Owing to obesity as a complex disorder of appetite regulation and energy metabolism controlled by specific biological factors. Obesity prevention failure, medicinal treatment of obesity may become an obligation and it is more fruitful when we can acquire the medicinal treatment directly from nature, which is more preferred and healthy rather than going for chemical and surgical treatment. Alternatively, inhibition of carbohydrate to fatty acid conversion reaction can lead to obesity control. This can be done by assay of Hydroxycitric acid ([(-)-HCA]), which inhibits the formation of ATP-citrate lyase, responsible for lipogenesis. HCA is a derivative of citric acid and found in Garcinia fruit as the principal acid. Many in vitro and in vivo studies have demonstrated that [(-)-HCA suppresses the de novo fatty acid synthesis and lipogenesis. However, results from clinical studies showed both negative and positive anti-obesity effects of [(-)-HCA. In this review paper an attempt has been made to explore and give an insight of [(-)-HCA taking account of the literature coverage on specified topics: Its discovery, properties, extraction and estimation and its significance in role in anti-obesity activity.

**Keywords:** Hydroxycitric acid, HCA, Garcinia, Anti-obesity, ATP-citrate lyase, Lipogenesis.

**INTRODUCTION**

Obesity is becoming a catastrophic physiological challenge for the present generation human race and in the near future, it will overcome the consequences of under nutrition, which is a significant advantage to the poor and ill health conditions [1]. In fact, obesity is a complex disorder of appetite regulation and energy metabolism controlled by specific biological factors. Hypertension, metabolic syndrome, diabetes, dyslipidemia, myocardial infarction, stroke and its related complications are normally associated with obesity. Whenever prevention fails, medicinal treatment of obesity may become an obligation and it is more fruitful when we can acquire the medicinal treatment directly from nature, which is more preferred and healthy rather than going for chemical and surgical treatment. Weight loss can be achieved with treatment. But after weight reduction, its long term maintenance is very difficult. Thus, the treatment often remains unsuccessful [2-4]. Inhibition of carbohydrate to fatty acid conversion reaction can lead to obesity control. This can be done by assay of Hydroxycitric acid ([(-)-HCA], a derivative of citric acid found in Garcinia and in some varieties of tropical plants and has been established to be a potential metabolic regulator of anti-obesity activity and inhibitor of lipogenesis. The presence of [(-)-HCA as the principal acid has added importance to the genus Garcinia. The genus Garcinia Linn., belonging to the Kingdom Plantae, Order Malpighiales, family Clusiaceae includes about 200 species found worldwide. Garcinia is commonly used; a large genus of evergreen trees or shrubs, distributed in tropical Asia, Africa, and Polynesia of which about 30 species are found in India. Garcinia species are found in forest lands, riversides and wastelands. These plants prefer evergreen forest, but sometimes they also thrive in areas with relatively low rainfall. It is also cultivated on a small scale. It does not require irrigation, spraying of pesticides or fertilizers [5-7].

**HCA Unearthing**

The fruits of Garcinia species are too acidic and sour in taste. The dried rinds of the fruit of Garcinia species are extensively used for cooking purposes. The organic acids present in the fruit are responsible for the bacteriostatic effect of the pickling medium. The fruits are also anthelmintic and useful in piles, dysentery, bilious affections, tumor, pains and heart complaints. Sun dried rinds are anthelmintic and useful in piles, dysentery, bilious affections, tumor, pains and heart complaints. Sun dried rinds of the fruit of Garcinia are also cultivated on a small scale. It does not require irrigation, spraying of pesticides or fertilizers [5-7].

**Properties**

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**Table 1: Physical properties of HCA and lactone from Garcinia**

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**The chemistry and properties of [(-)-HCA and its lactone**

HCA [C₆H₆O₇] has two asymmetric centers, thereby two pairs of diastereoisomers or four different isomers (I, II, III and IV) are possible [Figure: 1] [1.2]. Being a γ-hydroxy acid, it cyclizes readily to the corresponding lactone (C₆H₆O₇). The molar mass of HCA and HCA lactone are 208.12 and 190.106 g mol⁻¹ respectively.

The absolute configurations of the HCA lactones of *G. cambogia* and *hibiscus* were determined to be (2S, 3R)- and (2S, 3S)-2-hydroxycitric acid-2, 5-lactone, respectively [fig. 2]. The structure and absolute configuration of the calcium hydroxycitrate and (-)-HCA lactone was done by X-ray crystallography [13, 14]. Stallings et al. have studied the crystal structures of the ethylenediamine salts of diastereoisomeric hydroxycitirates [15].

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A comparative physical properties of (-)-HCA and lactones from Garcinia are presented in Table 1. The IR spectra of the ethyl ester showed ester and hydroxyl groups at 5.41-5.76 and 2.74-2.79 \( \mu \)m, respectively [10]. The structure of the (-)-HCA lactone was further established by IR and 1H NMR spectroscopy. The (-)-HCA lactone displayed strong IR bands at 3200, 1760, and 1680 cm\(^{-1}\). 1H NMR spectra of the (-)-HCA lactone showed two protons at the \( \gamma \)-carbon, which give an AB quartet at \( \delta \) 2.53 and 2.74 with \( J = 17.1 \) Hz, and one proton at the \( \alpha \)-carbon showing a singlet at \( \delta \) 5.15 [16].

Importance

HCA is purported to be one of the active components in various over-the-counter weight-loss formulations and appetite-suppressor products. (-)-HCA being a potent inhibitor of ATP: Citrate lyase, which catalyzes the extramitochondrial cleavage of citrate to oxaloacetate and acetyl-CoA, limits the availability of acetyl-CoA units required for fatty acid synthesis and lipogenesis [17-23]. Many studies demonstrated both \textit{in vitro} and \textit{in vivo} that (-)-HCA suppresses the de novo fatty acid synthesis and lipogenesis. Extensive works have been carried out on plant systematics, distribution as well as on traditional medicinal uses and chemical constituent of Garcinia species in the last few decades. Some of these works are reviewed as below:

Extraction methods and estimation of HCA

Lewis \textit{et al.} isolated the principal acid in the fruit rinds of \textit{G. cambogia} and identified it as (-)-HCA on the basis of chemical and spectroscopic studies [10]. Boll \textit{et al.} have reported that, the absolute configuration is determined from Hudson's lactone rule, optical rotatory dispersion curves, circular dichromism curves, and calculation of partial molar rotations [11]. Glusker \textit{et al.} have reported the structure and absolute configuration of the calcium hydroxycitrate and (-)-HCA lactone by X-ray crystallography [13, 14]. Stallings \textit{et al.} have reported the crystal structures of ethylidenamine salts of diastereomeric hydroxycitrates [15].

Upon concentration and evaporation free (-)-HCA gives (-)-HCA lactone. Acid-Base titration method gives total acidity of the extract, but concentrations of (-)-HCA and (-)-HCA lactone cannot be estimated separately. Gas chromatography (GC) estimation of (-)-HCA content of \textit{G. cambogia} fruit was developed by Lowenstein \textit{et al.}, which involves conversion of acid to volatile silyl derivative. Silylation requires completely dried samples, but free (-)-HCA readily cyclizes to give its corresponding lactone upon drying. Thus the free (-)-HCA cannot be estimated [Figure: 3] [24]. Moffett \textit{et al.} have developed a process for the aqueous extraction of (-)-HCA from \textit{Garcinia} rinds. The extract was loaded onto an anion exchange column for adsorption of (-)-HCA, and it was eluted with sodium/potassium hydroxide for the release of (-)-HCA. The extract was passed through a cation exchange column to yield a free acid and have reported the preparation of (-)-HCA concentrate from \textit{Garcinia} rinds with 23-54% (-)-HCA and 6-20% lactone [25, 26]. Jayaprakasha \textit{et al.} have reported that (-)-HCA and its lactone can be quantified separately from the dilute extracts, without concentration and drying [27-29]. Jena \textit{et al.} have reported on determination of organic acids in fresh leaves, fruits, and dried rinds of \textit{Garcinia cowa} by high-performance liquid chromatography. The major organic acid was found to be (-)-HCA present in leaves, fruits, and rinds to the...
Gogoi et al.


extent of 1.7, 2.3, and 12.7%, respectively. (−)-HCA lactone, and osalic and citric acids are present in minor quantities [30]. In 2003, an improved liquid chromatography (LC) method for determination of organic acids in leaves, pulp, fruits, and rinds of *Garcinia* was developed. The commonly used LC method for analysis of organic acids in *Garcinia* extracts uses the direct application of the extracts in the column, which gradually reduces efficiency of the column and shortens its life. In the improved method, the interfering substances such as pigments and xanthones were effectively removed by passing the aqueous extract through an ODS cartridge [31].

In a study on the presence of (−)-HCA and its estimation using HPLC and acid-base titration method in two months old fruits and the leaves of four species of *Garcinia* namely *G. gummi-gutta*, *G. indica*, *G. tinteroria* and *G. cowa*. Among the four species studied *G. tinteroria* had very low (−)-HCA in leaves and fruits. It was revealed that fruit rinds contained more amount of (−)-HCA in comparison with leaves. The magnitude of (−)-HCA in leaves and fruit rinds followed in the order of *G. gummi-gutta* > *G. indica* > *G. cowa* > *G. tinteroria* irrespective of the methods studied. The titration method gave more amount of (−)-HCA than HPLC. This is due to the estimation of total acidity (all organic acids) in titration method, whereas in HPLC only (−)-HCA was determined [32].

Muessrettharam et al. have developed Capillary zone electrophoresis (CZE) method for quantitative determination of (−)-HCA and (−)-HCA lactone in herbal products of *Garcinia atroviridis* Griff. Advantages of the developed CZE method over previous HPLC methods include simple sample preparation, faster analysis time in 5 minutes and better resolution of analytes [33]. The microwave power has been used successfully to extract (−)-HCA from the dried rinds of *G. oblongifolia*. The method gave effective result with reduced time for extraction at 25 min and higher extraction yields of total amount of organic acids as compared to Soxhlet extraction and pressure cooker distillation [34].

Naveen et al. reported on chemical constituents of the fruit rind and seed of *G. gummi-gutta*, analyzed by Atomic Absorption Spectroscopy and did proximate analyses and physicochemical analyses of the extracts of *G. gummi-gutta* [35-37]. Kumar et al. developed a rapid, sensitive and simple reverse-phase HPLC-PDA method with solvent system consisting of a mixture of acetonitrile-water (90:10,v/v) and methanol-acetic acid (99.5:0.5,v/v) as a mobile phase followed by photo diode array (PDA) detection of peaks at 220 and 276 nm with run time less than 25 minute for the simultaneous identification and quantification of HCA lactone (HCAL), isoxanthochymol (Isoxan) and xanthochymol (Xan) in different extracts of *G. indica* [38]. Upadhyay et al. developed a simple HPLC sensitive isotropic method for the detection and quantification of HCA in *G. cambogia*. Content of HCA present in plant extract has been found to be in the range of 50% using reversed-phase HPLC with ultraviolet detection. The methanolic extract of *G. cambogia* analyzed by this method found to contain 50-55% HCA [39]. Recently Gogoi et al. have reported on the development of a cost effective and improved HPLC analysis method using water as mobile phase for estimation of HCA in the fruits of *G. lanceaefolia* [40].

**HCA stability and preparation of derivatives**

Genus *Garcinia* contains 20-30% of (−)-HCA as its principal acid. But, (−)-HCA is susceptible to lactonization upon evaporation and concentration. Therefore the preparation of stable derivative was a necessity. Martius et al. have succeeded in synthesizing the four possible stereoisomers of hydroxycitrate. Among these four possible stereoisomers, (−)-HCA is found in *Garcinia* and (+)-all-HCA in *Hibiscus* species [41,10,12]. Salt of potassium hydroxycitrate was prepared by extracting (−)-HCA from the fruits of *Garcinia* and the extract was treated with potassium hydroxide to yield potassium hydroxycitrate precipitate [42]. The soluble metal double salt of (−)-HCA was prepared by treating aqueous extract of (−)-HCA with different metal hydroxides and metal chlorides [43]. Sodium hydroxycitrate was prepared by treating the aqueous extract of (−)-HCA with aqueous sodium hydroxide at 80 °C [44].

**Scrutinizing the Role of (−)-HCA in anti-obesity activities**

Flourished nutraceutical industries and increasing interest in scientific credibility gave a thrust to many companies and scientist. The evaluation of the potential toxicity of weight control supplement is of the utmost importance as it requires long term continuous consumption in order to maintain its effects. With the dilemmatic reports demonstrating the efficacy of *Garcinia* extract or HCA without any toxicity and as an active ingredient in some products, showing potential toxicity for that, to draw a fine line was of a necessity as of the topic concern. Weight gain occurs when the limited capacity for storing glycogen in the liver and muscles is attained, and beyond this point excess glucose is converted into fat and stored in fat cells throughout the body. Watson et al. reported inhibition of ATP: citrate Oxalacetic lyase by (−)-HCA with purified enzyme from rat liver. ATP: citrate lyase (ATP: citrate Oxalacetic lyase, EC 4.1.3.8) a citrate cleavage enzyme found abundantly in animal tissues and has been mentioned to play a physiological role in lipogenesis from carbohydrate and gluconeogenesis [45]. The synthesis of fatty acid takes place in the cytosol and acetyl-CoA in mitochondria.

The oxidation of pyruvate to acetyl-CoA in mitochondria leads to conversion of carbohydrate into fat. The primary source of carbon atoms for fatty acid synthesis is the acetyl-CoA. From the mitochondria acetyl group of acetyl-CoA are transferred to the cytosol for fatty acid biosynthesis. To transfer acetyl-CoA from mitochondria to cytosol requires conversion of acetyl-CoA to citrate. In the mitochondrial matrix condensation of acetyl-CoA with oxaloacetate produces citrate, which can bypass the obstacle. After transport of citrate to cytosol by the tricarboxylate transport system, acetyl-CoA is regenerated from citrate by ATP: citrate lyase in the following catalytic reaction:

\[
\text{Citrate + CoA + ATP} \rightarrow \text{Oxalacetic + Acetyl − CoA + ADP + Phosphate}
\]
Cheema-Dhadhi et al. reported inhibition of citrate cleavage enzyme by both free (-)-HCA and (-)-HCA lactone [54]. Szutowicz et al. reported (-)-HCA to be a potent inhibitor of citrate cleavage enzyme in rat brain synaptosomes [55]. In similar studies, it was found that out of the four isomers of HCA only (-)-HCA was the potential inhibitor of ATP [15,21]. Yamada et al. have reported that, (2S, 3R)-HCA, inhibits pancreatic α-amylase and intestinal α-glucosidase, leading to a reduction in carbohydrate metabolism in vitro [56]. Lowenstein et al. incorporated 3H from 3H2O to measure the rate of fatty acid synthesis in rat liver and found that (-)-HCA strongly inhibited fatty acid synthesis by Rat liver in vivo [17]. Sullivan et al. have reported that, the in vivo rate of lipogenesis was markedly decreased from [14C] alanine following the administration of (-)-HCA either intraperitoneally or intravenously. Fatty acid and cholesterol synthases were significantly inhibited by the oral administration of (-)-HCA only when the compound was given before the feeding period. In 1974, they have reported that oral administration of (-)-HCA to rats significantly depressed the in vivo lipogenic rates in a dose dependent manner in the liver, adipose tissue, and small intestine and caused significant reductions in body-weight gain, food consumption, and total body lipid [18-20, 23].

Pharmacological approaches for treating the obese patient, (-)-HCA has been used as a potentially safe and effective pharmacological intervention for obesity for at least 30 years [57]. In isolated hepatocytes Beynen et al. observed inhibition of fatty acid synthesis by (-)-HCA, when fatty acid synthesis takes place from glucose [58]. Indicating that (-)-HCA acts as an inhibitor of lipogenesis when cytoplasmic acetyl-CoA is produced by citrate cleavage enzyme reaction. But (-)-HCA activated fatty acid synthesis when the source of acetyl-CoA is acetate [59-62]. Hood et al. have shown that (2S, 3R)-HCA reduced the synthesis of fatty acids from lactate and glucose in bovine adipose tissue and rat adipose tissue, respectively, and suggested that the conversion of lactate to fatty acids probably occurs by way of citrate. In the (-)-HCA treated rat liver cells, there was a decrease in the formation of phospholipids and triglycerides from lactate [63].

A significant reduction in food intake, decrease in the feed efficiency ratio, body-weight gain, epididymal fat, and serum triglyceride in the albino rats was observed by feeding lipogenic diets along with (-)-HCA. The reduction in appetite in (-)-HCA-fed rats were due to the specific effect of (-)-HCA ingestion. It was not due to alterations of taste of the fed diet as the control group fed with citrate taking consideration of the close structural relationship of (-)-HCA to citrate and it is reasonable that (-)-HCA does not affect the taste of the food [64]. Vicario et al. have also reported the inhibition of lipogenesis from lactate in rat brain by (-)-HCA, and the transfer of lactate carbons through the mitochondrial membrane is accompanied by the translocation of citrate [65]. Gouatelle et al. reported (-)-HCA exerts its anti-obesity effect by inhibiting ATP citrate lyase, consequently inhibiting the cleavage of citrate to oxaloacetate and acetyl-CoA, a key molecule, which plays a critical role in energy storage as fat. Here, instead of wasting energy to synthesize fat, the energy is diverted to the production of glycogen in the liver and muscles. This slows the production of fatty acids, cholesterol, and triglycerides with the net effect of reduced fat production and storage [66].

Several studies have found a positive effect of (-)-HCA administration alone or in combination with other ingredients on appetite, energy intake, body weight loss, fat oxidation or energy expenditure, but some studies did not. Heymsfield et al. performed a randomized, double blind, placebo controlled trial to prove the efficacy of (-)-HCA as a potential anti obesity agent. But their findings failed to detect either weight loss or fat mobilizing effects of (-)-HCA beyond those of placebo [67]. Kriketos et al. hypothesis study failed to demonstrate an effect of (-)-HCA on Respiratory Quotient (RQ) or Energy Expenditure (EE) in the fasted state either during rest or during moderately intense exercise on a cycle ergometer under laboratory conditions in male adults consuming a typical mixed diet. They did not detect an effect of (-)-HCA on circulating concentrations of blood substrates associated with fat oxidation and regulation of glucose metabolism. It is possible, however, that their (-)-HCA treatment was not sufficiently long or that the dose used was insufficient to inhibit the enzyme citrate lyase under the influence of a typical mixed diet [68]. Mattes et al. study did not support a satiety effect of HCA on weight loss through suppression of hunger. No effects of the HCA were observed on appetite variables. The active treatment group did not exhibit better dietary compliance or significant correlations between appetite variables and energy intake or weight change. The study concluded that the compound may be more useful for weight maintenance after an initial loss [69]. But Mahendran et al. have reported the modulating effect of G. gummi-gutta extract on the ethanol induced peroxidation and on lipids and lipoprotein composition in decamethanone administered rats [70].

As reported earlier, when dietary supplements contain high glucose, HCA significantly reduces body weight regain and was not diminished when the diet contained 24 % of the energy as fat. Leonardt et al. studied whether dietary supplementation of HCA reduces food intake and body weight regain in rats after 10–15% weight loss. In their study HCA reduced body weight regain after substantial body weight loss, and the effects are presumably linked to its inhibiting effect on lipogenesis, suggesting a very strong effect of HCA on food intake and increased energy expenditure [71].

Kovacs et al. hypothesized that HCA supplementation might affect appetite and Body Weight (BW) regulation by increasing fat oxidation and metabolic rate, reflected by an increase in EE and combination of HCA and Medium-Chain Triglycerides (MCT) may have a stronger effect on fatty acid oxidation and consequently on satiety compared to HCA alone. But the results did not support the
hypothosis [72]. Westerterp-Plantenga et al. did assessment of the effects of daily administration of HCA on Energy Intake (EI) and satiety in overweight men and women for a period of 2 weeks and found that HCA might not primarily be a weight loss agent, as indicated by the minor changes observed in body weight, but might be effective in preventing weight regain and time dependent effect of HCA-SX was studied by Shara et al. in Sprague-Dawley rats over a period of 90 days. The study indicated that HCA-SX is safe and efficacious in weight management under the conditions employed in the study but did not cause any changes in hepatic and testicular lipid peroxidation, DNA fragmentation, or histopathological changes [74].

Hayamizu et al. found that extracts of G. cambogia can efficiently improve glucose metabolism and display leptin-like activity. The precise mechanism for suppression of leptin and insulin production was not clear. Their findings indicated that upregulation of leptin production is accompanied by enhanced insulin production. They concluded that further studies are required to clarify if the leptin-like activity and its mechanism are effectively due only to the HCA presence or the remaining 40% components in the extract have an important role [75]. In order to study the safety and the influence of Garcinia extract on androgen in humans, Hayamizu et al. administered Garcinia extract to human subjects at a dose of 3,000 mg/day for 30 days to evaluate the influence of surplus doses on Blood and subjective symptoms and influence of surplus doses on sexual testosterone level in healthy men. Their study confirmed the safety of Garcinia by high dose administration study in healthy man [76]. In their subsequent studies on the effects of 12 weeks of G. cambogia extract administration on visceral fat accumulation and on body indices, they reported that G. cambogia may be useful for the prevention and reduction of the accumulation of visceral fat and there was no rebound effect observed when treated with placebo at the end of the treatment period and did not affect the markers of reproductive toxicity such as serum testosterone, estrone and estradiol levels. The result of serum testosterone levels of the study was supported by their previous work. Additional human studies are required to confirm these findings [77, 79].

Preuss et al. have reported that optimal doses (4667 mg) of (-)-HCA-SX alone and in combination with nicin-bound chromium (NBC) and a standardized Gymnema sylvestre extract (GSE) given 30–60 min. before meals, is highly bioavailable, efficacious and safe as weight-management supplements and has been shown to reduce appetite, inhibit fat synthesis and decrease body weight without stimulating the central nervous system. NBC has demonstrated its ability to maintain healthy insulin levels, while GSE has been shown to regulate weight loss and blood sugar levels [79, 90]. Soni et al. Systematically reviewed on the available safety and toxicity literature on HCA to determine its safety in-use. On the basis of scientific procedures, which included human, animal, analytical, and other scientific studies, and history of exposure and use; they concluded that, the consumption of HCA or HCA-SX at a dose level of 2800 or 4667 mg/day, respectively, is considered safe [81]. In a study by Saito et al. in Zucker rats, being genetically predisposed to obesity was treated with (-)-HCA showed that high doses (778 mg HCA/kg BW/d and higher) led to significant suppression of epididymal fat accumulation, but also had high testicular toxicity. But it was not observed at 389 mg HCA/kg BW/d or 51 mmol HCA/kg diet and thus this level was deemed to be the No Observed Adverse Effect Level (NOAEL) [82]. This study has been criticized by Burdock et al. (2005) for possible contamination of the (-)-HCA used and various design flaws [83].

Downs et al. have reported that, the structural characteristics of a novel Ca2+ and K+ bound (-)-HCA salt (HCA-SX or Super CitriMax) make it completely water soluble as well as bioavailable. Both Ca and K act as buffers in pH homeostasis. HCA-SX has been shown to increase serotonin availability, reduce appetite, increase fat oxidation, improve blood lipid levels, reduce body weight, and modulates a number of obesity regulatory genes without affecting the mitochondrial and nuclear proteins required for normal biochemical and physiological functions [84]. Deshmukh et al. have reported on the safety of HCA-SX for long-term human consumption, which may eradicate obesity and related disorders including cardiovascular dysfunctions, diabetes and arthritis. In their developmental two generation reproductive toxicity study, HCA-SX was not found to be teratogenic in the Sprague-Dawley rat and did not cause maternal toxicity, adverse effects on the gravid uterus, soft tissue abnormalities, skeletal abnormalities or external developmental two generation reproductive toxicity. In their two reviews, established a comprehensive safety profile of HCA as a dietary supplement for treating obesity taking account of cytotoxicity, genotoxicity, acute toxicity, subchronic safety, two-generation reproductive and teratogenic studies. The clinical studies verified the safety of HCA and HCA-SX for Human consumption and reported that those products which possess adverse effects are either polyherbal or multi-component in nature and concluded that the comprehensive scientific evidence had shown NOAEL at levels up to 2800 mg/day, suggesting its safety for use [94, 95].

Supplementation of HCA can significantly lower visceral fat accumulation and adipocytoc size via inhibition of fatty acid synthase
activity and its mRNA expression in visceral adipose tissue, along with enhanced enzyme activity and gene expression involved in adipose fatty acid β-oxidation. HCA supplementation can protect against HFD-induced obesity by modulating the adipose fatty acid synthesis and β-oxidation, but induces hepatic fibrosis, inflammation and oxidative stress [96]. HCA has been found to be protective against the liver toxicity associated with ethanol and dexamethasone administration, and to maintain serum aspartate aminotransferase, alanine aminotransferase and alkaline phosphatase at near normal levels. In both animal and clinical literature, elevated intakes of HCA per se have not led to signs of inflammation or hepatotoxicity. The compound has been found to reduce markers of inflammation in the brain, intestines, kidney and serum [97].

Oral sustained release matrix tablet of anti-obesity drug from G. cambogia has been formulated in an attempt to design a dosage form that manifests desirable release profile. An antiobesity liquid formulation of G. cambogia extract, L. Carnitine and Chromium Picolinate was developed by Patel et al., which gives good microbial stability and pharmacological activity. The formulation was prepared by using coconut water as base and flavour in different combinations. In Ayurveda, it is said that sour flavours such as those from Garcinia activate digestion. Garcinia is considered to make foods more filling and satisfying and has been used routinely for many centuries with no toxicity [98, 99].

CONCLUSION

Present day generation is threatened with increased body mass index (BMI: defined as the mass in kilograms divided by the square of the height in meters) or we can say obesity. Though losing weight has become a modern day obsession, in the developed world, various factors do contribute to the increased number of overweight and obese individuals. The treatment of obesity should be done as a physiological disorder, not as a physical disorder [2]. Whenever prevention fails, medicinal treatment of obesity may become an obligation and it is more fruitful when we can acquire the medicinal treatment directly from nature, which is more preferred and healthy rather than going for chemical and surgical treatment. The preliminary research based on laboratory and animal experiments suggests that (−)-HCA may be a useful weight loss aid. (−)-HCA has been demonstrated in the laboratory to reduce the conversion of carbohydrates into stored fat by inhibiting certain enzyme processes. Animal research also indicated that (−)-HCA suppresses appetite and food intake to induce weight loss.

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CONFLICT OF INTERESTS

The authors hereby declares no competing financial conflict of interest.

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