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REVIEW

Biosynthesis of Food Flavours and Fragrances - A Review

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Major flavours and fragrances in food industries are currently produced by chemical synthesis which act as artificial flavours or naturally identical flavours, however these are not eco-friendly. This review provides a wide idea of those flavours and fragrances which can be produced naturally by biotransformation of chemicals from their precursors using enzymes/whole cells (biocatalysis), fermentation (microbial metabolite biosynthesis), production of flavours from agricultural wastes and plant cells, *etc*. Biosynthesis provides an abundant amount of compounds with flavour of cherry, almond, strawberry, pine apple, cheese, onions, and grapes. They are mainly synthesized using biocatalysts such as lipase, carboxylesterases, hydrolase and protease. Biosynthesis of flavours are eco-friendly, has specific selectivity (regio-, enantio), wastes can be recycled easily and can be produced under mild reaction conditions such as room temperature, neutral pH and solvent free environment compared to chemical synthesis. Adoption of this naturally produced flavours will be beneficial to human health and creates chemical free atmosphere.

Keywords: Flavours, Fragrances, Biotransformation, Agricultural wastes, Natural synthesis, Biocatalysis.

INTRODUCTION

Flavours set up a great platform in food industry. It is important because of consumers and without flavours, consumer's avidity on food will be gone. Foodstuffs containing artificial and synthetic flavours are mostly avoided, because the consumers doubt that these flavour producing components are toxic to their health [1].

Most of the food flavouring compounds are produced by chemical synthesis or extracted from natural resources. However, recent market surveys have analyzed that consumers also prefer foodstuff that should be labelled "natural" [2-5]. Natural aromas produced by microorganisms are finally recognized as natural and are safe [4-6].

Furthermore, chemically synthesized flavours will often results in environmentally unfriendly production processes will also cut the substrate selectivity, which may also result in formation of undesirable by products, thus reducing process yield and increasing the downstream costs. On the other hand, the producing flavours by direct extraction from plants is also subjected to various problems. These raw materials often has low concentrations of the desired compounds, making the extraction even more expensive. These disadvantages of both methods and the establishing interest in natural products have to manage many investigations towards the search for other strategies to produce natural flavours [5-9].

Nowadays, many researchers and industries have switched to bio-catalytic flavour synthesis due to consumer's inclination towards natural flavours over chemical ones. These reactions use very mild operating techniques, have high specificity with reducing the side reactions and produces good purity of flavoured compounds by avoiding the more expensive separation techniques [10].

In view of the emerging concept of biological production of natural flavours, the term 'natural' is explained in the USA as well as in Europe [11,12].

In USA, a distinct difference is made between natural and artificial flavour compounds and according to the 'Code of Federal Regulations' (1990), the 'natural flavour' means the essential oil, essence or extractive, oleoresin, protein hydrolyzate, distillate of any product of roasting, heating, which has flavouring constituents derived from a, spices fruit juices, edible yeast, herb, vegetable or vegetable juice, parts of plants like (bud, bark, root, leaf) or similar plant material, meat, poultry, seafood, eggs, dairy products or fermentation products thereof, whose noteworthy functions of food is imparting flavours and not nutrition.

Although the biocatalytic approaches to these compounds are often expensive, different applications have been described.

Eco friendly conditions and high chemical selectivity make bio catalytic approaches attractive. Two separate fields should be examined: (i) industrial production of flavouring compounds and (ii) academic synthesis of selected flavours (synthesis not used for industrial production but mainly for scientific interest). Few applications are related to the first case in which isolated enzymes, fermentation products, bio-transformations are mainly used. Lipases is the most liked catalyst because they show remarkable chemo-selectivity, regio-selectivity and enantio-selectivity [13,14]. Moreover, they are easily available on a large scale and remain active in organic solvent [15].

Enzymes for the synthesis food flavours

Certain techniques such as enzyme encapsulation and eventually coenzyme regeneration might result in highly efficient and specific bio-catalytic processes for flavour synthesis. An advanced example is conversion of 1-phenyl-2-propanone with NADH + H^+ dependent yeast alcohol dehydrogenase into (S)-1-phenyl-2-propanol; NAD^+ regeneration is obtained by the coupling reaction, in turn formic acid is converted into gaseous CO_2 by formate dehydrogenase [8,16]. This conversion of 1-phenyl-2-propanone into (S)-1-phenyl-2-propanol was performed with NADH+ H^+ dependent yeast alcohol dehydrogenase (Fig. 1).

The cherry and almond-tasting benzaldehyde can be produced from the cyanogenic glucoside amygdalin, which is present in cherry kernels and almond meal, using β-glucosidase and mandelonitrile lyase enzymes (Fig. 2) [8,17].

Another industrial example is the production of L-menthol, the major constituent of peppermint oil. Microbial lipases have been found which preferentially hydrolyze L-menthylesters (from the DL-racemate mixture) into L-menthol, leaving the D-menthylesters intact [8,17].

Lipases: Among different enzymes, lipase is the most widely used for the flavour development. Lipases is used for esterification in organic solvents to produce flavour esters (Fig. 4) such as isoamyl acetate (banana) [18] isoamyl butyrate [19] geranyl acetate (rose) [20], citronellyl acetate (lemon) [21].

Lipase catalyzed production of flavour esters by esterification reactions is influenced by a number of esterification factors like molarity of alcohol, addition of water, agitation speed, temperature and amount of immobilized enzyme [22].

Based on the preference of the customers towards natural flavours, biosynthesis of the flavour esters, namely octyl acetate and methyl butyrate were done through immobilized lipase mediated esterification under solvent-free conditions [22].

Nowadays, butyl acetate, a pineapple flavour has been applied widely in food, beverage, cosmetic and pharmaceutical industries. In this research, butyl acetate, a flavour ester was successfully synthesized *via* green synthesis of enzymatic reaction route.

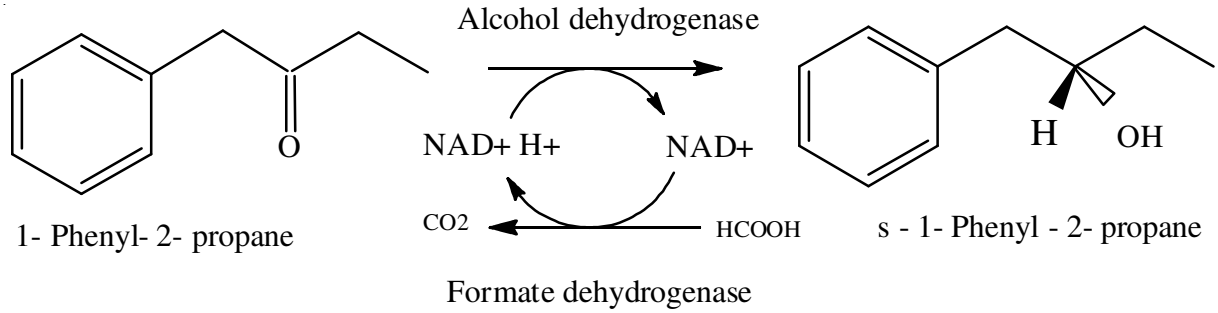

Fig. 1. Production of (S)-1-phenyl-2-propanol using alcohol dehydrgenase

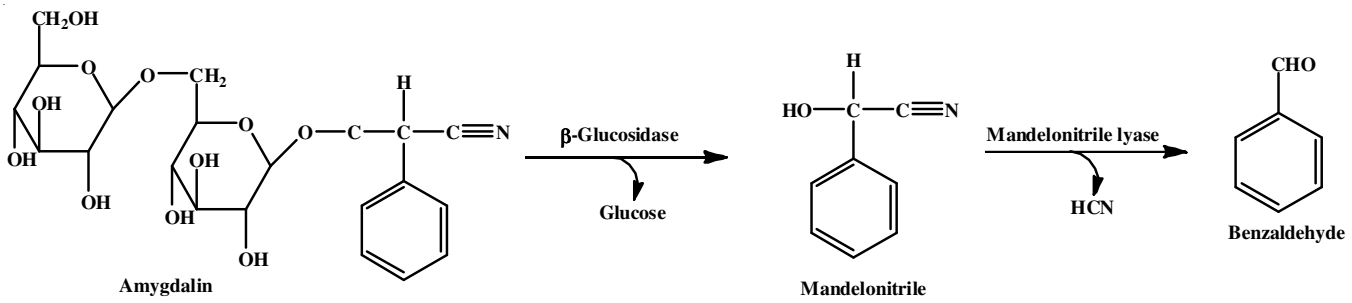

Fig. 2. Production of benzaldehyde by enzyme β-glucosidase

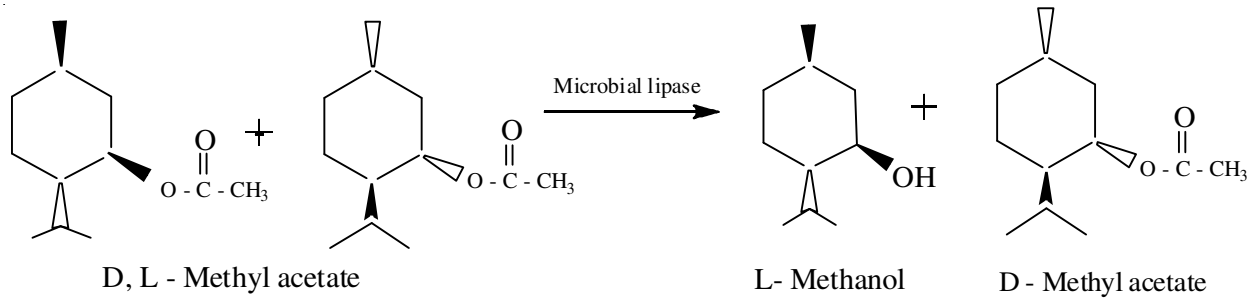

Fig. 3. Production of D-methyl acetate using microbial lipase

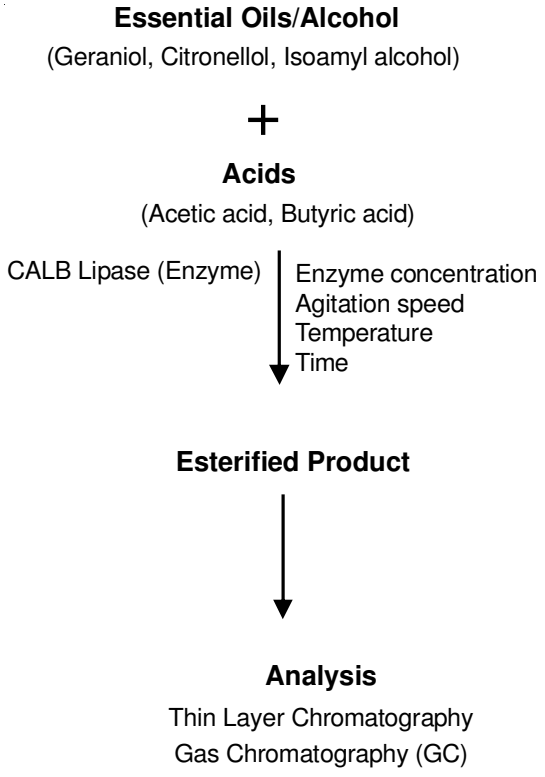

Fig. 4. Production of flavours by esterification

Many research papers shows the synthesis of butyl acetate, a pineapple flavour using immobilized lipase liposome RMIM (*Rhizomucor meihei*) as biocatalyst using solvent free system. Flavour esters have been commonly produced by lipases from various good sources in organic solvents. However, solvent toxicity and high production costs are the major problems in most reactions [23].

The main goals are to synthesize a flavours ester and to better understand the relationships between reacting compounds and their variable parameters (temperature, amount of enzyme and reaction time) [24]. Ethyl valerate (green apple flavour), ethyl butyrate (pineapple favour) and isoamyl acetate (banana flavour) are synthesised through esterification of lipase enzyme [23]. The immobilized lipase enzyme was used for the above study and it was mainly obtained from *Candida rugosa* and porcine pancreas [24-26].

Carboxyesterases: The volatility of these ester compounds plays a major role in giving the exact flavour and aroma to the product. For example, specific ester compounds are responsible for the flavour such as acetate, which gives the fine flavour of banana. These acetyl esterase compounds produces more like a flowery or a fruity smell, volatiles of acetates are produced by condensed alcohols which contributes to characteristic aroma of the specific product. A negative correlation of volatiles is found in the case of tomato, in which the research results is fail to produce tomato flavour from the esterase. The presence of sugars, acids and volatiles of tomato are not achieved through this esterase synthesis [27].

Many other microbial enzyme immobilization also resulted in production of fine flavours (e.g. *Rizophous oryzae*). For obtaining banana flavour *Bacillus licheniformis* S-86 esterase. The enzyme responsible for the characteristic banana flavour is named as esterase II and this enzyme is from the extra-cellular surface of Bacillus. Bacillus generally has an advantage of enzyme production since it is generally recognized as safe (GRAS) [26,28].

Soy lipoxygenase is claimed to be able to convert eugenol and coniferylaldehyde directly into vanillin. The optimization of the fermentation process resulted in levels of over 1 g dm^{-3} [73].

Hydrolaze: Enzymes are able to catalyze hydrolysis of the ester linkages as in the case of triglycerides, for example vegetable oil which is a combination of fatty acid and glycerol. Thus, esters will be formed from the hydrolazes when mixed with acid or alcohols in a non-aqueous system. Various flavouring compounds such as ethyl butyrate, isobutyl butyrate, isoamyl butyrate are synthesized using this method [29-31].

Protease: Enzyme is responsible for the flavour productions in soy sauce, fish sauce, nato, tempeh and miso. Esterification and transesterification of the protease enzyme will give rise to the flavour productions. Protease mediated hydrolysis is used to produce unique protein hydrolytes which will enhance and add on flavours to the food, particularly savoury flavours. A main drawback of protein hydroxylated flavours is that they will cause a bitterness, this bitterness can be controlled by hydrolyzating under vacuum [31-33].

Protease enzyme treatment over the by-products of crayfish processing allowed to the enhanced the concentration of flavours like benzaldehyde and pyrazines. This studies also were responsible for the production of savoury flavours by heating protein compound in acidic pH [6,34,36]. Protease is also responsible for the enzyme modified cheese flavour production. The flavour enhancement by protease enzyme is 30 folds higher than the natural cheese production [6,37].

Other enzymes: Several enzymes can also produce amicable flavours in which immobilized alcohol dehydrogenase obtained from *Lactobacillus kefir* was used to synthesis (R)-phenyl-ethanol from acetophone. Hydroxylaze enzyme obtained from cytochrome P450 monooxygenase type is found to be involved in the production of nootkatone, a grape flavour. Amine oxidase enzyme is involved in production of vanillyl-amine from *A. niger*. Continuous production can be done in immobilized enzyme technique [6,38,39]. L-Glutamic acid which is responsible for the characteristic flavour of soy-sauce is obtained from microbial glutaminases, a natural flavour enhancers in food industries [6,40,41]. Various other enzymes which produces the flavour are summarized in Table-1.

Biosynthesis of flavours by fermentation

A most common production of flavours by fermentation is cheese, wine and other alcoholic products. Sources vary from bacteria, yeast and moulds (fungi). Sometimes this fermentation may also lead to growth of certain beneficial bacteria for human like lactic acid bacteria. Development of flavours and sometimes off-flavours are also achieved through fermentation.

Grapes plays a major role in production of wine and gives a unique flavour when subjected to fermentation. *Saccharomyces cerevasiae*, one of the most commonly used micro-flora [44] and *Tyromyces chioneus* along with apple pomace as a carbon source is used to decide the flavour and aroma changes of wine by aroma extract dilution analysis (AEDA) and odour activity values (OAV) method. Aroma extract dilution analysis was carried out to find the off flavour by sniffing the sample. This off flavour

TABLE-1
ENZYMES RESPONSIBLE FOR FLAVOUR PRODUCTION

Substrate/microbes	Enzyme	Product/flavour	Ref.
1-Phenyl 2-propanone with NADH+ H^+	Yeast alcohol dehydrogenase	1-Phenyl 2-propanone	[8,16]
1-Phenyl 2-propanone	Yeast alcohol dehydrogenase	1-Phenyl 2-propanone with NADH+ H+	[8,16]
Cyanogenic glucoside amygdalin from cherry kernels and almond meal	β-Glucosidase and mandelonitrile lyase	Cherry and almond tasting benzaldehyde	[8,17,42]
Hydrolyse-L-methyl esters	Microbial lipase	1-Menthol (peppermint oil)	[8,17,42]
Essential oil isoamyl alcohol + acetic or butyric acid	Lipse	Flavour esters like isoamyl acetate (banana)	[18]
Essential oil isoamyl alcohol + butyric acid	Lipase	Isoamyl butyrate	[19]
Essential oil geraniol + acetic or butyric acid	Lipase	Geranyl acetate (rose)	[29]
Essential oil citronellol + acetic or butyric acid	Lipase	Citronellyl acetate (lemon)	[25]
Lipozyme RMIM	Lipase	Butyl acetate pineapple flavour	[23,25]
Ethyl valerate	Lipase	Green apple flavour	[23,25]
Ester compounds like acetate	Carboxy esterase	Flowery and fruity smell	[43]
Acetyl ester II	Carboxy esterase	Banana flavour	[26]
Eugenol and coniferyl aldehyde	Soy lipoxygenase	Vanillin	[28]
Triglycerides + acid, triglycerides + alcohol	Hydrolase	Ethyl butyrate, isobutyl butyrate, isoamyl butyrate	[29-31]
Esterification of protease	Protease	Soysauce flavours, nato, tempeh, fish sauce and miso.	[31-33]
Esterification of protease	Protease	Savoury flavours	[8,34-36]
By product of cray fish processing	Protease	Benzaldehyde, pyrazines	[8,38,39]
Esterification	Protease	Enzyme modified cheese flavours	[8,37]
R-Phenylethanol	De hydrogenase	Nootkatone grape flavour	[8,38,39]
Immobilized enzyme	Amine oxidase	Vanillylamine	[8,38,39]
Microbial glutaminases	Glutaminases	Soy sauce L- glutamic acid.	[6,40,41]

is achieved by De novo biosynthesis of Basidiomycetes (*Tyromyces chioneus*) [45,46]

Fermentation also leads to the synthesis of intracellular enzymes or metabolites. In such cases common yeast *Saccharomyces cerevasiae* is found to produce fruity flavour to beer. This fruity flavour is obtained by volatile acids and esterification process where the formation of volatile esters is accompanied by dissolved oxygen and Acetyl coA in the fermentation medium. The lipid content is mainly responsible for the esterification process. Two esters which are responsible for fruity flavour is alcohol acetyl transferase I and II.

Apart from yeast, fungi can also convert compounds into flavours by fermentation process. Two process is followed for the production of vanillin. One of the most common fungi *Aspergillus niger* which convert ferulic acid into vanillin with the help of Basidiomycetes. Two Basidiomycetes is responsible for the conversion is *Pycnoporus cinnabarinus* or *Phanerochaete chrysosporium*, which can further convert the fermentation into formation of vanillin.

Another way of synthesis of vanillin is through bioconversion of eugenol *via* ferulic acid, ferulaldehyde or coniferylaldehyde by *Arthrobacter*, *Corynebacterium* or *Pseudomonas* strains. Bacteria also seems to convert the eugenol into vanillic acid way better than yeast *Pseudomonas putida* strain was able to convert ferulic acid efficiently into vanillic acid and that a *Streptomyces setonii* strain transformed ferulic acid into vanillin at levels of up to 6.4 g $dm^{-3.2}$ [8].

Propynyl benzenes, a common aromatic compound from benzene group is transformed into a useful flavour by microbial transformation. Although this propynylbenzenes are found to be harmful for most microbes. Recent studies has shown that certain microbes can convert this into a potential flavour by natural synthesis. Production of various aromatic compound like vanillin, vanillic acid, anisaldehyde, coniferyl alcohol, coniferyl aldeheyde can be achieved through the biotransformation of propynylbenzene in pathway, which is called as epoxide-diol pathway. This is the first step in the biosynthesis of important products, *viz.*, vanillin, coniferyl alcohol, coniferyl aldehyde and others. These microorganisms include: *Aspergillus, Rhodococcus, Corynebacterium, Pseudomonas, Klebsiella, Enterobacter, Serratia, Bacillus* and *Arthrobacter* species. Table-2 summarized the flavour production by fermentation process by various microorganisms.

Fig. 5 shows that ferulic acid, vanillic acid or coniferyl alcohol was the main product in the bio- transformation of eugenol catalyzed by *Pseudomonas sp*. HR199 and *Rhodococcus opacus* PD630. To improve the yield of vanillin, metabolic engineering was introduced. The vanillic alcohol oxidase gene (vaoA) from *P. simplicissimum* CBS170.90 was expressed in *R. Opacus* PD630 and *Amycolatopsis sp.* HR167, along with the coniferyl alcohol dehydrogenase (calA) and coniferyl aldehydedehydrogenase (calB) genes from *Pseudomonas sp.*HR199. The recombinant strains is then converted eugenol to ferulic acid, which could be transformed to vanillin [47].

Production of flavours from agrowaste

Synthesis of vanillin from agricultural waste by using vanillin plant pods from vanilla bean. This produces with the help of microorganisms which can convert the precursor like ferulic acid. Material waste from wood pulp industry is used as a potential source for biovanillin production from lignin. Research [48] shows that ferulic acid from agrowaste can be used for producing vanillin by bioconversion process. This agrowaste is called as lignocellulose waste which contains cellulose, hemicellulose and lignin. Biovanillin can also be produced from the bioconversion of ferulic acid with the help

TABLE-2
FLAVOUR PRODUCTION BY FERMENTATION

Substrate	Organism	Product/flavour	Ref.
Grape	*Saccharomyces cerevasiae*	Wine	[44]
Apple pomace	*Tyromyces chioneus*	Changes of flavour and aroma of wine	[45,46]
Apple pomace	*Basidiomycetes (Tyromyces chioneus)*	Wine off flavours	[45,46]
Intracellular lipids	*Saccharomyces cerevisiae*	Fruit flavour in beer	[8]
Ferulic acid	*Aspergillus niger*	Vanillin	[8]
Ferulic acid	*Bacidiomycetes* (*pycnoporous cinnabarinus* and *phanerochacte chryososporium*)	Vanillin	[8]
Eugenol *via* ferulic acid	*Arthrobacter, cornybacterium* and *pseudomonas strains*	Vanillin	[8]
Eugenol *via* ferulic acid	*Pseudomonas putida*	Vanillic acid	[8]
Ferulic acid	*Streptomyces setonii*	Vanillin	[8]
Propynyl benzenes	*Aspergillus, Rhodococcus, Cornybacterium, Klebsiella, Pseudomonas, Enterobacter, Serratia, Bacillus, Arthrobacter* species	Vanillin, vanillic acid, anisaldehyde, coniferyl alcohol, coniferyl aldehyde	[47]
Eugenol	*Pseudomonas* HR199 and *Rhodococcus opacus* PD630	Vanillin	[47]

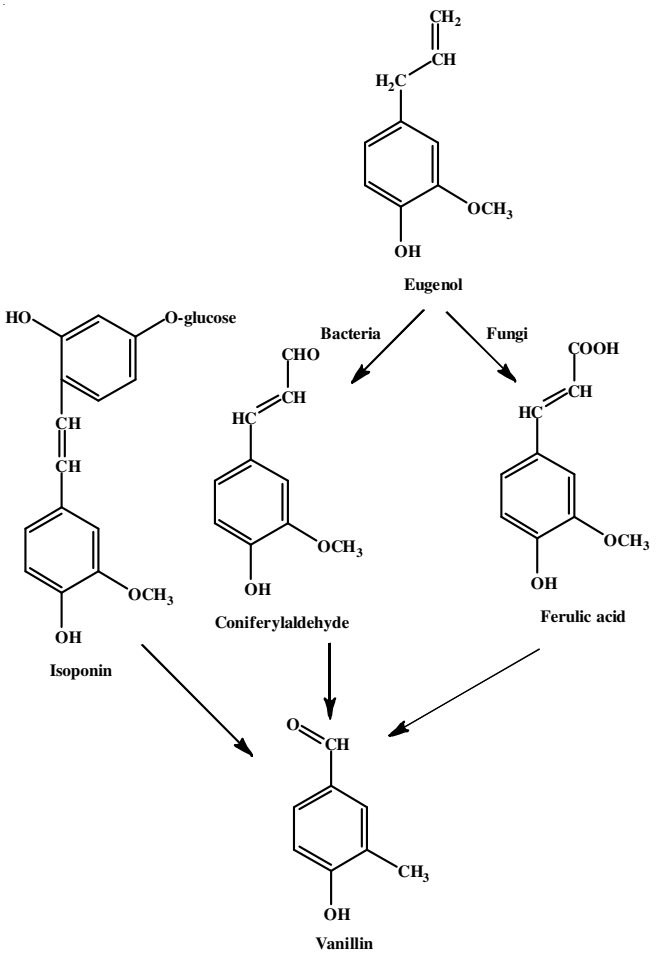

Fig. 5. Production of ferulic acid by fermentation

of *Amycolatopsis sp.* or *Streptomyces setonii* in a 10 L bioreactor after 17 substrates input [49].

A two steps process which involves the transformation of ferulic acid into vanillic acid with the help of *Aspergillus niger* and then it is converted to biovanillin by *Pycnoporus cinnabarinus* or *Phanerochaete chrysosporium*. Another study conducted used *Aspergillus niger* enzyme, later identified as pectinase, to release ferulic acid in cereal bran from sugar beet pulp. Cereal bran is used for the production of ferulic acid by a bioconversion with bacterial strain *E. coli* JM109 (pBB1) which has been genetically engineered by inserting the functional genes of *Pseudomonas fluorescence* BF13 for vanillin production from ferulic acid.

Other agro by-products such as rice bran, which was produced more than 10,000,000 tonns per year in the rice refining industry in China, also produces ferulic acid in abundance (Fig. 6). Besides esterified to arabinofuranosyl residue of heteroxylans in the cell walls of cereal grains [50] ferulic acid was also found in waste residue of rice bran oil (crude oryzanol) as a mixture of esterified ferulate of cycloartanol, 24-methylene cycloartanol campesterol, bsitosterol and cycloartenol [51,52]. Table-3 summarized the flavour production by means of agrowastes.

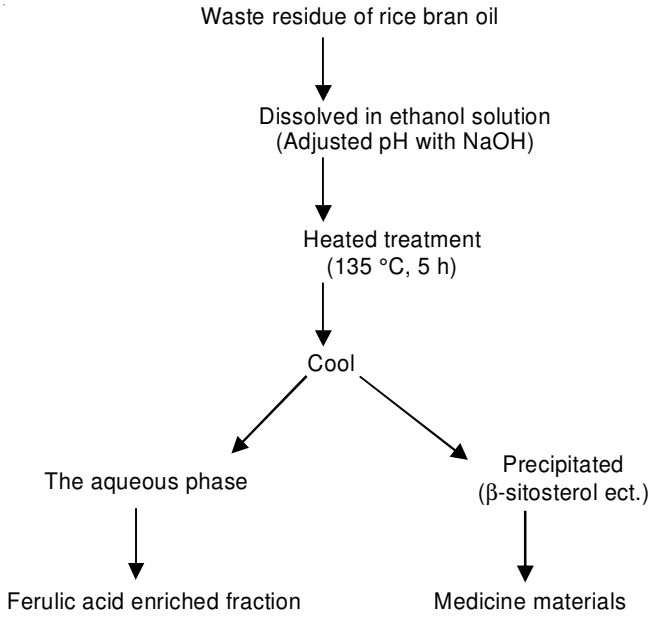

Fig. 6. Production of ferulic acid from rice bran oil waste

Sugar beet pulp produces ferulic acid, the precursor for vanillin from sugar refining industries, which also used to feed cattle is found to be having high amount of galacturonic acid, (< 2 g/kg) arabinose, (< 2 g/kg) rhamnose, (< 2 g/kg) and ferulic acid (< 0.8 g/kg). Palm oil industry also gives its part in production of biovanillin from ferulic acid. The effluents from palm oil refining industries which contains both palm

TABLE-3
PRODUCTION OF FLAVOURS FORM AGRO WASTES

Waste material	Product/flavour	Ref.
Wood pulp waste (ligno cellulose)	Vanillin	[48]
Microbial waste *Streptomyces setonii sp.*	Bio vanillin	[49]
Microbial waste by *A. niger*	Vanillic acid	[50]
A. niger enzyme pectinase from sugar beet pulp	Ferulic acid	[50]
Cereal bran waste by *E.coli*	Ferulic acid	[51,52]
Pseudomonas fluorescence	Ferulic acid Vanillin	[50]
Rice bran waste form cell wall of the grain	Ferulic acid	[50]
Waste residue from rice bran oil (crude oryzanol)	Ferulic acid and ferulate which contains cycloartenol. 24-methylene, cycloartenol campesterol, bsitosterol cycloartenol	[51,52]
Sugar beet pulp waste	Ferulic acid (biovanillin)	[53]
Palm oil effluents	Biovanillin	[53]
Cassava processing waste (bagasse)	Fruity aroma flavour	[54]
Cassava bagasse + soya bean + apple pomace	Strong fruity aroma flavour	[54]
Wheat bran + cassava bagasse + sugar cane bagasse	Fruity aroma flavour	[54]
Wheat bran + cassava bagasse + sugar cane bagasse + glucose	Intense aroma	[54]
De- starched wheat bran	Produces xylanase enzyme which releases ferulic acid	[50]

oil mill effluents and water. So, this could be used as a potential source for replacing the chemically synthesized vanillin in commercial industries [53].

Cassava processing unit can able to produce fruity aroma flavours. The bagasse produced from the processing as the industrial waste is utilized for the potential aroma and flavour production. The fruity aroma production is by the *Ceratocystis fimbriata* in solid cultures. The main operation in production of this flavour performed by solid state fermentation. Cassava bagasse was used in combination with soya bean or apple pomace. This combination produces a strong fruity aroma. Wheat bran, cassava bagasse and sugar cane bagasse are found to produce a fruity aroma flavour with the help of *Ceratocystis fimbriata*. Addition of glucose to the solid medium gives an intense aroma [54].

Another method for producing ferulic acid from agrowaste is from wheat bran. Wheat bran is destarched by the addition of *Trichoderma* and *A. niger*. This influences the production of xylanase enzyme which is required to release the ferulic acid [50].

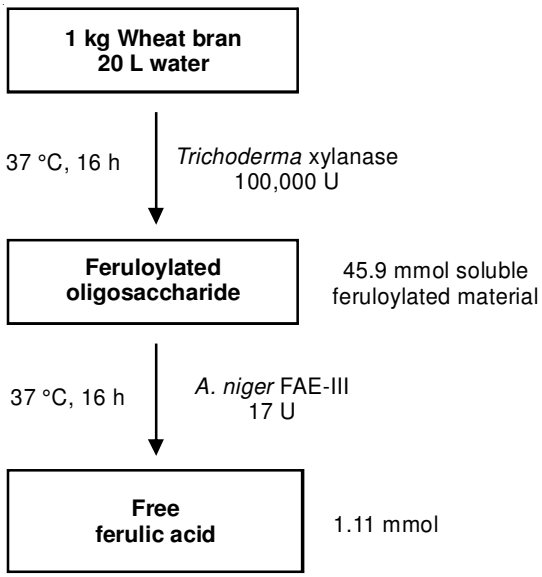

Fig. 7. Production of free ferulic acid from wheat bran oil waste and water

Production of flavours using plant cells

Major plant sources and plant materials are having many compounds like essential oils and fragrances. Some important fruit components like furanones and pyrones are obtained from bark and leaves of many tree species [55-57]. These are carbohydrate derived flavour compounds and consists of a light odour characteristics which is due to the presence of uncommon group of flavour molecules with exceptional low odour threshold [53]. Furanones are mainly present in the fruit part alone whereas pyrones are obtained from barks and leaves of plant species like *Larix deciduas*, *Evodiopanax innovans*, *Cercidiphyllum japonicum* and four kinds of Pinaceae plants [58,59].

Furanol is another flavour compound which is produced in similar way like furanones I. Furanol plays an important role in producing attractive key flavours in fruits [60]. A most common flavouring compound which also acts as bioactive compound in treating various diseases in human is terpenoids. Peppermint produces an abundant amount of commercially valuable, menthol and nutrient rich essential oils obtained from the primary compound called p-menthane monoterpenes [56].

The glandular trichomes of sweet basil (*Ocimum basilicum*) are rich in phenylpropenes as well as monoterpenes and sesquiterpenes [62]. Hence, terpenes are commercially available and widely used as flavouring compound, insecticides, perfumes, antimicrobial agents and most importantly used as raw materials for the manufacture of vitamins and many other chemicals. Many terpenes are constantly used in nutraceuticals and pharmaceutical industries for producing antimalarial and antiretroviral agents [56,63].

The commercial production of flavours from industries started with the help of production of cinnamaldehyde compounds from cinnamon and benzaldehyde from bitter almond oil, this single chemical from the plant is responsible for the whole characteristic flavours and aroma [51,59]. A small fraction of essential oil is present in grape fruit called nootkatone which is derived from valencene plays a dominant role in flavour and aroma of the grape fruit. This gives the characteristic aroma for the fruit [64]. And monoterpenes plays an important role in the production of flavours compound from strawberry. This compound acts as the responsible flavour [65,66].

A woody aroma is obtained from a tropical grass called the vetiver, which is scientifically called as *Chrysopogon zizanioides* used for the production of essential oils. β-Vetivone is the bioactive compounds responsible for the characteristic woody fragrance from the plant, it is one the key components present in vetiver oil [67,68]. Vanillylamine is also produced from natural ingredients of pepper and capsicums [6,38,39].

Several plant cells and parts, which produces the flavour are summarized in Table-4.

TABLE-4
FLAVOUR PRODUCTION FROM PLANTS

Plants parts	Components/ flavours	Ref.
Barks and leaves	Fruit components like furanones and pyrenes	[57]
Fruit part alone	Furanones	[59]
Leaves and barks parts obtained from plants like *Larix deciduas, Evodiopanax innovans, Cercidiphyllum japonicum* and four kinds of *Pinaceae* plants	Pyrone	[57]
Fruit part	Furanol	[60]
Peppermint	*p*-Methane monoterpens	[61]
Sweet basil plant *Ocimum basilicum*	Phenylpropenes	[62]
Ocimum basilicum	Sesquiterpenes	[62]
Cinnamon	Cinnamaldehyde	[56,64]
Bitter almond oil	Benzaldehyde	[56,64]
Grape fruit essential oil	Nootkatone	[69]
Strawberry	Monoterpenes	[65]
Vetiver	β-Vetivone	[67]
Capsicum and pepper	Vanillylamine	[6,38,39]
Allium cepa	Onion flavour	[70]
Allium sativum	Garlic	[71]
Theobromo cocoa	Cocoa flavour	[72]
Vanilla planifolia	Vanillin	[73]
Malus silvestris	Apple aroma	[74]
Oryza sativa	Basmati flavour	[75]

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