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REVIEW ARTICLE

Kokum (*Garcinia Indica*) and its Many Functional Components as Related to the Human Health: A Review

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Abstract

Kokum (*Garcinia Indica Choisy*) is an ancient fruit that is widely consumed in the form of sarbat. Kokum is a fruit tree of culinary, pharmaceutical, nutraceuticals and industrial uses. Kokum has a long history in Ayurvedic medicine as it was traditionally used to treat sores, dermatitis, diarrhea, dysentery, ear infection, and to facilitate digestion. Kokum seeds are used for oil extraction. That oil is called kokum butter and used in curries, cosmetics, medicines, and costly confectionery preparations in foreign countries. The kokum fruit acts as an anti-oxidant, acidulant and appetite stimulant and helps in fight cancer, paralysis and cholesterol. The kokum fruit is a good digestive tonic and used to improve skin health. The high pressure performance liquid chromatography (HPLC) analysis of *Garcinia indica* fruit shows major physiochemical hydroxyl citric acid (HCA) which is claimed to have fat-reducing properties in the human body. The aim of this review was to present an overview of the functional, medicinal and physiological properties of the kokum fruit.

Key words: Kokum, Hydroxyl citric acid, Functional food, Anthocyanins, Kokum Butter, Garcinol.

1. Introduction

Kokum (*Garcinia indica Choisy*) is one of the important indigenous tree spice crops originated and grown in Western Ghats of India, South Konkan region of Maharashtra, Coorg, Wynad and Goa and is found in evergreen and semi evergreen forests and as a home garden tree (Subash Chandran, 2005). The tree grows extensively in the Konkan region of Maharashtra, Goa, coastal areas of Karnataka and Kerala, evergreen forests of Assam, Khasi, Jantia hills, West Bengal and Gujarat. It is known by various names across India including *Bindin*, *Biran*, *Bhirand*, *Bhinda*, *Kokum*, *Katambi*, *Panarpuli*, *Ratamba or Amsol*. It is indigenous to the Western Ghats region of India, along the western coast. It is found in forest lands, riversides, and wasteland, and also gets cultivated on a small scale. In India the tree mainly found along costal belt of Konkan region of Ratnagiri district of Maharashtra, Goa, Uttara Kannada, Udupi and Dakshina Kannada Districts of Karnataka and Kasaragod area of Kerala.

Western Ghats, a rich source of biodiversity for a number of plant species, harbours a wide diversity of kokum trees. There are wide variations in naturally distributed kokum populations in fruit quality due to the dioecious nature and cross pollination. Fig 1a shows the kokum fruit and Fig 1b shows the kokum rind. The ripe kokum fruit is coloured either dark purple or red tinged with yellow. It contains 3-8 large seed embedded in a red acid pulp, in a regular pattern like orange segments, in a white pulpy material (Krishnamurthy, 1984; Krishnamurthy, 1982). Shape of fruit varies from round to oval and its weighs around 21-85g. The expected shelf life of this fruit is about 1 week. Sun drying is a commonly used method to preserve the fruit and it takes around 6-8 days for complete drying. The fruit is mainly used for culinary purposes. Kokum is collected from the wild, grown in home gardens and cultivated at a limited scale as a rainfed crop, usually mixed with other fruit trees and in the Western Ghats region, estimated to be grown in an area of 1200 ha with an annual production of 10,400 tonnes which constitutes the dried rind of the fruit is used mainly as an acidulent in cosmetic products and moisturising and rind has got medicinal properties and used in the treatment of piles, dysentery, tumours and heart complaints (Patil *et al*., 2009).

Fruit kokum, rind and seed have many applications such as culinary, foods, fruit drinks, pharmaceuticals and industrial. It is also called as an Indian spice with a pleasant acceptable flavour and has a sweet acidic (sour) taste which makes it a popular food-

(a) (b)

Fig 1: (a) Kokum fruits, (b) Seed embedded with pulp and rind

additive. It is traditionally used as acidulant in many Indian dishes. This crop is gaining increasing importance, as its fruits have multifarious utilities ranging from the pharmaceutical uses to high quality beverages. Kokum has been reported for the treatment of dysentery, tumours, heart complaints, stomach acidity and liver disorders (Bhaskaran and Mehta, 2006; Krishnamurthy *et al*, 1982).

2. Chemical Composition of Kokum

Kokum rind contains three important chemical constituents' viz, Garcinol, Hydroxycitric acid and anthocyanin pigment. Garcinol is a fat soluble yellow pigment; Hydroxycitric acid is used as an acidulant and physiologically active compound has been shown to significantly reduce body weight. The kokum fruit consists of different chemical constituents these are given in Table 1.

Table 1: Chemical Constituents of Kokum

Sr. No.	Character	Value
1	Moisture (%)	80.00
2	Protein (N x 6.25) %	1.92
3	Crude Fat (%)	10.00
4	Crude Fibre (%)	14.28
5	Total Ash	2.57
6	Carbohydrates by Difference (%)	35.00
7	Starch (%)	1.00
8	Pigments (%)	2.40
9	Tannin (%)	2.85
10	Pectin (%)	5.71
11	Ascorbic Acid (%)	0.06
12	Acid (as Hydroxyl Citric acid)	22.80

Krishnamurthy *et al.* (1982)

3. Kokum as a Functional Food

Functional foods are those that provide more than simple nutrition; they supply additional physiological benefits to the consumers (Krishnamurthy 1996; Devasagyam *et al.*, 2006). In India also, demand for functional foods is increasing in recent years. In this aspect, foods rich in preparation from kokum and its syrup can be considered as functional foods. Due to recent trends in nutrition towards development of healthy foods in the form of 'Functional foods', one of the desirable properties of dietary component is considered to be its antioxidant effects (Peter, 2001; Wildman, 2001). There is no one definition of the term functional food, which is used in many contexts *viz.* technological advances, food marketing and food regulatory norms (Palou *et al.*, 2003). This term has already been defined several times (Roberfroid, 2002) and there is still no unitary accepted definition for this group of foods (Alzamora *et al.*, 2005). In most countries, there is no legal definition of the term and drawing a border line between conventional and functional foods is challenging even for nutrition and food experts (Niva, 2007).

Several working definitions used by professional groups and marketers have been proposed by various organizations in several countries. In the United States, functional foods are not officially recognized as a regulatory by the FDA. However, several organizations have proposed definitions for this rapidly growing food category, most notably the International Food Information Council (IFIC) and Institute of Food Technologists. The IFIC considers as functional foods those that include any food or food component that may have health benefits beyond basic nutrition (IFIC, 2009). Similarly, a recent report of the Institute of Food Technologists (IFT, 2009) defined functional foods as

"foods and food components that provide a health benefit beyond basic nutrition (for the intended population).

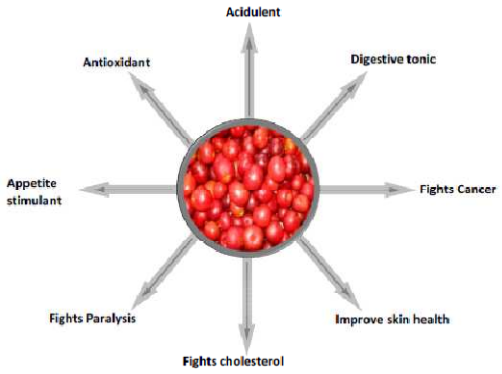

Fig 2: Principal function and medicinal effects of kokum

The European Commission (EC) Concerned Action on Functional Food Science in Europe regards a food as functional if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being or reduction of risk of disease. In this context, functional foods are not pills or capsules, but must remain foods and they must demonstrate their effects in amounts that can normally be expected to be consumed in the diet (EC, 1999).

The concept of the functional food is complex and may refer to many possible aspects, including food obtained by any process, whose particular characteristic is that one or more of its components, whether or not that component is itself a nutrient, affects the target function of the organism in a specific and positive way, promoting a physiological or psychological effect beyond the merely nutritional (Viuda *et al*., 2010). The positive effect of a functional food may include the maintenance of health or well-being, or a reduction in the risk of suffering a given illness (Perez *et al*., 2003). Kokum fruit conforms to this definition in several ways, although the establishment of any function would involve identifying the bioactive components to help specify their possible beneficial effects on health.

4. Historical Uses of the Kokum

The fruits of *G. Combogia* are valued for their dried rinds, which are used extensively in South India, Western Ghat for culinary purposes and particularly as a Condiment, in place of tamrind or lemon, for flavouring curries, meat and seafood dishes. The food extract also serves as a unique flavor enhancer for beverages, gourmet spice and as a post-prandial carminative. The fruit has also been used for centuries to make meals more filling (Sergior, 1988; Mattes and Bormann, 2000). Dried rind of *G. Combogia*, which contains HCA, is also used in pickling fish (Sreenivasan and Venkatraman, 1959; Clouatre and Rosenbanum, 1994); the commercial pickling of fish is called "*Colombo Curing*" (Sreenivasan and Venkatraman, 1959; Lewis *et al*., 1964). The organic acid present in the fruit are responsible for the bacteriostatic effect of pickling medium by a simple lowering of the pH. In addition to flavouring and preservative effects of the fruit extract, in the traditional system of herbal medicine in India (Ayurveda), Garcinia is considered to be one of the prime herbs that are beneficial for health. A concentrate of the fruit rind is given for rheumatism and bowel complaints. In veterinary medicine, the extract is employed as a rinse for some diseases of the mouth in cattle (Jena *et al*., 2002). HCA, the organoleptically characterizing ingredient of kokum is a popular compound of several dietary supplements' marketed under various trade names.

Kokum has a long history in Ayurvedic medicine as it was traditionally used to treat sores, tumors, dermatitis, heart complaints, diarrhea, dysentery, ear infection, and to facilitate digestion. Kokum Juice is also used as a natural remedy for stomach and liver disorders (Bhat *et al*., 2005; Krishnamurthy, 1984; Krishnamurthy *et al*., 1982; Mishra *et al*., 2006). The major organic acid component that imparts that the savory taste to the fruit is hydroxyl citric acid (HCA), which is an important ingredient in many fat reducing supplements and it is claimed to increases fat burning (Jena *et al*., 2002). The seed of *Garcinia indica* contains oil, which remains solid at room temperature. It finds its application in foods, pharmaceutical and cosmetic industries (Krishnamurthy, 1984). The chemical and spectral investigation revealed the kokum contains Garcinol, a fat soluble yellow pigment and two water soluble anthocyanin pigments as a cyanindin-3-glucoside and cyanindin-3-sambubioside (Krishnamurthy, 1988).

5. Composition

Kokum contains the following phytonutrients: Anthocyanins (Cyanidin-3-sambubioside, Cyanidin-3-glucoside); Kokum butter; Hydroxycitric acid (HCA) and Garcinol. Anthocyanins are well known for their antioxidant, anti-inflammatory and anti-carcinogenic activity. Hydroxycitric acid (HCA) has gained much attention in recent years for its pivotal role in fat/lipid metabolism, with implications for use in weight loss.

5.1 Anthocyanins

Kokum contains 2 to 3 % of red colour pigment. Anthocyanins of kokum are water soluble and possess

antioxidant activity. Two major pigments characterized in kokum are cyanidin-3-glucoside and cyanidin-3-sambubioside which are usually present in the ratio of 4:1 (Nayak *et al.*, 2010). These two anthocyanins were first identified by thin layer chromatography using acetic acid: HCl: water in ratio of 15:3:82 (Nayak *et al.*, 2010). The respective sugars associated with these two pigments are glucose and xylose. Thus, the extract of anthocyanins contains water, pigment and sugars. Due to high water content these extracts have low shelf life and thus commercially they are concentrated. This also further reduces the transportation and storage cost. Concentration of such color by conventional evaporation or distillation results in loss of hue and chroma. Thus, membrane processes such as microfiltration, ultra-filtration or reverse osmosis are employed. But these methods have few drawbacks such as need of high pressure, membrane clogging, maximum achievable concentration and reduction in the gradient. A novel forward osmosis method is also developed for concentration of Kokum anthocyanins using semi-permeable nonporous active skin layer of cellulose triacetate embedded in a nylon mesh with NaCl solution as an osmotic agent (Nayak and Rastogi, 2010).

Anthocyanins constitute approximately 2.4% of the total fruit biomass. These pigments can scavenge free radicals and are water soluble. They can be extracted from the fruit rind by hydraulic press using 1% acidified water as a solvent (Nayak *et al*., 2010). The monomeric anthocyanins in kokum can be measured using pH differential method (Wrolstad *et al*., 2005). The general structure of anthocyanidin pigment is shown in Fig 3. This basic structure of anthocyanidin pigment is responsible for a number of different colour compounds produced by chemical combination with glycosides and acyl groups. The most common sugar groups occurring in nature are glucose, rhamnose, xylose, galactose, arabinose and fructose while common acyl groups are coumaric, caffeic, ferulic, p-hydroxy benzoic, synapic, malonic, acetic, succinic, malic, oxylic etc. Substitution of hydroxyl and methoxyl groups has influence on different shades of colours of anthocyanins. Increase in the number of hydroxyl groups gives more bluish shade while increase in methoxyl groups increases redness. Depending upon the number and position of hydroxyl and/or methoxyl groups there are total 17 anthocyanidins of which 6 are the most common ones, namely cyanidin, delphinidin, pelargonidin, malvidin, peonidin, petunidin. Cyanidins have hydroxyl groups attached at 3, 5, 7, 3' and 4' position. It gives magenta and crimson shades (Delgado-Vargas *et al*., 2000). Cyanidin-3-glucoside found in kokum has hydroxyl groups attached at the corresponding positions and glycosidic linkage at position 3. The other major pigment cyanidin-3-sambubioside is similar in structure and has disaccharide sambubiose attached instead of glucose.

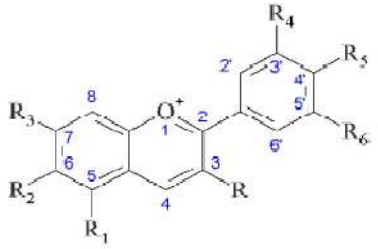

Fig 3: General structure of anthocyanidin pigment (Delgado-Vargas *et al.*, 2000)

5.1.1 Nutraceutical Potential of Anthocyanins

Anthocyanins have been shown to possess strong antioxidant activity. Given their wide distribution in nature, daily intake of anthocyanins is 25 to 215 mg/person depending upon gender and age (Delgado-Vargas *et al.*, 2000). Anthocyanins prevent ascorbic acid oxidation, scavenge free radicals, show inhibitory effects against oxidative enzymes and reduce the risk of cancer and heart diseases (Bridle and Timberlake, 1997). The 3' and 4' –OH in B-ring determine radical scavenging capacity with a saturated 2, 3- double bond. Different glycosylation and hydroxylation positions determine their potential as an antioxidant (Wang *et al*., 1997). With increase in hydroxyl groups in B-ring, antioxidant activity increases when present as glucosides. Corresponding aglycones have weaker activities (Tsushima *et al*., 1996). Azevedo *et al*. (2010) showed antioxidant properties of anthocyanins with DPPH, FRAP and oxygen consumption assays. They showed radical scavenging activity and reducing capacity increased with the number of hydroxyl groups present in B-ring. 3' and 4'–OH groups are important in preventing ascorbic acid oxidation by anthocyanins-metal chelation (Sarma *et al*., 1997). Anthocyanins also have effect on lipid peroxidation. They are better agents against lipid peroxidation than α-tocopherol. Anthocyanins also have scavenging properties against –OH and O2-. Bioflavonoids such as leucoanthocyanidins, catechins, flavonols etc. along with anthocyanins such as cyanidin-3-glucoside have shown activity to improve permeability and strength of capillaries, to accelerate the ethanol metabolism and to reduce inflammations and edematic reactions (Delgado-Vargas *et al.*, 2000).

5.2 Kokum Butter

Kokum oil or kokum butter is nutritive, demulcent, smoothening, softening, astringent, and

emollient and has a great demand in pharmaceutical industry for preparation of ointments, cosmetic industry for face creams and lipsticks. The composition of the kokum fat is given in Table 2.

Table 2: Characteristics and Composition of Kokum Fat

Sr. No.	Character	Value
1	Melting Point	39.5-40.0°C
2	Sap Value	189
3	Iodine Value	37.4
4	Unsapen Matter (%)	1.4
5	Free Fatty Acid (% as oleic)	7.2
	Component Fatty Acid (% by Weight)	
6	Palmitic	2.5
7	Stearic	56.4
8	Arachidic	-
9	Olein	39.4
10	Linolein	1.7
	Component glycerides (% by mol)	
11	Tristearin	1.5
12	Oleodistearin	68
13	Oleopamitostearin	8
14	Palmitodiolein	20
15	Triolein	2

Kureel *et al.* (2009).

The kernels of kokum seed contains about 33 to 44 per cent oil, which is commercially known as "kokum butter". In addition, due to its suitability for ointment, suppositories and other pharmaceutical purposes kokum is commoditing greater export potentiality. The ointment is used for the local application for treating ulcer, fissures of lips, cracks/cuts in chopped hands and feet's etc. Due to high content of di-saturated and mono-saturated glycerides, it is in great demand as a substitute for cocoa an extender in chocolate and confectionery products preparations. Hydroxy citric acid (HCA) is one of the ingredient of kokum and used as an anti obesity agent for keeping fatty acid symbiosis at lower level. Kokum seed is reported to contain a compound which could turn liquids in to solids. It can be used in the manufacture of wine, champagne and liquor. It could be an ideal substitute for grapes in the wine industry. As kokum reduces fat, cools body, purifies blood, fights cholesterol, wine and liquors made from kokum will attract health conscious people (Vishwaprasad Sediyapu, 2001). The kokum butter is shown in Fig 4. The seed contains about 32 to 35% fat having food and non-food applications. Kokum butter is mainly used as an edible fat. It is also used as an adulterant of ghee. Kokum fat remains solidified at room temperature. It is edible, nutritive, demulcent, astringent and emollient (Pruthi, 1979). It is also used as confectionery butter and also for candle and soap manufacture. It can be used for the production of stearic acid from the fat with a yield of 45.7%. It can also be employed in the sizing of cotton yarn (CSIR, 1956). The cake left after the extraction of oil is used as manure.

Fig 4: Kokum Butter

5.2.1 Neutraceutical Properties of Kokum Butter

Kokum butter is considered nutritive, demulcent, astringent and emollient. It is suitable for ointments, suppositories and other pharmaceutical purposes. It is used for local application to ulcerations and fissures of lips, hands etc. Kokum butter is used as a specific remedy for diarrhea and dysentery (Kureel *et al*., 2009). Kokum butter is very soothing for burns, chaffed skin and scalds. Kokum butter exhibits excellent emollient properties and high oxidative stability, which can assist emulsion integrity. With its relatively higher melt point, it melts slightly at skin temperatures making it ideal for lipsticks and balms; it's also a great addition to bar soaps and skin lotions.

5.3 Hydroxycitric Acid (HCA)

Hydroxycitric acid, both free acid and lactone forms, is present in fruit rind of *Garcinia indica,* which are commercially available in India. As an inhibitor of the synthesis of fat and cholesterol, hydroxycitric acid has been shown to significantly reduce the body weight and lower lipid accumulation. It is also the only known anorectic agent found as a natural constituent of edible foods consumed by humans. Major portion of organic acids in kokum is hydroxycitric acid (HCA) (1, 2 dihydroxypropane-1, 2, 3-tricarboxylic acid). Rinds contain about 20-30% of (-)-HCA on dry basis. Due to its presence in high amounts in Garcinia species it is also called as garcinia acid. (-)-HCA is separated from rinds of Kokum by aqueous extraction. (-)-HCA has tendency towards lactonization during purification, evaporation and concentration. So it is converted to its sodium,

potassium or calcium salts, lactones or esters (Jena *et al*., 2002). Liquid chromatographic method has been developed to determine the amount of HCA and HCA-lactone in kokum leaves as well as rinds (Jayaprakasha and Sakariah, 2002).

Extract containing HCA has proven its strength to reduce fat synthesis in the body from 40 to 70%. Garcinia fruit lowers blood lipids such as cholesterol and triglycerides by triggering fatty acid oxidation in the liver via thermogenesis (raising body temperature to speed up the body's metabolism which increases burning of fats). It burns the fat slowly and gently without stimulating the central nervous system (Raju, 2001). Today's consumer constantly struggles to control weight gain which is generally brought about by over-eating, unhealthy food choices, stress and lack of exercise. When we consume a carbohydrate-rich diet, glucose is partially used and stored in the form of glycogen in liver and muscles. The excess glucose is converted to lipids and stored as fat throughout the body which causes weight gain. ATP-citrate lyase is an enzyme that cleaves citrate, produces oxaloacetate and acetyl-CoA (a key molecule used in fat storage).

5.3.1 Neutraceutical Properties of Hydroxycitric Acid (HCA)

The fruit *Garcinia indica* containing hydroxycitric acid (HCA) and other acids have some potential for development as weight-loss aids, through their potential to increase lipid metabolism (Rao and Sakariah, 1988). The reputed effect of HCA as anti-obesity effect are based on its action as a potent inhibitor of the enzyme ATP-citrate lyase, and thus limits the availability of acetyl–CoA, a key molecule, which plays a critical role in energy storage as fat. The claimed weight reducing effect of HCA are attributed not only to reduced food intake and increased energy expenditure, but also to a suppression of fatty acid synthesis and an enhancement of glycogen synthesis in liver. Other researchers have also reported anti-obesity properties of this compound (Greenwood *et al*, 1981; Rao and Sakariah, 1988). One of the ingredients of kokam, hydroxycitric acid (HCA), has been patented for use as a hypocholesterolaemic agent. HCA is a potential anti-obesity agent. It suppresses fatty acid synthesis, lipogenesis and food intake and induces weight loss (Jena *et al*., 2002). The main active component in kokum is hydroxycitric acid (HCA) which is regarded as a fat reducer (Froukje, 2008).

The HPLC analysis of *Garcinia indica* fruit shows major phytochemical HCA which is claimed to have fat- reducing properties for the human body. HCA is mainly found in the rind of the fruit. It is shown that HCA can inhibit the enzyme, citrate lyase which is needed for conversion of carbohydrates into fats. The fruit also shows presence of anthocyanins which are pigmented flavonoids. They are water soluble and help in scavenging free radicals. Flavonoids are known for their antioxidant activity, although it is research is going on in this field. Flavonoids are also referred to as bioflavonoid, since all flavonoids are biological in origin.

5.4 Garcinol

Garcinol is a polyisoprenylated benzophenone derivative and contains phenolic hydroxyl groups. This makes it active antioxidant. It is also called as camboginol, a triisoprenylated chalcone. It has β-diketone moiety and thus resembles a known antioxidant viz. curcumin (Pan *et al.*, 2001). Molecular weight of Garcinol is 602 ($C_{38}H_{50}O_6$) and its melting point is 122°C (Nayak *et al*., 2010). It is crystallized out from hexane extract of the fruit rind. The absorption spectral data and molecular formula indicate relation to isomeric xanthochymol and in terms of optical rotation to cambogin. The 1, 3-diketone systems is enolisable since presence of two isomeric trimethyl ethers. The UV spectrum of garcinol shows that 1, a 3-diketone system is conjugated to the 3, 4-dihydroxybenzoyl moiety. The IR spectrum of trimethyl ethers shows there is presence of saturated carbonyl group and two α, β-unsaturated carbonyl groups. Some features of the garcinol molecule indicate it can be derivable from Maclurin (2,4,6,3',4'- pentahydroxybenzophenone) and five isoprenyl units (Padhye *et al.*, 2009). The general structure of garcinol is shown in Fig 5.

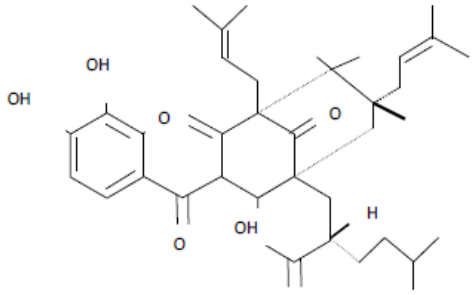

Fig 5: Structure of garcinol (yamaguchi *et al.,* 2000).

5.4.1 Nutraceutical Properties of Garcinol

Garcinol has been studied for its anti-cancer, anti-ulcer, anti-oxidative and antiglycation activity (Nayak *et al*., 2010). The antioxidant activity of Kokum syrup, aqueous and boiled extract has been measured by various techniques such as ORAC, FRAP, ABTS etc. and it is shown that these preparations have very good antioxidant potential due to presence of garcinol and anthocyanins (Mishra *et al*., 2006). Garcinol can

scavenge alkyl-peroxyl radicals to form hydroperoxy derivative of garcinol and cambogin or isogarcinol. Isogarcinol has similar biological activities as garcinol and is potent antioxidant as well. These compounds can induce apoptosis in human leukemia HL-60 cells; inhibit NO radical generation and LPS-induced iNOS gene expression. Thus, garcinol has been shown to have better anti-tumor activity than curcumin (Sang *et al*., 2002; Sang *et al.*, 2001). Garcinol has been shown to possess antioxidant activity in H_2O_2-NaOH-DMSO system and radical scavenging activity against hydroxyl radical, methyl radical and superoxide anion. The emulsified garcinol suppresses superoxide anion similar to DL-α tocopherol (by weight), while it has three times greater free radical scavenging activity against 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals than DL-α- tocopherol by weight (Yamaguchi *et al*., 2000). Garcinol is also shown to possess antioxidant activity against arachidonic acid metabolism and NO radical synthesis by modulation of arachidonic acid metabolism. Defective arachidonic acid metabolism and generation of NO radicals are involved in carcinogenesis and inflammation (Hong *et al*., 2006). Liao *et al*. (2005) showed garcinol prevents NO radical accumulation in LPS induced inflammatory mediators such as iNOS and COX-2. Thus garcinol may have neuro-protective effects against brain injury. A recent study by Koeberle *et al*. (2009) showed that garcinol interferes with two enzymes, 5- lipoxygenase and microsomal prostaglandin PGE2 synthase that play important role in inflammation and tumorigenesis. Garcinol and its oxidative products interact with colon cancer cells such as HT-29 and HCT-116 as well as normal immortalized intestinal cells such as IEC-6 and INT-407. They have potent growth-inhibitory effects on all intestinal cells but more effective on cancer cells than normal ones. Thus, at certain concentration garcinol can be used to inhibit growth of cancer cells (Hong *et al*., 2007). Another similar study on garcinol has shown inhibition of growth of human leukemia HL-60 cells suggesting its chemo preventive action (Matsumoto *et al*., 2003). Balasubramanyam *et al*. (2004) have shown non-specific inhibition of histone acetyltransferase by garcinol suggesting anti-HIV property. Above research shows that garcinol has very promising antioxidant, anticancer, anti-inflammatory properties.

Garcinol is also reported to show some antimicrobial activity. It plays important role in treatment of gastric ulcers caused by *Helicobacter pylori* chronic infection. This bacterium along with cells from gastric mucous membrane produces hydroxyl radicals and superoxide anions. Conventional antibiotics such as clarithromycin have side effects and thus garcinol can be a good alternative (Chatterjee *et al*., 2003; Chatterjee *et al*., 2005). Garcinol also showed antimicrobial activity against *Staphylococcus aureus* which was comparable to traditional antibiotic Vancomycin (Rukachaisirikul *et al*., 2005; Iinuma *et al*., 1996). Yoshida *et al*. (2005) reported, garcinol fortified diet decreases the incidence of tounge neoplasms and pre-neoplasms. It also induces apoptosis through the activation of caspases and thus works as anti-tumor agent (Pan *et al*., 2001). There are numerous reported mechanisms through which garcinol acts as antioxidant, anti-inflammatory or anti-cancer agent as explained above.

5.5 Anti Cancer Agent

It was found that garcinol from kokum suppresses colon carcinogenesis in rats by inhibiting inducible nitric oxide synthase (iNOS) and cyclooxygenase (COX-2) enzymatic reactions. Histone acetyltransferase (HATs) has a key function in the modulation of gene transcription, cellular differentiation and cellular proliferation. However, if the HAT enzyme is altered, this affects the cell cycle or gene transcription causing cancer, neurodegenerative diseases, or other neurological syndromes. Balasubramanyam *et al*. (2004) have demonstrated that garcinol from kokum inhibits HAT activity and induces cell apoptosis. Hence, this investigation suggested that the garcinol from kokum acted as an anti-cancer agent by inhibiting HAT activity and instigating apoptosis.

5.6 Antioxidant Activity

Antioxidants are micronutrients that have gained importance in recent years due to their ability to neutralize free radicals or their actions. Free radicals have been implicated in the etiology of several major human ailments, including cancer, cardiovascular diseases, diabetes and arthritis. Due to the recent trends in nutrition towards development of healthy foods in the form of 'functional foods', one of the desirable properties in a dietary component is considered to be its antioxidant effect (Mishra *et al*., 2006).

Many therapeutic effects of the kokum fruit have been described in traditional medicine based on Ayurveda. These include its usefulness as an infusion, in skin ailments such as rashes caused by allergies, treatment of burns, scalds and chaffed skin, to relieve sunstroke, remedy for dysentery and mucous diarrhea, an appetizer and a good liver tonic, to improve appetite and to allay thirst, as a cardiotonic and for bleeding, piles, dysentery, tumours and heart diseases. One of the ingredients of kokum, hydroxycitric acid (HCA), has been patented for use as a hypocholesterolaemic agent. HCA is a potential anti-obesity agent. Hydroxycitric acid and its derivatives are useful in the treatment of obesity (Jena *et al*., 2002). It suppresses fatty acid synthesis, lipogenesis and food intake and induces

weight loss. Garcinol, a polyisoprenylated benzophenone purified from *G. indica* fruit rind, displays antioxidant, anti-cancer and anti-ulcer properties (Yamaguchi *et al*., 2000). Apart from HCA and garcinol, kokum contains other compounds with potential antioxidant properties. These include citric acid, malic acid, polyphenols, carbohydrates (Cadenas *et al.*, 1996), anthocyanin pigments and ascorbic acid (Peter *et al.*, 2001).

5.7 Anti-Ulcer Activity

Gastric and duodenal ulcers are illnesses that affect a considerable number of people in the world and they are induced by several factors like stress, smoking, alcohol consumption, nutritional deficiencies and ingestion of non steroidal-anti-inflammatory drugs (NSAIDs) e.g. In domethacin, has side effects such as gastrointestinal irritation, erosion, bleeding, ulceration and perforation (Basil and Howard, 1995; Loguercio *et al*., 1993; Naito *et al*., 1998; Nash *et al*., 1994; Sagar and Ahamed, 1999; Suleyman *et al*., 2002). Although a number of antiulcer drugs such as H_2 receptor antagonists, proton pump inhibitors and cytoprotectants are available for ulceration all these drugs have various undesirable effects such as arrhythmias, impotence and hematopoietic changes and limitations (Ariyoshi *et al.*, 1986; Del *et al.*, 1985; Satoh *et al*,, 1988).

The fruits of *Garcinia indica* have been suggested in the Indian system of medicine for a number of diseases. These include its usefulness as an infusion, in skin rashes caused by allergies, treatment of burns, to relieve sunstroke, remedy for dysentery and mucous diarrhea, an appetizer and antiulcer, liver tonic, to allay thirst and as a cardiotonic (Deore *et al*., 2011). The outer rind of the fruits of *Garcinia indica* has been shown to be antioxidant activity (Devasagayam *et al.*, 2006; Khare 2007; Kirtikar and Basu, 1991; Sheth *et al*., 2006). Garcinol a polyisoprenylated benzophenones, has antioxidative, chelating, free radical scavenging, antiglycation, anticancer, anti-inflammatory and antiulcer activities (Lin and Liao, 2005; Ho *et al*., 2002; Yamaguchi *et al*., 2000). One of the ingredients of kokum, hydroxycitric acid (HCA), has been patented for use as a hypocholesterolaemic agent (Heymsfield *et al*., 1998; Mattes and Bormann, 2000; Sakariah *et al*., 2002). Kokum contains other compounds with potential antioxidant properties include citric acid, malic acid, polyphenols, carbohydrates, anthocyanin flavonoids and ascorbic acid (Cadenas and Packer, 1996; Peter, 2001; Einbond *et al*., 2004; Rastogi and Nayak, 2010; Yoshikawa, 2000).

5.8 Anti-Hyaluronidase, Anti-Elastase Activity

During ageing, elasticity of the skin decreases due to enzyme elastase leads to sagging and at the same time hyaluronic acid in the skin also diminishes and skin becomes dry and wrinkled. Hence, there is need to conserve matrix metallo proteins by inhibiting the activity of these matrix metallo proteinases. Certain plant extracts are reported to be good antioxidants. Garcinol and cambogiol present in the fruit rinds of *Garcinia indica* were reported to be good antioxidants due to presence of phenolic group. Along with this various preparations of *G. indica* play a role in prolonging ageing, we fractionated crude Methanolic Extract (ME) into Ethyl Acetate and Water Fraction (WF) and those fractions were screened for anti-hyaluronidase and anti-elastase activity (Sahasrabudhe and Deodhar, 2010).

During ageing, elasticity of the skin is decreased due to enzyme elastase which leads to sagging. At the same time, the amount of hyaluronic acid in the skin also diminishes and skin becomes dry and wrinkled. In the connective tissue fibroblasts are the cells which synthesize collagen and other important matrix metallo proteins. In young and healthy skin, the balance between synthesis and degradation of these proteins is maintained (Aslam *et al*., 2005). But this intricate balance gets disturbed as we age. For maintaining youthful skin, when production of metallo proteins is not enough, the best way is to conserve them is by inhibition of matrix metallo proteinases (MMPase) (Aslam *et al.*, 2005). Like hyaluronidase, elastase too contributes significantly in other activities. Human neutrophil elastase (HNE) has broad substrate specificity capable of not only enzymatic cleavage, of elastin but also other ECM proteins such as collagen, hyaluronan, laminin etc. Under normal physiological conditions, endogenous inhibitors protect healthy tissue from damage but when impaired balance get disturbed, it leads to variety of diseases such as lung disorders, cardiovascular disorders, arthrosclerosis and cancer etc (Kobayashi *et al.*, 2004).

The kokum is anthelminthic and cardiotonic and used in the treatment of piles, dysentery and tumors etc. Fruit rinds of *G. indica* contain about 2.4% anthocyanins. Out of them two were identified as cyanindin 3-glucoside and cyanindin 3-sambuboside (Krishnamurthy *et al*., 1981). Garcinol, yellow coloured pigment and cambogiol present in the fruit rinds showed good antioxidant activity due to the presence of phenolic group (Krishnamurthy *et al*, 1982) and earlier methanolic extracts of fruit rinds of *G. indica* showed good hyaluronidase and elastase inhibition (Sambhus, 2006). But no extensive work has done yet on hyaluronidase and elastase inhibition activities of different fractions of *G. indica.*

6. Application in Food and Allied

Industries

The value addition to the kokum fruits through processing assumes an important activity because raw/ripe fruits need to be processed before their consumption. In this context, kokum crop has attained the status of economical importance. The resultant of this activity creates employment opportunities at rural area and on the other hand develops suitable products for earning the foreign exchange through the export of kokum derivatives. The medicinal and antioxidant properties of kokum butter and flowers also priced to be very high and much useful in cosmetic application. As a result of this many pharmaceutical industries have shown keen interest in kokum and its derivatives. With this situation, India is the only country enjoying the monopoly with respect to kokum production in the world. The different products developed by processing of kokum are given below:

6.1 Kokum Syrup

Kokum fruits have certain medicinal properties. Juice extracted from this fruit is sweet and sour and thus liked by many. A glass of cold kokum syrup is refreshing and it also improves the digestive system. The product is popular in the state since long and now it is sold in nearby states as well. Since it is a natural fruit extract, it is preferred by many people. In traditional method kokum rind is separated by removing fruit pulp and seeds. Pulp and seeds are not used for squash production. Equal quantity of sugar mixed with kokum rind in a wide mouth vessel. This mixture of sugar and kokum kept open for sun rays up to eight to ten days. In this process juice comes out from kokum rind and already sugar is mixed with juice. If balance sugar accumulation is found at the bottom of the vessel no additional sugar is to be added. Filtering juice and rind with help of a cotton cloth. This clean Kokum Syrup is to be filled in clean glass bottle. For long term preservation these filled bottles again kept sun light for another ten days without capping. You have to cap the bottles at end of process (Patil *et al*., 2008)

6.2 Kokum Agal (Kokum Juice Concentrate)

Kokum fruits are selected randomly and washed with clean water. The fruits are crushed and seed and pulp from the fruit is removed manually. Salt is added in the hollow space of the rind and the mixture of kokum rind and salt is kept in available plastic drum or container and is covered with cloth. Juice form the container is collected and filled in glass bottles of 750 ml to 1000 ml size. The colour and quality of *agal* varies from location to location as proportion of slat used ranges from 10 to 20 per cent and it depends on the quality of fruits used and also on the person making it. Colour of the *agal* obtained is dark brown to blackish in colour.

6.3 Kokum *Sarbat*

The kokum *sarbat* is prepared by using the kokum syrup. The water is added into kokum syrup at 1:5 proportions and some salt and cumin powder is added to make the kokum sarbat.

6.4 Kokum *Solkdhi*

Generally *agal* is ready to use for preparation of *Solkadhi* when mixed with coconut milk. In this process the grinded green chilli, cumin paste, salt and jaggery depending upon how much sweetness we require are used for the preparation of kokum *solkadhi*.

6.5 Kokum *Amsul* (Dried Salted Rind)

The amsul is made from the peel of the fruits 'Kokum'. Amsul is a fine ingredient in veg-dishes and curries for the sour taste also it is useful for skin boils and irritation, if rubbed against the irritated parts. In traditional process, fresh kokum fruit washed properly and cut into two halves to separate the seed, pulp and the rind. The seed and the pulp are mixed with around 10 percent salt. The salt solution leached out from this mixture is used for the dipping of the separated rind. The rind then placed for sun drying during the daytime. The next day the dried sample is again dipped in the salt solution, which was leached on the second day from the salt seed mixture. Then the rind is again placed for the drying. The process of dipping and drying is repeated for 4 to 5 times to get the amsul.

6.7 Kokum Butter

The fat is used mainly for edible purposes obtained by primitive methods is just off white, and free fatty acid levels are low indicating absence of any powerful lipolytic activity. The fat can be easily refined in the usual way, and bleached to a near white colour in the conventional manner. Prompted by enquiries from foreign buyers and realising its potential as a high value fat for export, oil millers have in the past decade, organised the collection of kernels and the fat is now recovered in a small way (about 200 tonnes or so) for export. The residual oil in the extracted cake is also recovered by solvent extraction. Despite slight increase in FFA, this quality also finds a ready export market.

6.8 Kokum Beverages

Kokum extract is having approximately 4% sugar which can be fermented to produce high quality red wine. The extract from kokum can be converted to many health beverages and squash like products with sugar addition.

6.9 Cosmetic Applications of Kokum

Kokum has emollient property, it is used as a natural moisturizer to keep skin supple and silky smooth. Effective for treatment for severely dry skin, ulceration and fissures of lips, hands, feet, etc. Kokum butter is also nutritive and astringent. Uses include candle, soap, ointments and other pharmaceutical purposes.

7. Conclusions

The consumption of kokum by various processed form has increased tremendously due to its reported health benefits. The kokum and its derivates, such as dried rind powder, sarbat, solkadhi, and butter from seed are rich sources of several high-value compounds with potential beneficial physiological activities. The rich bioactive profile of kokum makes it a highly nutritious and desirable fruit crop. The research evidences that kokum and its extract may protect against and even improve several diseases including cholesterol, antioxidant, digestion tonic, paralysis; it may even help to prevent and arrest the development of certain cancers, in addition to protecting the health of mouth and skin. The kokum rind has also medicinal value and used in the treatment of piles, dysentery, tumours and heart complaints. Apart from the medicinal values kokum has the lot of the processing value. The different value added products are prepared from the processing of kokum e.g. kokum sarbat, kokum solkadhi, agal, amsul, butter etc.

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