Therapeutic exploration of insulin plant

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**Abstract**

The family *Costaceae* consists of *Costus igneus* Nak (also known as *Costus pictus* D. Don, *Costus mexicanus* Liebm ex Petersen, and *Costus congenitus* Rowle). This family contains four genera with approximately 200 species, the largest of which is *Costus*, which represents nearly 150 species. *Costus igneus* is native to Southeast Asia. It is used as an ornamental plant in India to enhance the value of the landscape. In Indian, people call it as as the "insulin plant" because of its ability to raise insulin levels in the body, acting as an anti-diabetic agent. Insulin plant leaves were phytochemically screened and found to be high in protein, iron, and antioxidant components such as ascorbic acid, α-tocopherol, β-carotene, terpinoids, steroids, and flavonoids. Historically it was used to extend life span, reduce skin related diseases like rash, relieve symptoms of fever, treat asthma and bronchitis and obliterate intestinal worms. Besides it has diverse uses, including anti-diabetic activity, anti-proliferative activity, anti-microbial activity, anti-urolithiatic activity, effects on learning and memory, anti-oxidant activity, hepatoprotective activity, and so on. The objective of this section is to carry out a pharmacognostic study on the healing properties of promising insulin plant and to explore its therapeutic potential.

**Key words:** Insulin plant, anti-diabetic activity, hypolipidemic, antioxidant, antiurolithiatic.

**Introduction**

Medicinal herbs have been used since the Vedic times. The Rigveda (4500-1600 B.C.) contains numerous shlokas and hymns written in appreciation of plants and it contains the earliest reference about the use of herbal remedies in India. They were being used to reduce the risk of developing a variety of illnesses, including epidemics, for thousands of years. Few plants are also used as delectable sauces, food preservatives, dyes, and flavours (Bamola *et al*., 2018).

The therapeutic benefits of the plant are almost universal. The medications are either made from the entire plant or from various plant components like the leaves, stem, bark, roots, flowers, and seeds, among others. Some are even made from excretory plant materials such gums, resins, and latex. A significant portion of the modern medical system now offers a variety of plant-derived medications. Plants are also a source of certain significant chemical intermediates used in the production of contemporary medications, such as diosgenin, solasodine, and -ionone. In addition to providing a steady and expanding market on a global scale, plants remain a significant source of novel pharmaceuticals and nutraceuticals (Santosh, 2015).

Phytochemicals are bioactive chemical compounds produced by in fruits, vegetables, grains and other plant foods through primary and secondary metabolism and are called as primary and secondary metabolites. Although these secondary metabolites are, in theory, not necessary for existence, they unquestionably help ensure the fitness and survival of the species as a whole. In order to utilise them now and in the future, plants make secondary metabolites and store them in a variety of organs, including leaves, roots, stems, bark, flowers, and fruits. Based on their chemical makeup, these secondary metabolites are categorised as steroids, terpenoids, flavonoids, glycosides, alkaloids, etc. These different naturally occurring substances found in plants have a significant therapeutic efficacy and can affect nearly all bodily systems (Santosh, 2015). These phytochemicals offer notable medicinal properties that include antidiabetic, anti-oxidative, anti-allergic, antibiotic and anti-carcinogenic properties.

*Costus igneus* Nak, also known as the blazing costus, Step ladder, Spiral flag, or Insulin plant, is a native of South and Central America. It is also known by the synonyms *Costus pictus* D. Don, *Costus mexicanus* Liebm ex Petersen, or *Costus congenitus* Rowle. This is a new American import to India as a natural treatment for diabetes, hence the widespread name "insulin plant” (Jose and reddy, 2012). In South India, it is a common ornamental plant grown in gardens, but it also grows wild in many locations (Benny, 2004). It is used to manage diabetes in India, and it is well known that diabetics should eat one leaf per day to maintain healthy blood sugar levels (Devi and Urooj, 2008).

The "insulin plant," or *Costus pictus*, has a huge spectrum of significant bioactive components, including hepatoprotective, antioxidant, anti-cancer, anti-inflammatory and anti-diabetic properties. The presence of numerous phytochemicals, especially flavonoids and phenolic substances, contributes to its distinctive properties (Selvakumarasamy *et al*., 2021). As a result, the focus of the current research is on discussing the therapeutic potential of *C. pictus* and the mechanisms underlying these encouraging outcomes.

**Morphology of insulin plant**

Tropical, upright, perennial plant belonging to the *Costaceae* family is called *Costus igneus*. It has simple, alternating, whole, oblong, evergreen leaves that range in length from 4 to 8 inches and have a parallel venation system. The tree's enormous, velvety, dark-green leaves are spirally coiled around the stems in elegant, arching bunches that emerge from underground rootstocks. The leaves have light purple undersides. It can grow to a maximum height of 60 cm, with the tallest stems toppling and laying on the ground. On cone-like heads at the ends of branches, stunning orange blooms with a 2.5–12.5 cm diameter are produced on hot days. Stem cutting is used in the multiplication of insulin plants. Common names include Insulin plant, Stepladder, Fiery Costus, Spiral Flag, and Spiral Ginger (Harini *et al*., 2016). The family *Costaceae* consists of four genera and approximately 200 species. The genus *Costus* is the largest in the family with about 150 species that are mainly tropical in distribution.

**Medicinal properties of insulin plant**

*Costus pictus* has been used as a medicinal herb for centuries, primarily for its tonic, stimulant, carminative, diuretic, digestive and antiseptic properties (Sivarajan and Balachandran, 1994). Various parts of the medicinal plant *Costus* species are used to treat a variety of diseases.

The leaves of the insulin plan have a high hypoglycemic potential. The stem has been shown to have significant antiurolithiatic activity. Besides, significant antioxidant activity has been demonstrated in both the stem and the root (Meti, 2018). Insulin plant rhizome is bitter, astringent, acrid, cooling, aphrodisiac, purgative, anthelmintic, depurative, febrifuge, expectorant, and useful in burns, constipation, leprosy, worm infection, skin diseases, fever, asthma, bronchitis, inflammations, and anaemia (Urooj and Devi, 2010).

Internally, the rhizome is used to treat abdominal discomfort, heart palpitations, liver problems, jaundice, gall bladder pain and other ailments (Sivarajan and Balachandran, 1994). *Costus pictus* rhizomes are used to treat colds, pneumonia, and rheumatism in India. It is used in Southeast Asia to cure diarrhoea and vomiting, light headedness, headache, ear, eye and nose pain. The rhizome extract was used by the Japanese to treat syphilis (Khare, 2007).

*Costus pictus* leaves and rhizomes are said to contain a steroid called diosgenin, which is anti-diabetic and used to treat type 2 diabetes. In glucose-fed mice, a methanolic extract of insulin plant leaf (200mg/kg, 500mg/kg b.w.) demonstrated significant hypoglycemic activity (Shiny *et al*., 2013). In addition to lowering blood glucose, the medicinal preparation has insulin-potentiating properties. Table 1 outlines the major components recognised in essential oil.

**Table 1: Major components of essential oil**

|  |  |  |
| --- | --- | --- |
| **Stem oil (%)** | **Leaf oil (%)** | **Rhizome oil (%)** |
| Hexadecanoic acid (28.3) | Hexadecanoic acid (24.51) | Hexadecanoic acid (25.26) |
| 9,12‑octadecadienoic acid (18.33) | 2‑pentanol (22.48) | 9,12‑octadecadienoic acid (7.74) |
| Dodecanoic acid (5.62) | Dodecanoic acid (3.96) | Dodecanoic acid (16.56) |
| Linalyl propanoate (6.03) | ß‑ionone (8.69) | Tetradecanoic acid (10.20) |
| Tetradecanoic acid (4.82) | Farnesyl acetone (7.04) | Linalool (8.48) |
| A‑eudesmol (3.55) | A‑ ionone (8.01) | α‑terpineol (4.44) |
| γ‑eudesmol (3.21) |  |  |
| 4‑ethoxy phenol (3.06) |  |  |

**Antidiabetic activity**

Insulin plant is a medicinal plant that is also a common ornamental plant in south Indian gardens. The leaves are the most important component, generating high anti-diabetic activity. It lowers fasting and postprandial blood glucose levels. However, the precise mechanism of action underlying the anti-diabetic property is unspecified. Together with antidiabetic activity, insulin plant reduces diabetic complications; brings renal and hepatic parameters to a controlled level, decreases the amount of glycosylated haemoglobin, maintains a healthy lipid profile, increases insulin level and shows substantial improvement in histopathological examination (Mathew and Varghese, 2019).

Chowdary *et al*. (2020) formulated a nutritionally rich cookie with *Costus igneus* leaf extract and determined the effect of cookie consumption on decreasing blood glucose levels in type 2 diabetic patients. A sample of 30 patients suffering from type 2 diabetes were chosen whose blood glucose levels were tested on the 1st, 15th day and 30th day of cookie consumption. The developed cookies were analysed for proximate and physico-chemical properties and revealed that it contained high amounts of secondary metabolites, including antioxidant compounds.  The average level of FBS and PBS in all four groups declined substantially from day 0 to day 30, implying that *C.igneus* cookies consumption had a good effect on controlling blood sugar levels. Moreover, in all four study groups HbA1C was reduced by one unit.

Shetty *et al*. (2010) analyzed glycaemic control in diabetic patients who had been consuming insulin plant leaves and tried to determine the adverse effects/benefits of its intake. All thirty patients either took one fresh leaf or one tea-spoon full of shade dried insulin plant leaf powder on an empty stomach in the early hours without discontinuing their previous diabetes treatments. The results showed that the fasting blood sugar levels were lowered in all thirty patients. The insulin leaf therapy was found to be beneficial as early as day fifteen. Intake of the leaves for a longer period of time continued to improve glycaemic control. The glycaemic control on the 60th day was better than on the 15th and 30th days. Moreover, the problem of non-healing ulcers and recurrent urinary tract was resolved in patients between 15 to 60 days of leaf consumption. Besides, cataract surgery could be performed successfully after fifteen days of treatment with insulin plant leaves. In all 12 insulin-treated patients, the dose of insulin could be cut in half while the glucose levels are better controlled in patients who were on oral hypoglycaemic drugs. As a result, the patients continued to consume the leaves as it was beneficial for glycaemic control as well as protecting them from the development of diabetic comorbidities like neuropoathy, retinopathy, nephropathy etc.

Al-Romaiyan *et al*. (2010) measured the effect of aqueous *C.pictus* extract on insulin secretion *in vitro* from the MIN6 β-cell line and isolated mouse and human islets. The findings show that *C. Pictus* has a direct stimulatory effect on insulin secretion by increasing β-cell intracellular Ca2+ concentrations, an effect that is completely abolished by removing extracellular Ca2+ or blocking voltage-gated Ca2+ channels (VGCC). These *in vitro* findings imply that one action mechanism of CP is to stimulate insulin secretion, which may be mediated in part by *C.pictus* ability to increase (Ca2+) levels via VGCC. *C.pictus* extracts may offer an affordable and low-cost option for treating T2DM patients.

Shiny *et al*. (2013) evaluated phytochemical and hypoglycaemic activity of *Costus pictus* plants from Kerala and Tamilnadu. A total of 24 extracts were prepared from three plant materials like rhizome, stem and leaf belonging to two regions using different solvents like hexane, ethyl acetate, methanol and water. The preliminary phytochemical screening revealed a high degree of similarity in the presence of chemical constituents in all 24 extracts of three samples from two regions. However, the methanol extract at the rate of 200mg/kg and 500mg/kg body weight of leaf demonstrated significant hypoglycaemic activity in glucose-fed mice. The research shows that C. pictus can be grown on a large scale in a variety of geographical locations since the phytochemical profile is quite steady with exogenous conditions.

**Mechanism of Action**

Chronic hyperglycemia affects how people generally metabolise carbohydrates, proteins, and fats. It causes the ailment known as "Diabetes mellitus." Hyperglycemia may result from dysfunctional insulin, aberrant insulin production, or both. Due to the absence of functioning beta cells, type I diabetes is completely insulin dependent and is characterised by insulin insufficiency. Insulin resistance is a term used to describe the condition of type 2 diabetes. Diabetes had elevated to the top medical issue due to its rising prevalence. Despite the availability of numerous medications to lower blood sugar, the long-term use and negative effects pose a serious hazard to humankind. The tendency toward herbal medicine was a result of these. Numerous local plants have been claimed to be successful in managing diabetes (Selvakumaraswamy *et al*., 2021).

Diabetes inhibits the liver's ability to use glucose, which lowers the amount of hepatic glycogen. Through the voltage-gated calcium channels, *C. pictus* extracts boosted the calcium ion [Ca2+] influx into the beta-cells of pancreatic islets. As a result, the amount of insulin secreted by the glucose-insensitive -cells in diabetes patients increased. These extracts reduced the phosphorylation of the proteins protein kinase C (PKC) and extracellular signal-regulated kinase (ERK), which in turn decreased the production of inflammatory cytokines and increased insulin sensitivity. These demonstrated that it might be a viable herbal substitute for synthetic medications, and the extracts were also determined to be non-toxic. By preventing muscle tissue damage brought on by hyperglycemia and by the anti-diabetic actions of the methanolic extract of C. pictus leaves, C. pictus extracts also increased body weight. They discovered an effective substance called methyl tetracosanoate, which increased the expression of GLUT4 mRNA and inhibited the PTP1B enzyme. These boosted PI3K and IR protein expression, which subsequently affected insulin sensitivity (Ashwini *et al*., 2015).

Significant amounts of bioactive compounds were found in insulin plant leaves. Tri-terpenoids primarily work by obstructing alpha-glucosidase and alpha-amylase activity, which slows down the absorption of carbs in the intestine and lowers postprandial insulin levels 40. It results in the correction of plasma glucose, insulin levels, and glucose metabolism as well as insulin resistance. Corosolic acid helps in glucose uptake. In the liver of diabetic rats, steroids like diosgenin reduce the activity of enzymes related to diabetes, including ATP-cytrate lyase, pyruvate kinase, and glucose -6-phosphate dehydrogenase. It increases pancreatic insulin secretion, which in turn causes plasma insulin levels to rise and blood glucose levels to be managed. It also aids in the repair of partially destroyed beta-cells. In addition, stigmasterol prevents beta-cell dysfunction brought on by glucolipotoxicity by reducing LDL-induced pro-inflammatory cytokine release and increasing cholesterol efflux. Because too much cholesterol may contribute to beta cell failure, glucolipotoxicity decreases insulin production by causing it to accumulate (Laha and Paul, 2019). By decreasing the buildup of free cholesterol, reactive oxygen species (ROS), enhancing insulin production, and raising insulin context, stigmasterol shields pancreatic beta cells from the harmful effects of glucolipids (Manjula *et al*., 2013).

Insulin plant provides beta-sitosterol, another anti-diabetic component. Fasting plasma insulin levels rise as a result. With a rise in glucose-induced insulin production, it enhances the oral glucose tolerance test. Additionally, it induces adipogenesis in differentiating preadipocytes and boosts glucose absorption in adipocytes. Like insulin, it inhibits GLUT4, although no clinical research has been conducted to yet (Behera *et al*., 2017).

**Table 2: Major compounds isolated from *Costus igneus* showing anti-diabetic activity**

|  |  |
| --- | --- |
| **Name of the Compounds** | **Activities** |
| Triterpenoid (Corosolic acid) | Glucose uptake activity |
| Steroid (Diosgenin) | Hypoglycemic property |
| Steroid (β- sitosterol) | Increases plasma insulin level and also increases glucose uptake activity |
| Flavonoid (Quercetin) | Increases insulin mediated glucose uptaking and activity of antioxidant enzymes |
| Phenol (catechin) | Inhibit α- glucosidase activity and antioxidant activity |
| Insulin like protein | Hypoglycemic activity |
| Fatty acid (Oleic acid) | Hypoglycemic activity |

Source: Laha and Paul, 2019

**Hypolipidemic activity**

Kanivalan *et al*. (2014) explored the hypoglycemic and hypolipidemic activity of *Costus igneus* leaf extract on Streptozotocin (STZ) induced diabetic albino rats. The treatment led to a significant increase in blood glucose levels as well as modifications in lipid profile, haemoglobin and insulin levels. This could be due to the excess of hepatic glycogenolysis and gluconeogenesis and decreased glucose uptake by tissues. The administration of ethanolic extract of the leaf to rats for twenty-eight days at the rate of 200 and 300mg/kg body weight caused a significant reduction in glucose levels, recovered haemoglobin, lipid profile and insulin.

Chacko *et al*. (2012) looked into the antihyperlipidemic activity of *Costus igneus* in Triton X-100-induced hyperlipidemic rats. Hyperlipidemic rats were given *Costus igneus* extract at different doses of 100mg/kg, 200mg/kg, and 400mg/kg daily for 1 week. The reference standard used was atorvastatin. At a dose of 400mg/kg (p.o), Costus igneus significantly reduced serum cholesterol, triglycerides, LDL, VLDL, and significantly increased serum HDL levels in Triton-induced hyperlipidemic rats. In 400mg/kg extract treated animals, there is also a substantial improvement in atherogenic index. As a result, it effectively suppressed Triton-induced hyperlipidemia in rats, implying a possible defensive function in Coronary heart disease.

**Mechanism of action**

Hyperlipidemia emerges as a result of abnormal glucose, fat, and protein metabolism in diabetes. A biochemical situation that is highly desired for the prevention of atherosclerosis and ischemia circumstances is a significant reduction in total cholesterol. Reduced cholesterogenesis and fatty acid production may be the origin of the hypolipidemic impact of insulin plant. A highly ideal biochemical situation for preventing atherosclerosis and ischaemia is a considerable reduction in total cholesterol and an increase in HDL cholesterol (Luc and Fruchart, 1991).

**Antioxidant activity**

Shivaprakash *et al*. (2014) investigated the antioxidant potential of *Costus igneus* leaves in albino rats subjected to ethanol-induced peroxidative damage. Four groups of Wistar albino rats of either sex was formed. Group I was the control group and received normal saline, Group II ethanol, Group III test drug CI at 300 mg/kg, and Group IV CI at 600 mg/kg for 30 days. The results after antioxidants estimation revealed that in the ethanol-treated group, levels of reduced glutathione, superoxide dismutase, catalase and malondialdehyde were significantly lower than in the control group. Reduced glutathione, SOD and catalase enzyme levels recovered completely in a dose-dependent manner. As a result, *Costus igneus* has the potential to boost antioxidant defence and thus prevent oxidative stress injury.

The current study was carried out by Kripa *et al*. (2014) to ascertain the mechanism of anti-inflammatory action of β-amyrin isolated from the leaves of *C. igneus* using a carrageenan-induced rat model and an in vitro model of LPS-induced human peripheral blood mononuclear cells (hPBMCs). The differential fractionation of *C. igneus* leaves demonstrated the greatest percentage inhibition of paw edema at a dose of 100 mg/kg body weight in methanolic extract (MEC). When compared to the carrageenan control, MEC inhibited cyclooxygenase (COX), lipoxygenase (LOX), myeloperoxidase (MPO) and nitric oxide synthase (NOS) activities in monocytes. MEC had a stronger effect than the regular drug Diclofenac (20 mg/kg body weight).

**Mechanism of action**

Free radicals, also known as reactive oxygen species (ROS), are byproducts of cellular respiration and include substances like nitric oxide, super oxide, peroxyl radicals, and hydroxyl radicals. Oxidative stress could result from the oxidation of proteins, lipids, and nucleic acids as a result. Many diseases, including cancer, neurological disorders, cardiovascular diseases, alcohol-induced liver disease, Alzheimer's disease, atherosclerosis, and ageing, are caused by free radicals. Under typical circumstances, antioxidant enzymes including glutathione peroxidase, superoxide dismutase, and catalase work to naturally remove ROS from the human body. Some non-enzymatic substances, such as vitamin C, -tocopherol, and selenium, also help to mitigate the effects of ROS. Due to the broad variety of phytochemicals found in plants, dietary antioxidants derived from plants became the newest area of research (Selvakumaraswamy *et al*., 2021).

The leaf extracts' ability to prevent hyperglycemic oxidative damage was demonstrated by the fact that when provided, they restored the levels of glutathione S-transferase, glutathione peroxidase, superoxide dismutase and catalase enzymes. *C. pictus* rhizomes also demonstrated antioxidant action (Majumdar and Parihar, 2012). By disrupting the pattern of lipid peroxidation in cell membranes, diosgenin in rhizomes protected it from the oxidative stress of polyunsaturated fatty acids. From the leaves of *C. pictus*, flavonoids, in particular quercetin, had a strong antioxidant effect (Son *et al*., 2007). This was caused by its ability to scavenge superoxide radicals and inhibit xanthine oxidase. The structural chemistry of polyphenols is optimal for their capacity to scavenge free radicals. Due to its propensity for metal chelation, notably for iron and copper, it prevented the generation of metal-catalyzed free radicals (Rice-Evans *et al*., 1996).

**Antiurolithiatic activity**

Yuvarani *et al*. (2017) probed the inhibitory action of *Costus igneus* aqueous extract on the development of calcium hydrogen phosphate dihydrate (CHPD) crystals. The single diffusion gel growth technique was used to grow CHPD crystals. The study's findings show that as the concentration of aqueous extract of *Costus igneus* increased, the weight of the formed crystals decreased from 2.03 g to 0.06 g (leaves), 0.05 g (rhizome) and 0.03 g (stem) for the CHPD crystals, respectively. Fourier Transform Infrared Spectroscopy (FTIR) was used to confirm the functional groups, and Powder X-Ray Diffraction Technique (XRD) was used to confirm the crystalline phases of the CHPD and hydroxyapatite (HAP) crystals. All the three sections of *Costus igneus* namely leaves, stems and rhizome were found to have the potential to block the formation of calcium hydrogen phosphate dihydrate crystals. This research proves that an aqueous extract of *Costus igneus* stem and rhizome can facilitate the growth of hydroxyapatite (HAP) crystals while decreasing the nucleation rate of CHPD crystals, a crucial constituent of calcium urinary stones.

Kushagra *et al*. (2020) examined the *in-vitro* anti-urolithic efficacy of a methanolic extract of *Costus igneus* leaves. The amount of calcium oxalate that dissolved in semipermeable egg membrane in the presence of extract was investigated and contrasted with that of the reference medication cystone. The percentages of methanolic extract and the common medication cystone that dissolved were discovered to be 86.12 and 80.34 percent, respectively. According to the findings, the plant can be used to make polyherbal formulations and treat urolithiasis in an efficient manner.

**Mechanism of action**

The hydroxyapatite (HAP) crystals were ready to develop when the insulin plant extract was added, and it also slows the formation of CHPD crystals, a substantial part of urinary calcium stones (Yuvarani *et al*., 2017).

**Conclusion**

The thorough background illustrates the insulin plant’s numerous effects. This plant exhibits a complex identity despite frequently being praised for its antidiabetic activity because of the large variety of potent phytochemicals it contains. The potential of tomorrow is the therapeutic herbs, which were once the customs of antiquity. Today, the transition from nutraceuticals to functional foods is becoming more significant. However, it is crucial to comprehend the internal elements that affect human digestion. Considering the alluring potential of insulin plant and its components, more research is required to fully comprehend their effects on human health. Additionally, a suitable dose of phytochemicals might be created for creating the uniqueness of functional food with the understanding on mechanisms involved and interactions between the ingredients.

**References**

Al-Romaiyan, A., Jayasri, M.A., Mathew, T.L., Huang, G.C., Amiel, S., Jones, P.M. and Persaud, S.J., 2010. Costus pictus extracts stimulate insulin secretion from mouse and human islets of Langerhans in vitro. *Cellular Physiology and Biochemistry*, *26*(6), pp.1051-1058.

Ashwini, S., Bobby, Z., Joseph, M., Jacob, S.E., Padmapriya, R., 2015. Insulin plant (*Costus pictus*) extract improves insulin sensitivity and ameliorates atherogenic dyslipidaemia in fructose induced insulin resistant rats: molecular mechanism. J. Funct. Foods 17, 749–760. doi:10.1016/j.jff.2015.06.024.

Bamola, N., Verma, P. and Negi, C., 2018. A review on some traditional medicinal plants. *International Journal of Life-Sciences Scientific Research*, *4*(1), pp.1550-1556.

Behera A, Kumar S and Jena PK: Nutritional and pharmacological importance’s of genus *Costus*: a review. International Journal of Pharmaceutical Sciences and Research 2017; 7: 1866-73.

Benny M. Insulin plant in gardens. Natural Product Radiance 2004;3:349‑50.

Chacko, N., Shastry, C.S., Shetty, P., Shyamma, P., D’souza, U. and Maulika, P., 2012. Anti hyperlipidemic activity of *Costus igneus* in Triton X-100 induced hyperlipidemic rats. *International journal of pharmaceutical and chemical sciences*, *1*, pp.813-8.

Devi VD, Urooj A. Hypoglycemic potential of Morus indica. L and *Costus igneus*. Nak: A preliminary study. Indian J Exp Biol 2008;46:614‑6.

Harini AP, Hegde L, Kumar S and Rao NP: Macromicroscopy and TLC atlas of leaves of *Costus igneus* nak. Journal of Ayurveda Medical Sciences 2016; 1: 5-11

Jose B, Reddy LJ. Analysis of the essential oils of the stems, leaves and rhizomes of the medicinal plant *Costus pictus* from southern India. Int J Pharmacy Pharm Sci 2010;2 Suppl 2:100‑1.

Laha S and Paul S: *Costus igneus* - a therapeutic anti-diabetic herb with active phytoconstitutents. Int J Pharm Sci & Res 2019; 10(8): 3583-91. doi: 10.13040/IJPSR.0975-8232.10(8).3583-91.

Luc G and Fruchart JC. (1991). Oxidation of lipoproteins and atherosclerosis. Am. J. Clin. Nutr.53, 206-209.

Rice-Evans, C.A., Miller, N.J., Paganga, G., 1996. Structure-antioxidant activity relationships of flavonoids and phenolic acids.. Free Radic. Biol. Med. 20 (7), 933–956. doi:10.1016/0891-5849(95)02227-9.

Selvakumarasamy, S., Rengaraju, B., Arumugam, S.A. and Kulathooran, R., 2021. *Costus pictus*–transition from a medicinal plant to functional food: A review. *Future Foods*, *4*, p.100068.

Shiny, C.T., Saxena, A. and Gupta, S.P., 2013. Phytochemical and hypoglycaemic activity investigation of *Costus pictus* plants from Kerala and Tamilnadu. *Int J Pharm Sci Invent*, *2*(5), pp.11-8.

Sivarajan, V. V. and Balachandran, I., 1994, Ayurvedic drugs and their plant sources, Oxford and IBH Publishing Co. pvt Ltd, New Delhi.

Son, I.S., Kim, J.H., Sohn, H.Y., Son, K.H., Kim, J.S., Kwon, C.S., 2007. Antioxidative and hypolipidemic effects of diosgenin, a steroidal saponin of yam (*Dioscorea* spp.), on high-cholesterol fed rats. Biosci. Biotechnol. Biochem. 71 (12), 3063–3071. doi:10.1271/bbb.70472

Majumdar, M., Parihar, P.S., 2012. Antibacterial, anti-oxidant and antiglycation potential of *Costus pictus* from southern region, india. Asian J. Plant Sci. Res. 2 (2), 95– 101.

Manjula K, Rajendran K, Eevera T and Kumaran S: Quantitative estimation of lupeol and stigmasterol in *Costus igneus* by High - Performance Thin-Layer Chromatography. Journal of Liquid Chromatography & Related Technologies 2013; 36(2): 197-12.

Mathew, F. and Varghese, B., 2019. A review on medicinal exploration of *Costus igneus*: the insulin plant. *Int J Pharm Sci Rev Res*, *54*(2), pp.51-57.

Meti R. Standardization, value addition and sensory evaluation of products prepared from insulin plant leaves (*Costus igneus*). International Journal of Advanced Educational Research. Volume 3, 2018 January, 374-376.

Shetty AJ, Parampalli S.M, Bhandarkar R, Kotian .S. Effect of the insulin plant ( *Costus igneus* ) leaves on blood glucose levels in diabetic patients: a cross sectional study. Journal of Clinical and Diagnostic Research [serial online] 2010 June [cited: 2010 June 12]; 4:2617-2621.

Shivaprakash G, Elizabeth D, Rai S, Nischal, Nandini, Reshma K, Fahim, Natesh and Pallavi. Evaluation of Antioxidant potential of *Costus igneus* in ethanol induced peroxidative damage in albino rats. Journal of Applied Pharmaceutical Science. Vol. 4, August 2014, 052-055.

Urooj A and Devi V D. Nutrient profile and antioxidant components of *Costus speciosus* Sm. and *Costus igneus* Nak. Indian Journal of Natural Products and Resources. March Vol. 1, 2010, 116-118.

Yuvarani T, Manjula K, Perumal A G. Growth Characterization of Calcium Hydrogen Phosphate Dihydrate Crystals Influenced By *Costus igneus* Aqueous Extract. International Journal of Pharmacy and Pharmaceutical Sciences. Vol 9, 2017, 173-178