutrients, phytochemicals and even power. Also, the tremendous nutritional and health benefits of carotenoids have led to an increased productionand utilization, however, bulk of the farm products are not efficiently processed, leaving farmers incurring huge loss due to storage issues. This paper therefore seeks to suggest a moreefficient strategy of managing wastes due to industrial processing of tomatoby converting these wastesinto electricity using microbial fuel cells (MFCs). The strategy will not only improve the environmental safety, but will also generate income and improve the economy.

Key words; carotenoids, tomato waste, microbial fuel cells (MFCs)

INTRODUCTION

One-third of the food produced in the world for human consumption every year is wasted; fruits, vegetables, roots and tubers have the highest rates of wastage of any food (FAO, 2017). The accumulation, handling, and disposal of crop wastes have become an environmental concern as a ton of crop waste results in nearly 0.45 tons of CO_2 emissions during its treatment and disposal process (Wrap.org.uk, 2017). These wastes often contain highly valuable bioactive molecules that can be used to make goods and services (Shide,Wuyep and Nok, 2004). Recently, attention has shifted to the recovery, recycling and upgrading of wastes to produce important compounds such as alcohol, carotenoids and electricity as opposed to ploughing into the land, burning *in situ* or landfill (Omojasola and Jilani, 2008; Laufenberg, Kunz and Nystroem, 2003).

Tomato (*Solanum lycopersicum*L.) is one of the most commonly cultivated vegetable crops across the globe. According to BritishTomatoes(Britishtomatoes.co.uk, 2017), the UK consumes about 500,000 metric tonnes of tomatoes while producing only about 90,000 metric tonnes. Daily, a significant amount of tomatoes is consumed all over the world as fresh fruits, tomato juice, paste, sauce, puree, and ketchup. Tomato pomace is usually generated during processing as a by-product. This by-product represents about 4% of the whole fruit weight, and it is made up of skins, seeds, and vascular tissues.

Culled (defective) tomatoes are other wastes generated by tomatoes farmers and packinghouses every year. The culled tomatoes do not meet customer requirements for firmness and colour because of growth cracks and freezing traces. Also, processing plants generate culls during washing, sterilisation, inspection, juice finishing, evaporation, pulping, packing, and storage.

These tomato wastes (pomace and culls) are rich in nutrients, and they are potential sources of ascorbic acid, folates, phenolics, polyphenolics, tocopherols, carotenoids, fibres, lipids, and proteins that exert positive effects on human health and wellness (Del Valle, Camara and Torija, 2006). Carotenoids (especially lycopene) extraction has been a major focus of recent studies (Vagi et al., 2007). The use of these wastes to generate electricity has also been reported (Fogg *et al*., 2015; Shrestha *et al*., 2016).

The Carotenoid Pathway

Carotenoids are fat-soluble organic pigments found in plants, algae, several bacteria and fungi. The only animals known to produce carotenoids are aphids and spider mites, it has beenhypothesized that they acquired the genes from fungi (Altincicek, Kovacsand Gerardo, 2011). There are over 600 known carotenoids which are divided into xanthophyll (contain oxygen) and carotenes (purely hydrocarbons without oxygen) (Nováková and Moran, 2012).

The basic building blocks of carotenoids are isopentenyl diphosphate (IPP) and dimethylallyl diphosphate (DMAPP) (Nisar *et al.*, 2015). Depending on the biological pathway used, these two isoprene isomers can be used to make many useful compounds in plants (Kuzuyama and Seto, 2012). Plants use plastidic methylerythritol 4-phosphate (MEP) to generate IPP and DMAPP for carotenoids synthesis. The MEP pathway results in a 5:1 mixture of IPP: DMAPP (Kuzuyama and Seto, 2012). IPP and DMAPP undergo several reactions, resulting in the major carotenoid precursor, geranylgeranyldiphosphate (GGPP). GGPP can be converted into carotenes or xanthophylls by undergoing several different steps within the carotenoid biosynthetic pathway (Cazzonelli and Pogson, 2010; Kuzuyama and Seto, 2012).

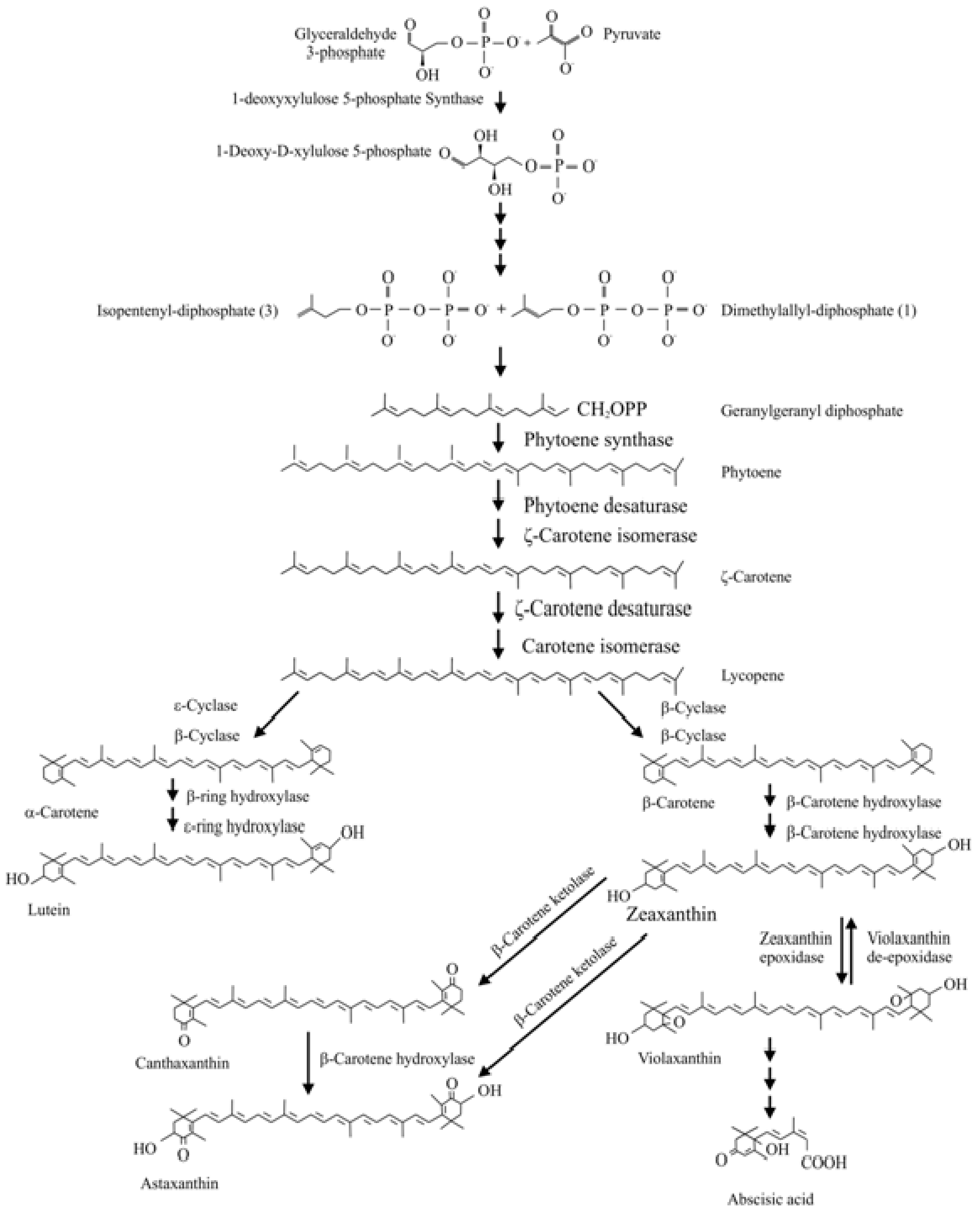

Figure 1: The carotenoid biosynthetic pathway (Cazzonelli and Pogson, 2010)

1.3 Health Benefits of Carotenoids

Researchers have shown that fruits and vegetables which are rich sources of carotenoids provide health benefits by decreasing the risk of various diseases. These beneficial effects of carotenoids are reasoned to be due to their role as antioxidants. The carotenoids that have been mostly studied in this regard are β-carotene, lycopene, lutein and zeaxanthin.

Carotenoids take part in photosynthetic light harvesting and protection against light stress in plants. Also, they accumulate to large levels as storage metabolites in chromoplasts of flowers, fruits, and taproots. Carotenoids are also essential to animals, which, however, are unable to synthesise them *de novo*, and therefore must rely on dietary sources of carotenoids. β-Carotene is the main dietary precursor of vitamin A and thus referred to as provitamin A. Vitamin A deficiency in humans represents a global health problem affecting approximately one-third of the countries of the world (Mayer *et al*., 2008).

Lutein, zeaxanthin and β-carotene are helpful for protecting vision (Perusek and Maeda, 2013), skin health (Sayo, Sugiyama and Inoue, 2013), and sperm health (Mora-Esteves and Shin, 2013). Population-based studies suggest that lycopene has anti-tumour properties effective for supporting cardiovascular health (Kuklev, Domb and Dembitsky, 2013).

Electricity Generation in Tomatoes

The skin and seed in tomato wastes contain high nutritional value and energetic potential. A gram of tomato waste contains half a microgram of riboflavin and thiamine both of which can serve as electron-transfer mediators to promote extracellular respiratory capabilities of exoelectrogens in microbial fuel cells (MFCs) (Di Lorenzo, 2010). Here, there is a possibility of tomato wastes producing electricity using MFCs owing to the variety of redox-active species such as carotenoids, kaempferol, malvin, myricetin, naringenin, naringin, petunidin, quercetin, and riboflavin present in tomato (Marsili*et al*., 2008; Su *et al*., 2016). The MFCs directly convert chemical energy stored in the organic matter into power by the catalytic activity of microbes. An MFC does not require expensive catalysts and, instead, uses microorganisms to transform the chemical energy in the organic matter into DC electricity under ambient conditions. Some earlier MFC studies used solid organic wastes (SOWs) such as food waste (Jia *et al*., 2013) and marine wastes (Gadhamshetty *et al*., 2013). Tomato waste is a potential feedstock due to its rich composition in sugars, vitamins, minerals, and redox-active mediators such as riboflavin and thiamine (Bond and Lovley, 2005; Velasquez-Orta, 2010). Also, tomato wastes have been found to outperform SOWS and wastewater in the production of electricity in MFCs (Shrestha *et al*., 2016).

This paper therefore aims to suggest more economical way of managing tomato wastes possibly throughthe generation of electricity,this may help in reducing environmental pollution due to tomato wastes whose accumulation and disposal has become global environmental concern.A microbial electrochemical cell that runs off tomato waste to generate electricity have been developed (Fogg *et al*., 2015; Shrestha *et al*., 2016). Bacteria are used to oxidize the organic materials (such as carotenoids) in waste tomatoes, and the electrons released as a result of this oxidation are captured as electricity.

Electricity Production Using Tomato Wastes

The tomato wastes are normally obtained from any processing plant and pre-treated as described in Shrestha *et al*. (2016). The tomato liquor is obtained by blending the waste with a minimal media containing NH_4Cl, KCl, $NaH_2PO_4.H_2O$, and $Na_2HPO_4.7H_2O$, vitamin mix and trace minerals are added for the optimal performance of the bacterial cells. The tomato liquor is used as the anolyte in a MFC.

The design of the two-compartment MFC according to Gadhamshetty*et al*., (2013)utilizes Ultrex membrane (hydrated with 5% sodium chloride at 40°C for 24 hours) to separate the anode from the cathode. The tomato liquor represents the anolyte while the catholyte will be ferricyanide and phosphate buffer to balance the current flux. The inocula (source of mixed microbial population) in the anode will be obtained from any wastewater treatment plant. The spent-anolyte is removed at the end of each batch, flushed with phosphate buffer, and the anode compartment isfilled with an equivalent volume of fresh tomato liquor. The electrons released as a result of this oxidation process at the anode will be captured as electricity as earlier described (Gadhamshetty*et al*., 2013).

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