Major constituents in leaf essential oils of *Curcuma longa* L. and *Curcuma aromatica* Salisb.

Curcuma longa L. var. *Rasmi* and *Curcuma aromatica* Salisb. var. *Bataguda* (Zingiberaceae) are the most commercially cultivated spice crops of India for the production of turmeric, and are indigenous to southern Asia. Rhizome of *C. longa* has been used in Indian systems of medicine as an antiseptic, carminative, stomachic, appetizer and tonic[1]. The cured, dried and ground rhizomes provide turmeric powder which is used as a supporting constituent of curry powders and as a food colourant. *C. aromatica* from *C. longa* by its pleasant, camphoraceous aroma of the rhizome[3] is used to cure pimples, whitening of skin and also as blood purifier; but it is not used as a condiment due to its bitterness[4].

The essential oil of turmeric rhizome has been studied in detail by a number of workers[5,6], and the main constituents were ar-turmerone, turmerol and atlantone[6]. Leaves of *Curcuma* species are a waste product during post-harvest operations. Traditionally, the leaves of *C. longa* are extensively used in culinary preparation, are aromatic and contain essential oil. There are a few reports on leaf oil from different origins[2,5,7]. However, no information is known about the constituents of *C. longa* var. *Rasmi* and *C. aromatica* Salisb. var. *Bataguda* leaf oils, which were collected from high altitude research station, Orissa and conserved in the Aromatic and Medicinal Plants Division, Regional Research Laboratory (RRL) Bhubaneswar, India. The present study was aimed at an investigation of the major constituents of leaf oils in both the *Curcuma* species.

Leaves of *C. longa* L. var. *Rasmi* and *C. aromatica* Salisb. were collected from the experimental garden of RRL (20°17′ 45″ N lat. and 85°49′15″ E long.) during December 1997 and 1998. Collected leaves were cut into small pieces and distilled by hydrodistillation using Clevenger's apparatus. GLC analysis was carried out in Perkin–Elmer auto-system fitted with capillary column carbowax 20 m of 50 m length flux ionization detector, Okidata 320 recorded digital computer DEC station feed with Turbochrom-3 software and nitrogen as carrier gas. Samples of essential oil were analysed by temperature programming of GC [60°C for 10 min followed by increase of 3°C/min to 200°C and kept at 200°C for 13 min]. Major volatile constituents were identified on the chromatogram by comparing their retention time with authentic compounds. Average plant height, tiller number, number of leaves per tiller, rhizome weight and percentage of rhizome and leaf oil of both the species were observed; they were not significantly different.

Leaf samples of *C. longa* and *C. aromatica* on hydrodistillation yielded 1.32 and 1.00% essential oil respectively, containing α-phellandrene (38.24%), C_8-aldehyde (20.58%), 1,8-cineole (8.64%), α-pinene (2.88%) and β-pinene (2.36%) in *C. longa*, and 1,8-cineole (28.01%), linalool (7.67%), α-pinene (4.74%), β-pinene (3.70%) and C_8-aldehyde (2.62%) in *C. aromatica*, as confirmed by GLC analysis (Table 1). The major compounds of *C. longa* leaf oil samples were α-phellandrene and C_8-aldehyde. Such predominance of C_8-aldehyde is novel. In *C. aromatica*, the major compounds are 1, 8-cineole (28.01%) and linalool (7.67%). These are responsible for using this species as raw material for making perfumes unlike the use of *C. longa* as a condiment.

α-phellandrene is present in greater amounts in *C. longa* var. *Rasmi* like in other samples of *C. longa* from different origins[2,8]. 1,8-cineole is a major component in *C. aromatica* leaf oil, which is identical with reports published earlier[10] and it is also a major component in *C. longa* from different origins. This compound is used as an expectorant, antiseptic, stain remover in dry-cleaning fluids, nose and throat spray, and also for the manufacture of cheap deodorant and copper-ore floatation[11,12]. Cineole imparts the camphory note in the species. 1,8-cineole is also present in leaf oils of *C. harmandii* as reported recently[13]. In *C. aromatica*, linalool is a specific component that has been reported earlier[10]. Both the hydrocarbons (α and β-pinene) are more in *C. aromatica*, and contribute to the turpentine-like odour, and in producing terpene chemicals which are abundantly used in cosmetics and in the pharmaceutical industry[12]. Earlier, *p*-cymene was listed as a major constituent, except in the *C. longa* leaf oil from Nigerian origin[2]. In earlier reports, terpinolene was a major constituent of *C. longa* leaf oil[2,5,7,8], whereas this turmeric leaf oil appears to be devoid of the component. Previous reports[10,13] on the composition of leaf oils of *C. harmandii* and *C. aromatica* show the presence of germacrone, camphor and curdione as the main constituents, whereas these are absent in both the leaf oils.

A comparison of *C. longa* L. var. Rasmi leaf oil with other oils from different origins shows a significant difference. The Nigerian oil of *C. longa* leaf contained more α-phellandrene, whereas in this sample 1,8-cineole and *p*-cymene were significantly higher. *C. aromatica* Salisb. var. *Bataguda* also shows a significant difference in the constituents when compared with other varieties (from Assam). These variations may be due to geographical and climatic conditions, and also due to different cultivars. It seems that both the leaf oils may find applications in pharmaceutical, perfumery, soap and cosmetics industries. Until the contribution of individual compounds, alone and in interaction, is established in leaf oils of *Curcuma* species, it is difficult to characterize and commercialize the oils as raw material for perfumery and pharmaceutical industries.

Table 1. Leaf oil composition of *C. longa* var. *Rasmi* and *C. aromatica* Salisb. var. *Bataguda*

Major constituents	*C. longa* (%)	*C. aromatica* (%)
α-pinene	2.88	4.77
β-pinene	2.36	3.70
Sabinene	0.40	0.68
Myrcene	1.17	0.39
α-phellandrene	38.24	1.40
1,8-cineole	8.64	28.01
p-cymene	6.05	1.45
C_8-aldehyde	20.58	2.62
Linalool	0.58	7.67
Caryophyllene	0.70	2.01
Geraniol	1.77	1.28
Methyl heptanone	0.05	–

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Porphyra – the economic seaweed as a new experimental system

Marine algae, popularly known as seaweeds, are sources of food, fodder, fertilizer, medicine and chemicals[1]. World trade in seaweed and its products was valued at US $ 50 million in 1970, US $ 250 million in 1990 and US $ 6.2 billion in 1999 (refs 1 and 2). About 20,000 marine algae species are distributed throughout the world, out of which only 221 species are utilized commercially. These include 145 species for food and 110 species for phycocolloid production[1]. *Porphyra* (Bangiales, Rhodophyta) popularly known as 'Nori' in Japan, 'Kim' in Korea and 'Zicai' in China has an annual value of over US $ 1.8 billion[3]. *Porphyra* is primarily used as food, wrapped around the Japanese delicacy 'Sushi' which consists of roasted blades, raw fish, rice and other ingredients. The alga is not only delicious but also contains high levels of protein (25–50%), vitamins (higher vitamin C than in oranges), trace minerals and dietary fibres[4]. The plant contains nearly 17 types of free amino acids, including taurine which controls blood cholesterol levels[5]. The alga is a preferred source of the red pigment *r*-phycoerythrin, which is utilized as a fluorescent 'tag' in the medical diagnostic industry[6]. *Porphyra* has been cultivated for the past hundred years in Japan and today it is one of the largest aquaculture industries in Japan, Korea and China[6]. Because of its economic importance and other health benefits, *Porphyra* cultivation is now being expanded to other countries[7]. Recently, it has been found that the plant has much more potential and can be used as an experimental system like *Arabidopsis thaliana* in the higher plants, some aspects of which are discussed here.

Nearly 133 species of *Porphyra* have been reported from all over the world, which includes 28 species from Japan, 30 from North Atlantic coasts of Europe and America and 27 species from the Pacific coast of Canada and United States[8]. Although seven species have been reported from the Indian coast, these are not being exploited commercially[9]. The genus *Porphyra* has a simple morphology. The plants are either round, round to ovate, obovate, linear or linear lanceolate (Figure 1 *a–d*). Individuals can also have blades that may be divided into male and female sections[10], or have a sectored morphology[11]. The plants can grow from 5 to 35 cm in length. The thalli are either one or two cells thick, and each cell has one or two stellate chloroplasts with a pyrenoid.

Porphyra has a heteromorphic life cycle with an alternation between a macroscopic foliose thallus which is the gametophytic phase, and a filamentous sporophyte called conchocelis phase. This diploid conchocelis phase in the life cycle was earlier thought to be *Conchocelis rosea*, a shell-boring organism. However, it was Drew in 1949 who demonstrated in culture that *P. umbilicalis* (L.) Kütz had a diploid conchocelis phase[12]. Until this landmark work concholeis was considered as an independent organism. These findings completely revolutionized the *Porphyra* industry in Japan and subsequently throughout Asia.

Porphyra reproduces by both sexual and asexual modes of reproduction. In sexual reproduction, certain mature vegetative cells of the thallus get differentiated into carpogonia, and others on the same or different thallus get differentiated into colourless spermatangia. After fertilization, the carpogonia divides to form packets of spores called zygotospores (carpospores). After release, the zygotospores usually germinate unipolarly to produce the filamentous conchocelis phase. The conchocelis can survive in adverse environmental conditions, but give rise to conchosporangia and conchospores under suitable conditions. The conchospores germinate by bipolar modes to give rise to young chimeric thalli, thus completing the life cycle (Figure 2).

In asexual reproduction, the vegetative cells in some species directly form the spores called archeospores which can directly germinate to form the thallus[13] (Figure 1 *i*). Recently, it has been found that besides these two modes of reproduction, *Porphyra* also reproduces by endosporangia or endospores which ultimately give rise to the thallus[14].

Different stages in the life cycle can be manipulated both in the laboratory as well as on an industrial scale. Large-scale conchocelis are being cultured in suitable environmental conditions by different Nori companies. Massive amount of con-