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A spent coffee grounds based biorefinery for the production of biofuels, biopolymers, antioxidants and biocomposites

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ABSTRACT

Spent coffee grounds are composed of lipid, carbohydrates, carbonaceous, and nitrogen containing compounds among others. Using n-hexane and n-hexane/isopropanol mixture highest oil yield was achived during soxhlet extraction of oil from spent coffee grounds. Alternatively, supercritical carbon dioxide can be employed as a green solvent for the extraction of oil. Using advanced chemical and biotechnological methods, spent coffee grounds are converted to various biofuels such as, biodiesel, renewable diesel, bioethanol, bioethers, bio-oil, biochar, and biogas. The in-situ transesterification of spent coffee grounds was carried out in a large scale (4 kg), which led to 80–83% biodiesel yield. In addition, a large number of value added and diversified products viz. polyhydroxyalkanoates, biosorbent, activated carbon, polyol, polyurethane foam, carotenoid, phenolic antioxidants, and green composite are obtained from spent coffee grounds. The principles of circular economy are applied to develop a sustainaible biorefinery based on valorisation of spent coffee grounds.

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1. Introduction

Coffee is an essential agricultural product and a widely consumed drink. Brazil, Vietnam, Colombia, Indonesia, Ethiopia, India, and Honduras are primary producers of coffee beans (Fig. 1) (ICO, 2016). International coffee organization (ICO) data shows that 80% of the coffee produced globally comes from ten countries. Brazil alone produces 2,859,502 tonnes of coffee every year and it is also a major coffee exporting country (Figs. 1 and 2) (ICO, 2016).

Statistical evaluation reveal that around 50% of coffee produced worldwide is used for drinking purposes (Ramalakshmi et al., 2009). During 'fruit to cup' transformation of coffee beans, the processing and utilization steps generate huge quantities of wastes, such as coffee silver skin and spent coffee grounds (Mussatto et al., 2011a, 2011b). According to Murthy and Naidu (2012) around 650 kg of spent coffee grounds is produced from 1 ton of green coffee beans. Furthermore, during the preparation of 1 kg of soluble coffee approximately 2 kg of wet spent coffee grounds are obtained (Pfluger, 1975). In 2014 around nine million tonnes of spent coffee grounds were dumped in landfills. The life cycle assessment of coffee shows formation of coffee waste and spent coffee grounds (Salomone, 2003, Fig. 3.)

In the above context, spent coffee grounds are a nonedible resource, which is not entering into food chain. Therefore, it will not impact food prices. The generated spent coffee grounds can be converted to biofuels and value added products such as, food additives, polyhydroxyalkanoates, carotenoids, biosorbents, activated carbons, polyols, polyurethane foams, phenolic antioxidants, composites, and nutraceuticals. In addition, biological treatment of organic wastes, namely composting can be used as a method for spent coffee grounds valorisation.

Currently, the circular economy concept is becoming an integral part of industrial green technological processes. In this regard, various companies are undertaking efforts for the utilization of spent coffee grounds as a resource for fuels, biopolymers, biosorbents, activated carbons, polyols, polyurethane foams, carotenoids, antioxidants, and composites production.

Conversion of spent coffee grounds to biofuels and value added products is gaining importance from the point of view of sustainable waste management policy (Mussatto et al. (2011a, 2011b); Campos-Vega et al., 2015). As a result, multiple research groups are engaged in complete valorisation of spent coffee grounds, since it contains high quantities of carbohydrate, oil, carbon, and nitrogen containing substances (Oliveira et al., 2008; Vardon et al., 2013; Kondamudi et al., 2008; Speer and Kölling-Speer (2006); Jenkins et al., 2014). The oil and carbohydrate containing portions can be converted to biodiesel and bioethanol. Furthermore, using pyrolysis, spent coffee grounds can be converted to bio-oil.

In this article, technical feasibility of producing biofuel and value added products from spent coffee grounds is evaluated.

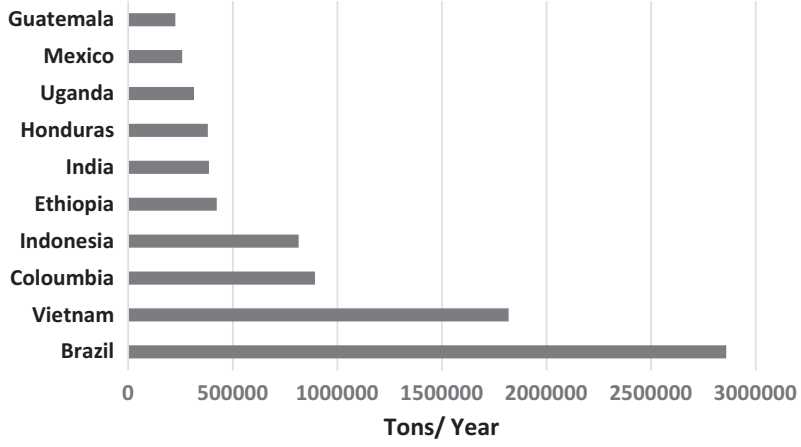

Fig. 1. World's major coffee producing countries (ICO, 2016).

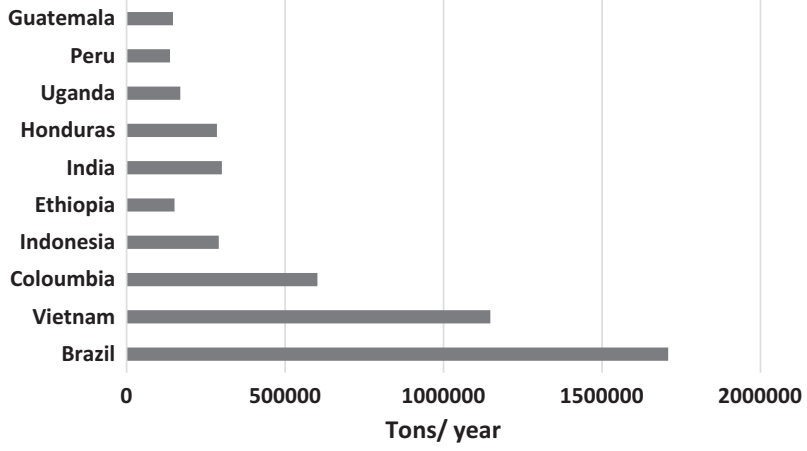

Fig. 2. World's major coffee exporting nations (ICO, 2016).

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