Salacia as an ayurvedic medicine with multiple targets in diabetes and obesity

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Abstract
The genus, Salacia belongs to the family, Celastraceae and is distributed across the world. Roots and stems of Salacia are used mainly as antidiabetic agents in traditional system of medicine such as Ayurveda and Unani. The roots are either chewed directly or taken in dried powdered form or as decoction. Apart from antidiabetic activity, several species of the genus Salacia are known to possess anti-inflammatory, antilipidemic, antiperoxidative, antimicrobial, antileukemic, astringent and antimarial activities. Salacia is being used in several herbal formulations for treating diabetes and obesity. It is also used to treat skin diseases such as leprosy, ulcers, hyperhydrosis, hepatopathy and dyspepsia. The present study is focussed on reviewing the progress made on the active principles of Salacia species, mainly S. oblonga Wall., S. reticulata Wght., S. chinensis Linn. and S. macrosperma Wght. and previeing their potential as an effective antidiabetic medicine.

Key words: Salacia, antidiabetic activity, α-glucosidase inhibitors, postprandial hyperglycemia, postprandial hyperlipidaemia

1. Introduction
The genus, Salacia belongs to the family, Celastraceae/ Hippocrateaceae. It is a scandent or sarmentosa shrub or small tree, and has 407 different species. The leaves are usually opposite, petioled and coriaceous. Flowers are small, axillary, extra-axillary, facicled or cymose, and seldom solitary. Fruit is baccate, edible, 1-3 celled with 1-4 seeded each and pulp is mucilaginous. Seeds are large, angular, with thick testa, cotyledons are thick and usually conflurminuate (Kirtikar and Basu, 1987; Nandkarni, 1993). Salacia oblonga Wall. is commonly known as Saptarangi, Chundan in Tamil, Ponkoranti in Malayalam, Vairi in Sanskrit and Anukuducettu in Telugu. S. reticulata Wght. is known as Himbutu in Sinhalese, Kothala himbutu in Hindi, Saptakrachra in Sanskrit and Ekanayakam in Kannada. S. chinensis Linn. is commonly known as Chinese Salacia, Chourondi in Malayalam, Chuntan, Karukkuvai in Tamil. Karukkuva in Tamil, Ponkoranti in Malayalam, Vairi in Sanskrit and Anukuducettu in Telugu. S. oblonga Wall. is commonly known as Himbutu in Sinhalese, Kothala himbutu in Hindi, Saptakrachra in Sanskrit and Ekanayakam in Kannada. S. chinensis Linn. is commonly known as Chinese Salacia, Chourondi in Malayalam, Chuntan, Karukkuvai in Tamil. It is a scandent or sarmentosa shrub or small tree, and has 407 different species. The leaves are usually opposite, petioled and coriaceous. Flowers are small, axillary, extra-axillary, facicled or cymose, and seldom solitary. Fruit is baccate, edible, 1-3 celled with 1-4 seeded each and pulp is mucilaginous. Seeds are large, angular, with thick testa, cotyledons are thick and usually conflurminuate (Kirtikar and Basu, 1987; Nandkarni, 1993). Salacia oblonga Wall. is commonly known as Saptarangi, Chundan in Tamil, Ponkoranti in Malayalam, Vairi in Sanskrit and Anukuducettu in Telugu. S. reticulata Wght. is known as Himbutu in Sinhalese, Kothala himbutu in Hindi, Saptakrachra in Sanskrit and Ekanayakam in Kannada. S. chinensis Linn. is commonly known as Chinese Salacia, Chourondi in Malayalam, Chuntan, Karukkuvai in Tamil. Karukkuva in Tamil, Ponkoranti in Malayalam, Vairi in Sanskrit and Anukuducettu in Telugu.

2. Distribution of Salacia
These species are widely distributed in South-West India, Peninsular region of India, Sri Lanka, Vietnam, China, Indonesia, Brazil, South Africa, Malaysia, Thailand and Philippines (Saldanha, 1998; Anshul et al., 2013). In India, it is well distributed in Karnataka (Western Ghats), Kerala (coastal forests of Kollam and Idukki districts) and Southern parts of Odisha (Orissa). S. oblonga growing in its natural habitat and images of other Salacia species : S. reticulata, S. chinensis Linn, S. macrosperma Wght. are shown in Figure 1.

3. Salacia and its uses in traditional system of medicine
Different species of Salacia have medicinal principles with a high pharmacological significance. In traditional system of medicine, different species of the genus, Salacia are being used as acrid, bitter, termogenic, urinary and as liver tonic. The aerial parts and roots of Salacia are extensively used in Ayurvedic system of medicine, traditional Indian medicine and Unani for treating diabetes, gonorrhoea, rheumatism, itching, asthma, ear diseases, leukaemia and inflammations (Kirtikar and Basu, 1987; Matsuda et al., 1999; Setzer et al., 2001). The multifarious uses of Salacia species are given in the Table 1.

4. Phytochemical constituents of Salacia
Phytochemical screening of Salacia species revealed the presence of anthocyanidines, catechins, sterols, phenolic acids, quinones, friedo-oleanones, quinonemethide, and related triterpenoids (celastroloids), alkaloids, flavonoids and tannins in the methanol and water extracts of S. oblonga (Basu et al., 2013). Durate et al. (2010) identified 20 different compounds, viz. triterpenes (3β-stearyloxy-oleanane, 3β-stearyloxy-ursane, seco-friedelane), xanthone, polyols, carboxylic acid, aromatic ester in S. elliptica.
Similarly, Wang et al. (2011) have reported the presence of triterpenes, including quinonemethides, friedelanes, oleananes and ursanestriterpenes, phenolics, polyol and chromanone in S. amplifolia. The presence of several compounds as revealed by the phytochemical analysis led to the isolation of several secondary plant products by different groups. The major bioactive constituents are xanthine, glucoside, mangiferin, and two components with unique, thiosugar structure sulfonium sulphate, viz. salacinol and kotalanol. Different compounds isolated from different species of Salacia having antidiabetic activity are shown in Table 2. Matsuda et al. (1999) isolated α-glucosidase inhibitors like salacinol, kotalanol from the water soluble portion and aldose reductase inhibitor, kotalgenin-16-acetate from the ethyl acetate soluble fraction of S. oblonga roots. Chemical structures of salacinol and kotalanol are shown in the Figure 2.

5. Pharmacological activity of Salacia

5.1 Diabetes mellitus and α-glucosidase inhibitors

Diabetes mellitus, called as diabetes in common parlance, is caused by a deficiency of the pancreatic hormone insulin. Deficiency of insulin hormone results in a failure to metabolize sugars and starch. This leads to the accumulation of glucose and other sugars in the blood and urine. Further, the resulting by-products of alternative fat metabolism disturb the acid-base balance of the blood in humans, causing convulsions and coma that are fatal. Therefore, it is vital for us to look for both short-term as well long-term remedies for this dreaded disorder. α-glucosidase inhibitors are used to establish greater glycemic control over hyperglycemia in diabetes mellitus type II. α-glucosidase inhibitors may be used with an appropriate diabetic diet. They are being used in conjunction with other antidiabetic drugs. Basically, α-glucosidase inhibitors reduce the rate of digestion of complex carbohydrates. Therefore, less glucose is released for absorption. This is because the carbohydrates are not broken down into the simpler, rapidly assimilable glucose molecules. In other words, these inhibitors/therapeutic molecules have short-term effects on diabetic patients and decrease the current blood glucose levels. On the other hand, the long-term effect is a modest reduction in haemoglobin A1c level.
5.2 α-Glucosidase inhibitors of Salacia

Stems and roots of Salacia contain potent α-glucosidase inhibitors (salacinol and kotalanol) and also the aldose reductase inhibitor, kotalgenin-16-acetate. Salacinol and kotalanol competitively bind to α-glucosidase present in the brush borders of small intestine and prevent the breakdown of oligosaccharides into monosaccharides and thus, maintain the normal blood levels in the human body (Matsuda et al., 1999). The enzyme aldose reductase catalyses the conversion of glucose to sorbitol (sugar alcohol). Sorbitol do not readily diffuse across the cell membranes and gets accumulated in the lens resulting in cataract formation. Kotalgenin-16-acetate competitively binds to the aldose reductase and thus, prevents cataracts (Matsuda et al., 1999). The various other active principles of Salacia are mangiferin, diterpenes, triterpenes, megastigmane glycosides, thiocyclitol, quinonemethides, friedelanes, oleananes, polysols and others (Matsuda et al., 1999). A comprehensive review on phytochemical and pharmacological aspects of Salacia has been carried out by Paarakh et al. (2008); Singh and Duggal (2010); Deokate and Khadabadi (2012); Anshul et al. (2013), Deepak et al. (2014) and Medagama (2015). They have critically reviewed the uses of Salacia for treating type II diabetes and obesity.

The two thiosugars isolated from S. oblonga extract, salacinol and kotalanol, have been found to have inhibitory effects, against the enzyme activities of maltase, isomaltase, and sucrase. It has also been found that the inhibitory effect against sucrase is more potent than the prescription α-glucosidase inhibitors acarbose and voglibiose that are used in the treatment of diabetes (Matsuda et al., 2005). If the compounds salacinol and kotalanol bind to the enzyme α-glucosidase and prevent the breakdown of di-, tri-, and oligosaccharides, carbohydrate absorption in the intestine is decreased, attenuating the postprandial glycemic response. Therefore, the undigested di-, tri-, and oligosaccharides pass through the small intestine into the colon where they are digested by the colonic microflora producing gaseous byproducts (Wolever et al., 1998). Lowering of postprandial glycemia by S. oblonga extract has been observed in rats fed either with maltose or sucrose, but not glucose, which is consistent with its α-glucosidase inhibitory effect in the small intestine (Shimoda et al., 1998).

5.3 Studies on antidiabetic activity of Salacia extracts

Matsuda et al. (1999) studied the inhibitory activity of S. oblonga root extract and its effect on serum glucose levels. Experiments were carried on sucrose and maltose loaded male Wistar rats (130-170 g). The rats are orally fed with 0, 100, 200 mg/kg methanolic extract of S. oblonga. Blood was collected from the retro-orbital sinus after 0.5 h, 1 h and 2 h and serum glucose levels were assayed. Sucrose loaded rats with 200 mg/kg methanolic extract showed reduced serum glucose levels. Maltose loaded rats fed with methanolic extract did not show significant decrease in serum glucose levels. S. oblonga extract showed postprandial glycemic activity in a randomized possible study of 43 healthy experimental subjects. The control subjects were fed with 480 ml of study beverage containing 82 g of carbohydrate, 20 g of protein and 14 g of fat and separately another subject control was fed with 1000 mg of S. oblonga extract. Plasma glucose levels were measured for 180 min which showed that the base line adjusted peak glucose response was not different across the meals (Collene et al., 2005). Williams et al. (2007) also studied the effect of herbal extracts of S. oblonga on 66 patients with type II diabetes.
<table>
<thead>
<tr>
<th>Name of the plant</th>
<th>Geographic location</th>
<th>Plant part used</th>
<th>Constituents isolated</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. oblonga</td>
<td>India and Sri Lanka</td>
<td>Root</td>
<td>Salacinol; kotanolol; kotalagenin 16 acetate, (glycerol; D-fructose; D-glucose; sucrose; galactinol; 3-O-a-D-galactopyranosyl 1 → 6)-O-b-D-galactopyranosyl-sn-glycerol; raffinose; stachyose, 26-hydroxy-1, 3-friedelanodione; 19-hydroxyferruginol; lambertic acid; 49-O-methylepilgalactocatehin; maytenolic acid; 3b,22a-dihydroxyolean-12-en-29-oic acid; few diterpenes and triterpenes</td>
<td>Matsuda et al. (1999)</td>
</tr>
<tr>
<td>S. reticulata</td>
<td>Tamil Nadu, India</td>
<td>Root</td>
<td>Salacinol; kotalagenin 16 acetate, 26-hydroxy 1, 3-friedelanodione; maytenolic acid, 3 β, 22-dihydroxy olean-12en-29 oic acid; kotanolol; (-)-Epicatechin; (-)-epigallocatechin, (-)-4′-O-methylepilgalactocatehin, (-)-epiafzelechin (-4β 8)-(-)-4′-O-methylepilgalactocatehin, (-)-epicathechin-(4β 8)-(-)-4′-O-methylepilgalactocatehin; mangiferin; Salaciquinone; isoiquesterinol; 30 hydroxy pristimerin; netzahualcoyene</td>
<td>Yoshikawa et al. (1997)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-)-Epicatechin; (-)-epigallocatechin, (-)-4′-O-methylepilgalactocatehin, (-)-epiafzelechin (-4β 8)-(-)-4′-O-methylepilgalactocatehin, (-)-epicathechin-(4β 8)-(-)-4′-O-methylepilgalactocatehin; mangiferin; Salaciquinone; isoiquesterinol; 30 hydroxy pristimerin; netzahualcoyene</td>
<td>Gunatilaka et al. (1993)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stem</td>
<td>Leucopelargonidin, dulcitol; Thirteen megastigmene glycosides, foliasalacinosides (A1, A2, B1, B2, C, D, E1, E2, E3, F, G, H, I); seven new phenolic glycosides, foliaichinonosides (A1, A2, A3, B1, B2, C, D), four dammarane-type, three lupane-type, and an oleanane-type triterpenes named foliasalacins A1, A2, A3, A4, B1, B2, B3, C from leaves and triterpenes</td>
<td>Viswanathan (1979)</td>
</tr>
<tr>
<td>S. macrosperma</td>
<td>Western Ghats, India</td>
<td>Root</td>
<td>24-hydroxy-3-oxofriedelan-29-oic acid hemiacetal; Saptarangi quinone A, B,C salaciuquinonemethide; pristimerin tingenone; hydrogenxytigenone salaspermic acid</td>
<td>Rogger et al. (1980)</td>
</tr>
<tr>
<td>S. chinensis</td>
<td>India</td>
<td>Stem and leaves</td>
<td>Salasone D and E; salauquinone B; salasol B; Salasone A,B,C; salauquinone A; salasol A; 3β, 22β dihydroxy olean-12-en-29-oic acid; tingenone; tingenin B; regol A; triptocalline A; mangiferine; Salacinol; Friedel-1-en-3-one; Friedelan-1,3-dione 7 α-ol; Friedelan-1,3-dione-24 al; Friedelan-1,3 dione; Friedelan-1,3 dione-24-oic acid; 24,25-oxidofriedelan-1,3 dione; 7,24-oxidofriedelan -1,3 dione; 25,26-oxidofriedelan-1,3 dione; Proanthocyanidin</td>
<td>Rastogi and Mehrotra (1960)</td>
</tr>
<tr>
<td>S. amplifolia</td>
<td>China</td>
<td>Aerial parts</td>
<td>Triterpenes, including quinonemethides, friedelanes, oleananes, ursanes triterpenes, simple phenolics, polyl, chromanone 2-hydroxyfriedelan-3-one, friedelin, lup-20 (29)-en-3, 21-dione, D-friedoolean-14-en-3-one, 3-(32 , 42 -dihydroxy-transcinnamoylxyloxy)-D-friedoolean-14-en-28-oic acid, 3, 22-dioxy-29-normoretane, Lupeol, β-Sitosterol, β-Daucosterol</td>
<td>Wang et al. (2011)</td>
</tr>
<tr>
<td>S. campestris</td>
<td>Brazil</td>
<td>Root</td>
<td>Salacin, pristimerin, maytenin, 20 α-hydroxy maytenin, and netzahualcoyene; Maytenin</td>
<td>Carvalho et al. (2005)</td>
</tr>
<tr>
<td>S. elliptica</td>
<td>Brazil</td>
<td>Root</td>
<td>2β-stearylxylo-oleanane, 3β-stearylxylo-ursane, one seco-friedelan), xanthone, polyls, caoxbylic acid, aromatic ester</td>
<td>Durate et al. (2010)</td>
</tr>
</tbody>
</table>
Postprandial glycemia and blood insulin levels were estimated in the subjects. The patients were categorized into 3 groups and each group was served with a control meal, control meal with 240 mg of S. oblonga extract and control meal with 480 mg/ml of S. oblonga extract. Both the concentrations significantly lowered the postprandial positive area under the glucose curve. Significant decreases of 14% and 22% in 240 mg and 480 mg extract-fed patients were recorded, respectively. A mixture of S. oblonga extract IP-PAI (SI tea) decreased the plasma glucose levels as reported by Nakata et al. (2011). SI tea significantly decreased the plasma glucose levels in KK-Ay/TaJcl type-II diabetic model mice.

Bhagayothi et al. (2012) studied various parameters such as random blood glucose levels, serum insulin, glycated haemoglobin and serum lipid profile with hydroalcoholic root extract of S. oblonga. Streptozotocin induced diabetic Wistar rats fed with 50 mg/kg and 100 mg/kg body weight S. oblonga extract showed 44% and 45% decrease in random blood glucose levels. The study showed significant increase in serum insulin and HDL-cholesterol and a significant decrease in plasma HbA1C and serum triacyl glycerol. Karunanayake et al. (1984) have evaluated the aqueous decoction of 40 Sri Lankan medicinal plants that are known to lower blood glucose levels. A maximum reduction of 30% blood glucose was seen in the Sprague-Dawley rats fed with decoction of S. reticulata. Serasinghe et al. (1990) have evaluated the aqueous extract of S. reticulata on streptozotocin induced diabetes rats to study its effect on plasma glucose levels. The experimental rats were orally fed with 0.5, 1 and 5 g/kg body weight and the plasma glucose levels were reduced by 42.8%, 45.4% and 87.5%, respectively. Aqueous extract of S. reticulata stems showed decrease in serum glucose levels when the rats were fed with sucrose, maltose and starch. Shimoda et al. (2000) also showed the strong inhibitory activities of α-glucosidase prepared from yeast and rat jejunum. Aqueous extracts from the roots of S. reticulata (200 mg) significantly suppressed the postprandial hyperglycaemia when healthy human volunteers were loaded with 50 g of sucrose. Yoshikawa et al. (1998) used bioassay guided separation to isolate kotalanol from S. reticulata root. Significant reduction in serum glucose level was noticed in hydrocortisone induced hypoglycemic rat models when fed with 500 mg/kg body weight of hydroalcoholic extract of S. reticulata (Rabban et al., 2006).

Oe and Ozaki (2008) isolated a thioceylitol, novel 13-membered ring from the aqueous stem extracts of S. reticulata. The activity was tested on maltose and sucrose loaded Wistar rats and the extract significantly lowered the postprandial glucose levels. Thioceylitol was also checked for α-glucosidase inhibitor activity in in vivo conditions. Shivaprasad et al. (2013) have evaluated the efficacy and safety of leaves and root bark of S. reticulata in a randomized, double-blind, placebo controlled method. The study was carried on patients with prediabetes and mild to moderate hyperlipidemia for 6-weeks. Twenty nine patients were fed with placebo or 500 mg twice a day with S. reticulata. Nine individuals were fed with placebo, 11 with S. reticulata leaves and 9 with S. reticulata roots. The results revealed a statistically significant decrease in fasting blood sugar levels and low-density lipoprotein cholesterol with no side effects. Jayawardena et al. (2005) investigated the effect of herbal tea extracts of S. reticulata in patients with type II diabetes in a randomised single centre, double blind method. The extract showed significant decrease in HbA1C and Jayawardena et al. (2005) concluded that S. reticulata herbal tea is safe and effective. Kajimoto et al. (2000) recorded a significant reduction in fasting plasma glucose levels, HbA1C and BMI in placebo group fed with aqueous stem extracts of S. reticulata. Venkateswari et al. (1990) have evaluated the antidiabetic activity of chloroform, ethanol and aqueous root extracts of S. macroperma on alloxan-diabetic rats and rabbits. The experimental rabbits were administered with 200 mg/kg body weight of crude and chloroform extracts. The alloxan-diabetic rats were administered with 150 mg/kg body weight of ethanolic extract. Ethanolic extract lowered the blood glucose levels in rabbits and rats. Venkateswari et al. (1993) have checked for antidiabetic activity in alloxan-diabetes rats. Alcoholic and methanolic root extracts of S. macroperma were tested and methanolic fraction has shown a better antidiabetic activity.

Sellamuthu et al. (2009) evaluated antihyperglycemic activity of mangiferin purified from methanolic root extracts of S. chinensis on streptozotocin induced diabetic rats. Forty mg/kg body weight was orally administered to the streptozotocin induced diabetic rats. Mangiferin treated diabetic rats exhibited significantly reduced blood glucose levels, glycosylated haemoglobin, and increased levels of insulin and haemoglobin. Joshi et al. (1973) isolated salacinol and Morikawa et al. (2003) isolated aldose reductase inhibitor from S. chinensis. Yoshikawa et al. (2003) studied the antiadibetogenic activity of methanolic extract of S. chinensis. Rats fed with the methanolic extract showed antihyperglycemic effect in oral sucrose or maltose loaded rats. Morikawa et al. (2003) showed that different constituents of S. chinensis showed the inhibitory effect on aldose reductase of rat and thus, signifying its antidiabetic potential.

6. Hepatoprotective activities of Salacia

Yoshikawa and co-workers (Yoshikawa et al., 2002) have tested the hepatoprotective activities of S. reticulata, using an oxidative stress-induced liver injury model. The extracts of the plant (400 mg/kg weight) considerably suppressed the glutamic oxaloacetic transaminase (GOT), and glutamic pyruvic transaminase (GPT) activities in carbon tetrachloride (CCL4) treated mice. The extracts of S. reticulata also inhibited CCl4 induced thiobarbituric acid reactive substance (TBARS) formation. These results indicated that the CCL4 induced increase in lipid peroxidation in the liver is being protected by Salacia extracts (Yoshikawa et al., 2002).

7. Antioxidant activities of Salacia

Yoshikawa et al. (2002, 2003) studied the antioxidant activities of hot aqueous and methanolic extracts of S. reticulata and S. chinensis. They used mangiferin, (−)-4′-O-methylgallocatechin and (−)-epicatechin-(4′-8)-(−)-42′-O-methylgallocatechin for antioxidative activity. They observed scavenging activity of DPPH radicals by the above compounds. Triterpenes like salacin, pristemerin, maytenin, 20 a-hydroxymaytenin and netzahualcoyene derived from S. campestris have recorded inhibition of DPPH radical activity (Carvalho et al., 2005). Likewise, salaquinone B and catechin isolated from S. chinensis have been reported to have radical scavenging activity against DPPH (Kishi et al., 2003). Vellosa et al. (2009) observed that ethanolic root extract of S. campestris possess free radical scavenging and antioxidant activity. High phenolic content and good antioxidant activity was reported in S. chinensis reported by Chavan et al. (2013). Krishnakumar and co-workers (Krishnakumar et al., 1999, 2000) have found antilipid peroxidative activity in the cardiac tissues of streptozocin diabetic rats. The rats also showed increased GSHPxase and GSSGRase enzymes in the cardiac tissues. Thus, it appears that several secondary plant products of Salacia species have significant antioxidant activities.
8. Antiobese activities of Salacia

Salacia has been known to control obese problems. Its activity on obese patients has been extensively studied. Pancreatic lipase, a well-known enzyme is highly critical for the digestion of dietary fat. Therefore, it is believed to contribute towards weight reduction in humans (Li et al., 2008). Huang et al. (2006) reported lipid-lowering activity from the root extracts of S. oblonga and also demonstrated olive oil induced inhibition of hypertriglyceridemia of rats by using the root extracts S. oblonga. Suppression of pancreatic lipase activity has also been reported by S. reticulata (Yoshikawa et al., 2002). Hence, it appears that the inhibition of pancreatic lipase activity in the small intestine is vital and perhaps is one of the important mechanisms for the attenuation of postprandial hyperlipidaemia as noted by Li et al. (2008). Thus, different species of Salacia appear to have multiple targets in controlling diabetes and obesity.

9. Antiproliferative activities of Salacia

Sekiguchi et al. (2012) studied the antiproliferative activities of S. reticulata leaves in interleukin-1-β-activated cells. The extract (850 µg/ml) showed 50% inhibition in synoviocyte like cell lines (inflammatory synovial tissues) and also suppressed matrix metalloproteinase genes. Mih et al. (2010) reported anticancer activity in 4 cancer cell lines with triterpenoids isolated from S. chinensis. The results indicate that Salacia has significant anti-proliferative activity.

10. Anti-inflammatory activity of Salacia

Anti-inflammatory activity of S. oblonga was studied by Ismail et al. (1997), using carrageenan-induced paw oedema and cotton pellet granuloma methods. S. oblonga showed an increased acid and alkaline phosphatase activity and decreased serum albumin in cotton pellet granulomatous rats.

11. Antimicrobial activity of Salacia

Antimicrobial activity of S. oblonga, S. chinensis, S. macroserpa and S. beddomei was studied against bacteria and fungi (Deepra and Narmathabai, 2004; Samy, 2005; Anjaneyulu et al., 2013). The studies showed Salacia has good antimicrobial activity against several pathogenic bacteria and fungi.

12. Toxicological and genotoxic studies on Salacia

Flammang et al. (2006, 2007) evaluated the toxicological effects of root extracts of S. oblonga in rats for 90 days. They noticed no chromosomal aberration in rat blood lymphocytes cultured in vitro. Genotoxicity was also studied by the same group using human lymphocytes. Root extracts of S. oblonga were used in these experiments and chromosomal aberration assay, and micronucleus assay were performed. The results revealed no genotoxic effect by root extracts of Salacia species. However, in many investigations, it has been found that S. oblonga extracts lowered the postprandial glucose response by 25-30% and the postprandial lactate response by 29-35%. It has been noticed that the extract did not cause any significant differences in perceived nausea, headache, abdominal cramping, bloating/excessive fullness, or satiety. The extracts of S. oblonga caused an increase in perceived flatulence, indicating the activity of the extract. Further, it has been reported that taking Salacia tea can cause dyspepsia and loose stool (Tanimura et al., 2005).

13. Conclusions

The important active principles of Salacia species such as salacinol and kotalanol, the potent α-glucosidase inhibitors showed effective reduction of plasma glucose in animal and human studies. All the studies discussed above provide an insight of the anti-diabetic action similar to standard glucosidase inhibitors. The above studies showed α-glucosidase inhibition is an important mechanism in reducing postprandial glucose levels, reduced fasting glucose and improves glucose handling. Since toxicity levels are negligible, the compounds have the potential to be used as effective α-glucosidase inhibitors and for controlling glucose levels. Further, the extracts also proved to have excellent antioxidant capacity besides antiobese activity. It is a highly promising herbal drug that can be used for effectively treating ailments like diabetes and obesity, the two dreaded disorders.

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Conflict of interest

We declare that we have no conflict of interest.

References


The above text contains various references to studies on *Salacia reticulata*, a plant species known for its potential antidiabetic properties. The studies discuss the effects of its aqueous extract on various parameters such as blood glucose levels, lipid profiles, and glycemic control. The text also mentions the use of *Salacia reticulata* in Ayurvedic traditional medicine and its potential applications in diabetes management.