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VERDANT SOURCE OF FERULIC ACID

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INTRODUCTION

Ferulic acid is a phenolic compound of plant origin having molecular formula C10H10O4 and molar mass of 194.18 g mol−1. IUPAC name of ferulic acid is called 3-(4-hydroxy-3- methoxyphenyl) propenoic acid. Ferulic acid is commercially available in the form of a white to off-white crystalline powder. It forms two geometric (cis and trans) isomers. The trans isomer is a white crystalline substance whereas the cis-isomer is a yellowish liquid substance. Ferulic acid occurs mainly as a trans isomer. It is a phenolic compound which is present in different parts of plants including fruits and leaves (Jankovska et al., 2001 and Shakeel et al., 2017). Phenolic compounds are comprised of a heterogeneous class of natural products with an aromatic ring moiety linked to one or more hydroxyl groups. Phenolics are usually divided into simple phenols, phenolic acids, and polyphenols. Ferulic acid is a phenolic acid isolated for the first time from Ferula foetida (Apiaceae) around the middle of the 19th century (Oliveira et al., 2017).

Compounds that oppose oxidation or inhibit reactions promoted by oxygen, thereby acting as preservatives, which show the capability to reduce free radical formation and scavenge ROS, inhibiting and repairing injuries caused by oxidation and degradation of other molecules and biomolecules are valuable products. The chemical structure of ferulic acid possesses a highly conjugated unsaturation, hence this molecule is a potent UV absorber. Ferulic acid can protect other light-sensitive compounds against oxidative damage by attenuating the amount of incident UV radiation on these molecules. Numerous biological activities and a variety of health benefits of ferulic acid have been reported against a variety of chronic human diseases. It has also been evaluated as a potent antioxidant, antimicrobial, anti-inflammatory, anti-allergic, cardio protective and anticancer compound (Shakeel *et al.*, 2017 and Oliveira *et al.*, 2017). Therefore, ferulic acid represents a major component in cosmetics and next generation therapeutics. Analytical techniques such as ultraviolet-visible spectroscopy, Fourier-transform infrared spectroscopy and HPLC have been employed for the characterization of ferulic acid.

Distribution of bamboo in India

Bamboo is a rapid growing fibrous plant available in abundance. It is a perennial, giant, woody grass and belongs to the monocotyledonous grass family *Poaceae* (or G*ramineae*) under the subfamily *Bambusoideae*. About 148 species in 29 genera of bamboos are currently found in India. Maximum species are found in Northeast, North and South India. At higher altitudes, bamboos are an important source of food for wildlife. The large genera of bamboos in India (with more than 10 species each) are *Dendrocalamus*, *Bambusa*, *Pseudooxytenanthera* and *Ochlandra*. Together, these genera represent about 45% of the total bamboo found in India. About 70% of the bamboo species in India are reported from Northeast India and the Western Ghats, which happen to be two biodiversity hot-spots in the country.

Bamboos grow right from the southern coastal plains and ascend to elevations of up to 3700 meters in the Himalayas. Physical geography together with precipitation, temperature and altitudinal variations, play an important role in the species diversity and richness of bamboos. Bamboo grows naturally in every state, but its numbers vary in different regions, primarily due to different climatic conditions. The study of state-wise distribution of bamboos in India has recently been undertaken in some states. Below are the details of some specific number of bamboos present in a particular state (Sharma and Nirmala, 2015).

States rich in bamboo species (Adapted from Sharma and Nirmala, 2015)	
Andaman's	22+2var.
Arunachal Pradesh	**47**
Assam	**38 + 2var.**
Bihar	19
Chhattisgarh	9
Himachal Pradesh	8
Jharkhand	10+1var.
Karnataka	10
Kerala	**22+2var.**
Madhya Pradesh	8
Maharashtra	**7+1 var.**
Manipur	**40+1 var.**
Meghalaya	**46-50**
Mizoram	**33**
Nagaland	**32**
Odhisa	12+1var.
Sikkim	**29-30**
Tripura	19+1var.
West Bengal	**32**

States with the least number of species (Adapted from Sharma and Nirmala 2015)	
Punjab	4
Jammu and Kashmir	2
Rajasthan	2
Gujarat	2
Haryana	2
Goa	2

Some international studies

In recent years, ferulic acid has been studied extensively. The *trans* isomer of ferulic acid predominates and accounts for up to 90% of the total phenolic acids of some fruits and vegetables. Ferulic acid and its precursors, *p*-coumaric acid (*p*-hydroxycinnamic acid), and caffeic acid (3,4-dihydroxycinnamic acid) are metabolites in the biosynthesis of lignins (Shakeel *et al.*, 2017 and Oliveira *et al.*, 2017).

Hemicellulose comprises almost 30% of the dry matter in soft-biomass of bamboo; hence it is one of the most abundant components of the bamboo plant along with cellulose. Hemicellulose consists of a main chain of beta-1,4 xylan that branches into alpha-1,3-arabinofranose or 1,4-glucopyranosyl glucan, which in turn branches into alpha-1,6-D-xylopyranose. The feruloylated oligosaccharides later on can be turned into ferulic acid prepared from arabinoxylan possessing antioxidative activity. Ferulic acid are major constituent found in bamboos as it exists as a phenolic cell wall constituent in a variety of monocotyledon plants (Maemura *et al.*, 2016, Yeasmin *et al.*, 2015 and Yuan *et al.*, 2017).

Some national studies

The work on extraction of ferulic acid is being done nationally, though most of the efforts have largely remained qualitative in nature. Conventional extraction procedures involve the use of different solvents that take into consideration the polarity of the compounds to be extracted. The first step consists of an alcohol extraction to obtain the soluble compounds, while the second step is an alkali hydrolysis to free the bound phenolics from the cell wall; this is followed by a series of several washes to purify the sample. One of the major drawbacks of this procedure is its requirement for large quantities of different solvents (i.e., methanol, hexane and ethyl acetate), which generates a significant quantity of toxic solvent waste. The procedure is also very time consuming, making the handling of several samples at once a challenging task. The quantitative information has generally been derived from fluorescence and absorbance spectroscopic measurements (Gogoi *et al.*, 2016).

Medicinal properties

Ferulic acid is a compound that opposes oxidation or inhibits reactions promoted by oxygen, which can be used as preservatives in various products. FA has capability or composition to reduce free radical formation and scavenge ROS by inhibiting and repairing injuries caused by oxidation and degradation of other molecules and biomolecules; thus acts as a valuable product. The chemical structure of ferulic acid possesses a highly conjugated unsaturation; this molecule is also a potent UV absorber. Ferulic acid can protect other light-sensitive compounds against oxidative damage by attenuating the amount of incident UV radiation on these molecules. Numerous biological activities and a variety of health benefits of ferulic acid have been reported as a

potent phenolic compound against the variety of diseases, chronic human diseases and oxidative damage and evaluated as a potent antioxidant, antimicrobial, anti-inflammatory, anti-allergic, cardioprotective and anticancer compound and Antioxidant activity. Tocopheryl ferulate and C1-C30 esters of ferulic acid are used in cosmetics and pharmacology due to their antioxidative, antibacterial, anticancerous and antihepatotoxic effects. Ferulic acid resulted in increased activities of superoxide dismutase, catalase, glutathione peroxidase, and the expansion of pancreatic islets, demonstrating that administration of FA greatly enhanced the antioxidant capacity of diabetic animals by neutralizing the free radicals formed, thereby reducing the intensity of diabetes. FA also inhibits lipid peroxidation in brown adipose tissue of diabetic mice and regenerates pancreatic beta-cells. Supplementation of ferulic acid to diabetic rats both decreased the levels of blood glucose, thiobarbituric acid-reactive substances, hydroperoxides, and free fatty acids, and it increased the level of reduced GSH in the liver of diabetic animals and regulates blood glucose levels by elevating glucokinase activity and production of glycogen and by modulating insulin-signaling molecules in the liver. Ferulic acid reduces blood glucose level and it has an enormous possibility to become an anti diabetic drug. It can fight coronary disease, lower cholesterol in serum and liver.

Ferulic acid displays a wide spectrum of antimicrobial activities, exhibiting effects against yeasts and Gram-positive and Gram-negative bacteria. It has strong inhibitory effect against gastrointestinal microorganisms like *Escherichia coli*. The antibacterial mechanism of ferulic acid is related to both the inhibition of arylamine *N*-acetyltransferase, a specific enzyme that catalyzes acetylation of arylamines in bacteria.

Ferulic acid shows different way of its anticancer action by giving the stimulation of uridine diphosphate (UDP) glucuronosyltransferases (UGTs) in the liver, contributing to a better detoxification of potentially carcinogenic compounds and, subsequently, to the prevention of gastrointestinal cancer. Other reported mechanisms include inhibition of cyclooxygenase-2 (COX-2), induction of apoptosis through the release of cytochrome *c* from mitochondria, and the activation of caspase-3. Ferulic acid might also inhibit proliferation and induce apoptosis via inhibiting the PI3K/Akt pathway in osteosarcoma cells or by targeting the fibroblast growth factor receptor 1-mediated PI3K-Akt-signaling pathway, leading to the suppression of melanoma growth and angiogenesis. Ferulic acid also shows interesting protective effects for organs, tissues, and cells, such as those related to the cardiovascular, neurologic, skin, and hematopoietic and auditory systems. Ferulic acid inhibits the formation of amyloid-*β*-peptide (A*β*) oligomers, which are responsible for initiating the pathological cascade of Alzheimer's disease.

Hypothesis

Plant cell wall is made up of cellulose, lignocellulose and lignin which are the major sources of plant biomass. The component of lignocellulose materials is cellulose, along with lignin and hemicellulose. Cellulose and hemicellulose are macromolecules made up of different sugars; whereas lignin is an aromatic polymer synthesized from phenylpropanoid precursors (Suteerapataranon *et al.*, 2008). The plant cell wall has a reserve of carbohydrate as a backbone. Cellulose makes up about 45% of the dry weight of wood. This lineal polymer is composed of D-glucose subunits linked by β-1,4 glycosidic bonds forming cellobiose molecules. These form long chains linked together by hydrogen bonds and van der Waals forces. Hemicellulose and lignin cover microfibrils. Cellulose can appear in crystalline form, called crystalline cellulose (Chauhan *et al.*, 2016).

The existence of ferulic acid has remained unexplored both qualitatively and quantatively in bamboo cell wall and none have used enzymatic degradation and alkaline hydrolysis synergic effect, which can be explored intensely by using various advanced microscopic techniques.

Due to the increasing need of potent antioxidant, antidiabetic and anticancer, commercial interest has risen for optimum extraction of ferulic acid. Microstructures information provides an essential complete detail of cell wall structural integrity studies, which, on their own, are incapable of defining the unsaturated carbon-carbon bonds of ferulic acid reacted with the thiol groups of proteins and form an intermolecular cross-linking between polysaccharides and proteins complex formation (Jankovska *et al.*, 2001).

In order to completely understand the microstructure of cell wall and purity of ferulic acid, kinetic studies of polysaccharides degradation enzymes are needed to complement the optimum extraction of ferulic acid. Overall the importance lies in efforts to understand the distribution of ferulic acid in bamboo shoots from different regions of India and its correlation with microstructures of bamboo cell wall.

CONCLUSION

Need of highly potent antioxidant, antidiabetic and anticancer substance is very much essential for health of today's population. Continuous efforts for maximum extraction of ferulic acid are important in view of its effectiveness in curing diseases depending on the targeted health conditions. Essential research and the results obtained will be a new contribution in understanding the microstructure degradation of bamboo shoots and leaves for extraction of ferulic acid. Thus the exploration of cell wall polysaccharides bond degradation and their effect for maximum release of ferulic acid can be helpful in providing the synthesis of pure ferulic acid.

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