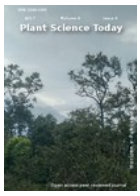
ISSN: 2348-1900
Plant Science Today
http://www.plantsciencetoday.online



Mini Review

Algae as Source of Natural Flavour Enhancers - A Mini Review

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Article history
Received: 28 August 2017
Accepted: 10 October 2017
Published: 19 October 2017

Editor
K K Sabu

Publisher
Horizon e-Publishing Group

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Abstract

Algae are popular sources of food, fodder, feed, fuel, fertilizers, pharmaceutical and nutraceutical products, and other co-products. The reason for preferring algae as source of a wide array of commercial products is that provisions for algal biomass production for application in different fields are long-term, pro-environmental and sustainable. This is related to the numerous varieties of ways and places in which algae can grow naturally or can be cultivated for commercialization. The fact that different species of algae have traditionally been used as preferred food or delicacy throughout the world speaks volumes about the taste attributes of edible algae. However, the use of algae or its derivatives as taste or flavour enhancers has not been explored enough, though sporadic works and reports can be found worldwide. This review attempts to scout the role of algae in imparting flavours in various cuisines made from algae or algae derived products. Also a number of fish and marine organisms have been reported to have flavours which are considered to contain flavour-enhancing compounds derived from algae, with uniqueness in such tastes been attributed to algae. Contrary to this, few algae have also been reported to impart "off-flavour" in some marine organisms. The present review brings together all such available reports to open avenues in bio-prospecting algae for extracting natural flavour enhancing products to enhance flavours of food items deficit in these appetite-stimulating flavours. Further, this review could stimulate research on "off-flavour" producing algae to remove distaste or toxicity imparting compounds by modification of biochemical pathways.

Keywords

algae; flavour; flavour character; flavour enhancer; seaweeds; umami

Citation

Choudhury S, Sen Sarkar N. Algae as Source of Natural Flavour Enhancers - A Mini Review. Plant Science Today 2017;4(4):172-176. doi: 10.14719/pst.2017.4.4.338

Introduction

Since ancient times algae have been put to various uses by human populations. Archaeological evidence (1), early written accounts (2-7) and traces of algae detected in ashes of prehistoric period (8) validate the use of algae since very early times as food. In this advanced era of biology, algae has been commercialised to meet the demands of fuel, pharmaceutics and nutraceutics, on a higher scale. Thus algae is being bio-prospected for developing and manufacturing different food and dietary supplements, value-added processed foods as well as non-food supplements in the form of tablets, soft gels and capsules (9). The age old tradition of consumption of algae as food and many times as delicacies opens up an avenue that seems promising

Table1: Natural Flavour Enhancing Compounds from Algae and their Characters

Name of Flavour Enhancer	Characters
Glutamic acid	A natural amino acid first identified in wheat gluten treated with sulphuric acid and has its commercial initiation in the Japanese cuisine Dashi which is a seaweed based preparation. It imparts umami flavour. Commercially prepared by aerobic fermentation of sugars and ammonia with the bacteria *Corynebacterium glutamicum*. An endophytic fungus *Penicillium sp* growing within the red algae *Gracilaria edulis* has commercial potential of yielding Glutamic acid (14), considerable amount of glutamate is also reported in green algae *Porphyra purpurea* and *P. lanosa* (13).
MSG (Monosodium glutamate)	A widely occurring non-essential amino acid and natural flavour – umami, first identified in the seaweed *Saccharina japonica*. Used as a flavour enhancer especially in Chinese cuisine and stimulates umami receptors for protein rich food. It is a subject of much controversy regarding its safety for consumption as a number of reactions known as MSG symptom complex are reported by many. However, lack of definitive evidence of link between MSG and these symptoms have made the US Food & Drug Administration (FDA) classify it as "generally recognized as safe" (GRAS) (15), but when MSG is added to any food it needs to be listed on the label (11). Previously it was made from gluten but now it is industrially manufactures by bacterial fermentation using *Corynebacterium* sp.
Monopotassium glutamate	All these flavour enhancers impart umami flavour like the MSG and are derivatives of glutamic acid. Thus all of these flavours find a natural origin in kombu and other seaweeds (12).
Calcium diglutamate	
Monoammonium glutamate	
Magnesium diglutamate	
Disodium guanylate, sodium guanylate	A natural sodium salt of guanosine monophosphate. It is quite an expensive ingredient, produced from dried seaweed, it imparts enhanced taste to instant noodles, potato chips, savory rice, tinned vegetables, cured meats and packaged soup. It is labelled unsafe for babies below twelve weeks, asthmatics and people with gout (12).
Inosinic acid	A natural food flavour enhancer, is also very important for proper metabolism of the body. It is reported as 5'inosinic acid (IMP) in dried and toasted nori - *Porphyra yezoensis* and is reported to be responsible for the umami taste of nori (13,16,17).
Maltol	Normally derived from the bark of larch trees, pine needles, chicory wood, oils and roasted malt; it may be produced synthetically. Also reported in green algae *Ulva prolifera* and *Monostroma nitidum* (18) and in red algae *Porphyra rubens* (19). This is an artificial sweetener, used in baked goods to impart 'fresh baked' taste, as chocolate substitute, and in soft drinks, ice cream and jam.
Glycine and its sodium salts	A natural amino acid and important flavour modifier. It is commercially produced from gelatin and is partly synthetic but is widely reported in many algae, of which *Palmaria palmata, Undaria pinnatifolia* and *Porphyra* enclose high amounts of glycine (20).
L-Leucine	A natural amino acid used as a flavour enhancer and modifier in food and beverage industries and also as a nutritional supplement. It enhances the aroma of bread and flour products. It is mainly produced from gelatin and is partly synthetic. It is reported in low concentrations in some red algae (21) and seaweeds like *Palmaria palmata*, *Ulva* sp. (22).
Aspartic acid	A non essential amino acid, it's methyl esters are used as low calorie sweeteners and its salts used to impart umami flavour. The common sources include asparagus, avocado, oat, sprouting seeds, oysters and molasses. It also constitutes a large proportion of the total amino acids of many seaweed species (22,23).
Bromophenol	A compound responsible for the distinct and unique 'ocean- like', shrimp-like', 'prawn-like' flavours of different seafood. It also enhances the intensity of umami. The compound is mainly produced by polychaetes, though some algae have also been reported to produce bromophenols. Shrimp, prawn, crabs etc acquire this compound from their diet on these algae and polychaetes (24). Several red and brown algal species and Ulva lactuca a green algae are reported to produce bromophenols or their derivatives (25).
Taurine	A non-protein sulphonic acid. It imparts flavour to sausages and fish fillets, It is not found in any land plant (26,27), and is essentially an animal source compound, but is widely reported in many seaweeds like *Laminaria japonica* (26), *Sargassum* (26), *Undaria* (16,26,27) and *Porphyra* (13,17,26,28) in significant quantities. It has also been reported in *Sachharina latissima* and *Porphyra tenera* (29). The presence of considerable amount of Taurine was noted in numerous green marine species especially the genera *Enteromorpha, Cladophora, Chlorodesmis, Codium, Caulerpa, Ulva, Neodilsea yendoana* and *Sargassum confusum* (26). Also reported in some microalgae – *Tetraselmis* (27) (Chlorophyceae), *Porphyridium* (27,30) (Rhodophyceae), *Oxyrrhis* (27,31) (Dinophyceae) and *Nitzschia* (27,32) (Bacillariophyceae).

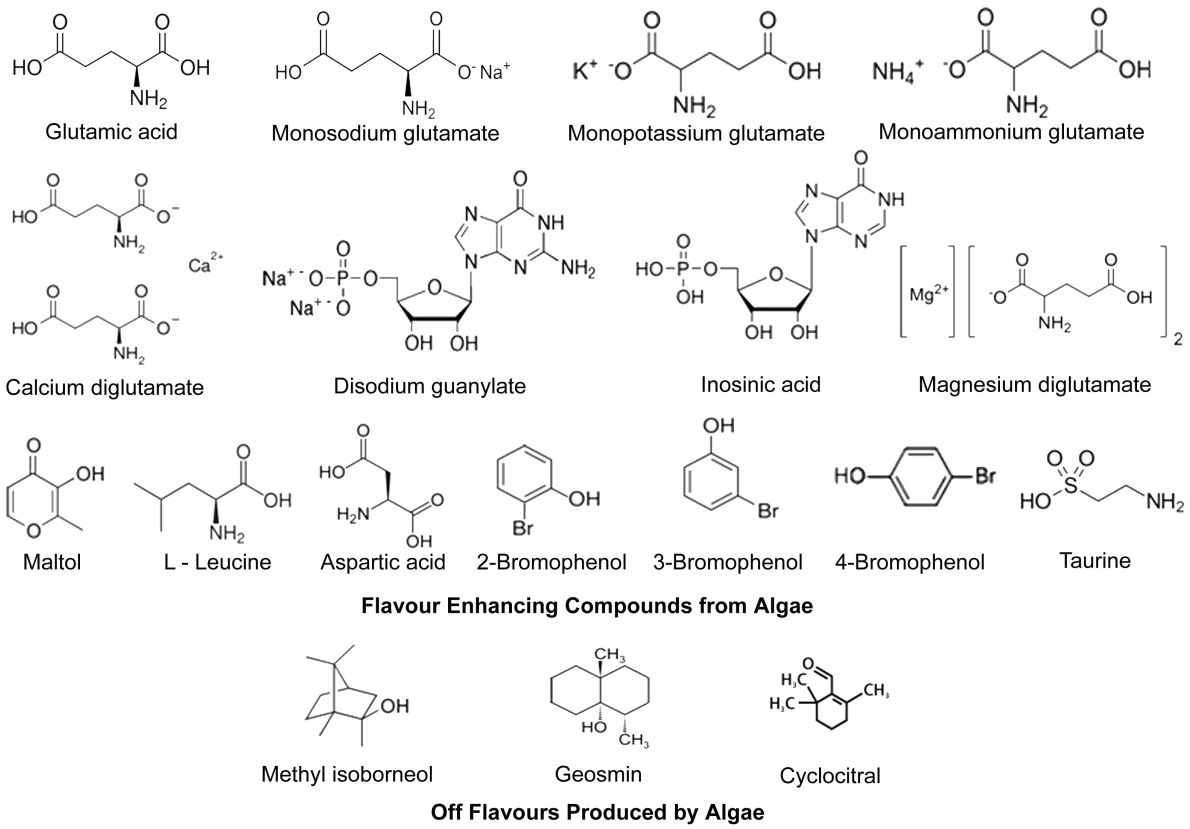

Fig. 1: Chemical structures of flavour enhancing and off-flavour producing compounds found in different algae

in terms of food processing industries. The world-wide growing preference for algae based foods like sushi, dashi, konbu, fat choy is indicative of the good taste of such foods and food derivatives. Thus emphasizing another avenue of bio-prospecting for algae in screening of different algae for taste enhancers that could be extracted and commercialized for enhancing taste of other foods and food derivatives and value added foods. This remains an area not much delved upon but one with immense prospects in future.

Defining flavour and taste

Flavour is a sensory impression created by what is eaten and is primarily determined by the chemical senses of taste and smell. It is an interplay of signals produced by sensing of taste, aroma, irritation (caused by hot peppers or cool peppermint), and texture of the food stuff that we consume (10). Flavour also includes the sensing of volatile compounds by the nose. The senses based on trigeminal nerve perceptions go on to detect chemical irritants, temperature and texture in the mouth and throat and play a role in adding to the perception of flavour (11). Taste refers to a broader classification of flavour and is defined as the perception created by intensities of different flavours on the tongue by sensory receptors (10). The flavour of any food can be altered with natural or artificial flavours which affect these senses.

Flavour Enhancers

Flavour Enhancers - as the name suggests increase the palatability of food without changing its taste. Food flavour enhancers are commercially added in the likes of instant soups, frozen dinners, snack-foods etc. Salt is the most common natural flavour enhancer for food and has been identified as one of the basic tastes. Flavour enhancers are usually added to modify flavours in food without adding any significant flavour on their own. Intake of controlled quantities are safe, but large quantities can lead to high blood pressure and even allergies (12).

Umami - the fifth basic taste

Umami is classified as the fifth basic flavour that the human palate can detect. The other tastes include sweet, salty, tasty and bitter. In 1908, Kikunae Ikeda, a Japanese professor, worked out dashi which is a broth of the seaweed kombu (*Saccharina japonica*) to find what makes it uniquely savoury and extremely popular in Japan. He extracted glutamate from kombu and determined that this was the ingredient that gave the soup its taste. Ikeda filed a patent to produce MSG as an additive to enhance flavours of other

foods and began to market it as a table condiment in 1909 calling it Aji-no-Moto – the essence of taste (12,13).

Flavour enhancers are classified worldwide according to an International Numbering System (INS) which is based on European system of naming food additives. The system is defined by *Codex Alimentarius*, the international food standards organization of the World Health Organization (WHO) and Food and Agriculture Organization (FAO) of the United Nations. A selected list of flavour enhancers that can be attributed to or be extracted from algae and their characters are highlighted in Table 1 and their chemical structures in Fig. 1 (12).

Off-flavours

Algal blooms produce toxins which are harmful for zooplankton, shellfish and finfish. Consumption of these toxin-affected organisms can lead to biomagnification and affect other organisms and even human beings consuming them (33). Apart from this direct toxicity, off flavours are common in cultured animals. These off-flavours are usually created by various chemicals which include Geosmin and 2-Methylisoborneol, produced by blue-green algae (BGA) and Actinomycetes. *Anabaena, Lyngbya, Oscillatoria,* and *Symploca* species have been reported to produce Geosmin or Methylisoborneol while blooms of *Aphanizomenon, Microcystis, Gomphosphaeria* and few species of *Anabaena* including *Anabaena macrospora,* produces Geosmin (34,35). *Phormidium* and *Oscillatoria tenuis, Oscillatoria brevis* produce methylisoborneol (MIB). The chemical structures of a few off-flavour producing compounds are elucidated in Fig. 1.

In addition to Geosmin and MIB, several other blue-green algal metabolites contribute to aquatic taste and odour problems. Among them is β-cyclocitral producing distinctive tobacco flavour. BGA are reported to produce a variety of organic compounds including hydrocarbons, fatty acids, aromatics, ketones, terpenoids, amines and sulfides which could contribute to the over-all flavour of water and aquatic organisms (34,35). The BGA *Planktothrix personata* has been reported to produce an earthy, musty flavour and a mud-taste (36). Bromophenols are also known to induce off-flavours. 4-bromophenol, 2,4-dibromophenol, 2,6-dibromophenol, and 2,4,6-tribromophenol in three species of brown algae *Padina arborescens*, *Sargassum siliquastrum*, and *Lobophora variegata* (38) and red algae *Rhodomela larix* (39). These off-flavours cause a lot of hazard in aquaculture and incur heavy economic loss too.

Conclusion

Very few flavour enhancers have been reported from algae and a lot remains to be explored. This review has pointed out few of the algal sources that are commercially exploited as flavour enhancers. Flavour enhancers obtained from algae can be used to increase the savoury of food strictly for vegans. Chemical substances that stimulate umami receptors are reported to be carcinogenic. So MSG and other flavour enhancers extracted from various algae can be commercialized in order to avoid such carcinogenic effects. Considerable research is also needed with respect to detection and 'off flavours' caused by algae.

Acknowledgements

The authors are grateful to the University of Kalyani and the Head of the Department, Department of Botany for giving permission and providing necessary infrastructure to carry out this work. NSS acknowledges the assistance received in the form of Personal Research Grant sanctioned by the University of Kalyani, Kalyani, West Bengal.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

NSS identified the issue to be addressed. SC initiated the study and drafted the manuscript. NSS enriched the manuscript, made necessary corrections and drafted the final manuscript.

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