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Nutritional, pharmacological and medicinal properties of *Momordica charantia*

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Abstract: *Momordica charantia* L. (Bitter gourd) is a flowering vine in the family of Cucurbitaceae. It contains an array of novel and biologically active phytochemicals including triterpenes, proteins and steroids. Medicinally, the plant has a long history of use by the indigenous people as a folk medicine. Bitter gourd is often used in Chinese cooking for its bitter flavor, typically in stir-fries, soups, and also as tea. Pakistan, Philippines, Panama and Nepal also use this bitter vegetable for culinary purposes in addition to India. Several medicinal properties of the bitter gourd have been studied by various researchers, such as anti-diabetic, anti-ulcerogenic, anti-mutagenic, antioxidant, anti-tumour, anti-lipolytic, analgesic, abortifacient, anti-viral, hypoglycemic and immunomodulatory. *In vitro* studies reveals that the bitter gourd proteins (α-and β-monorcharin) have inhibitory effect against HIV virus, and leaf extracts have broad-spectrum anti-microbial activity as well. Many *in vivo* studies have demonstrated the relatively low toxicity of all parts of the bitter gourd plant when ingested orally. This review also addresses taxonomy, phytochemical, culinary practices and pharmacological properties in detail. Over the years scientists have verified many of the traditional uses of this bitter plant that continues to be an important natural remedy in herbal medicine systems. Bitter gourd products such as concentrated fruit and seed extracts can be found in capsules and tablets, as well as in whole herb/vine powder forms and these supplements are becoming more widely available in many countries nowadays as prophylactic or therapeutic agents.

Keywords: *Momordica Charantia,* Phytochemistry, Nutrition, Pharmacology, Medicinal Importance

1. Introduction

Momordica charantia L. (Bitter gourd) has long been used as a food and medicine [1]. The plant is called by different names since it grows in tropical regions such as India, Malaya, China, tropical Africa, Middle East, America [2] and Thailand. Propagated by seed, bitter gourd vines flower in about 30 days, and produce mature fruits about 20 days after that. Mature fruits attain the size of medium-sized cucumbers and are then harvested like squash, and are cooked as green. For medicinal purposes the fruits may be used fresh as pulp or juice or dry in powders, or in fluid extracts [3].

Bitter gourd is one of the nature's most bountiful gifts and is one of the discarded vegetables by people, just because of its bitter taste. The Latin name *Momordica* means "to bite," referring to the jagged edges of the leaves, which appear as if they have been bitten. All parts of the plant, including the fruit, taste very bitter. In the Amazon, local people and indigenous tribes grow bitter gourd in their gardens for food and medicine purposes. They add the fruit and/or leaves to beans and soup for a bitter or sour flavor; parboiling it first with a dash of salt may remove some of the bitter taste.

2. Taxonomy

Bitter gourd is a flowering vine in the family Cucurbitaceae. It is a slender, climbing annual vine with long-stalked leaves and yellow, solitary male and female flowers borne in the leaf axils. Leaves: simple, usually palmately 5-7 lobed, tendrils unbranched or 2 branched. It bears simple, alternate leaves 4-12 cm across, with 3-7 deeply separated lobes. Fruit: ovoid, ellipsoid, or spindle shaped, usually ridged or warty, dehiscent irregularly as a 3 valved fleshy capsule or indehiscent. The young fruit is emerald green, turning to orange-yellow when ripened. On

maturity, the fruit splits into three irregular valves that curl backwards and release numerous reddish-brown or white seeds encased in scarlet arils. Seeds and pith appear as white color in unripe fruits, and red during ripening process. Bitter melon comes in a variety of shapes and sizes. The typical Chinese phenotype is 20-30 cm long, oblong with bluntly tapering ends and pale green in color, with a gently undulating, warty surface. The bitter melon more typical of India has a narrower shape with pointed ends, and a surface covered with jagged, triangular "teeth" and ridges. Coloration is green or white. Between these two extremes is any number of intermediate forms. The pods are smaller and bright orange when ripe with very sweet red seeds. Flowers: Staminate flowers usually solitary on a bracteate scape, hypanthium shallow, calyx 5 lobed, petals 5, usually yellow, distinct, 1-3 with incurved scales at base, stamens usually 3, inserted toward base of hypanthium, filaments distinct, broad, anthers distinct or coherent, 2 of them dithecal, the other monothecal, cells curved or flexuous; pistillate flowers usually solitary on a bracteate scape, hypanthium ovoid to spindle shaped, perianth usually smaller than in staminate flowers, staminodes absent or 3, ovules numerous, horizontal, stigmas 3, 2 lobed. Each plant bears separate yellow male and female flowers. Seeds: few to numerous, ovate, usually sculptured [4].

3. Phytochemistry

The plant contains an array of novel and biologically active phytochemicals [5, 6, 7, and 8] and some of the major phytochemical constituents of various parts are presented in Table-1.

Table 1. *Phytochemical constituents of Bitter gourd.*

Source	Phytochemicals	Reference
Plant body	Momorcharins, momordenol, momordicilin, momordicins, momordicinin, momordin, momordolol, charantin, charine, cryptoxanthin, cucurbitins, cucurbitacins, cucurbitanes, cycloartenols, diosgenin, elaeostearic acids, erythrodiol, galacturonic acids, gentisic acid, goyaglycosides, goyasaponins, multiflorenol.	[57- 61]
	Glycosides, saponins, alkaloids, fixed oils, cucurbitane-type triterpenes, proteins and steroids	[62]
Fruit	Momordicine, charantin, polypeptide- p insulin, ascorbigen, Amino acids – aspartic acid, serine, glutamic acid, threonine, glutamic acid, threonine, alanine, g-amino butyric acid and pipecolic acid, luteolin.	[63]
	Fatty acids – Lauric, myristic, palmitic, palmitoleic, stearic, oleic, linoleic, linolenic acid	
Seeds	Enzyme-Urease	[64]
	Amino acids – valine, threonine methionine, isoleucine, leucine, phenylalanine, glutamic acid	

Table 2. *Proximate composition of bitter gourd leaf, fruit and seed [65].*

Parameter	Leaf	Fruit	Seed
Moisture (%)	17.97 ± 1.00	10.74 ± 2.29	20.69 ± 5.85
Total ash (%)	15.42 ± 2.08	7.36 ± 0.52	9.73 ± 2.34
Crude fat (%)	3.68 ± 0.68	6.11 ± 0.42	11.50 ± 1.77
Fiber (%)	3.31 ± 1.25	1.7 ± 0.5	29.60 ± 1.25
Crude protein (%)	27.46 ± 1.60	27.88 ± 3.75	19.50 ± 0.73
Carbohydrate (%)	32.34 ± 0.24	34.31 ± 0.30	9.18 ± 0.86
Caloric value (kcal/100g)	213	241	176

Table 3. *Vitamin and Mineral composition of Bitter gourd [65].*

Vitamins	Concentration (ppm)	Elements	Concentration (ppm)
A	traces	Calcium	20510.00 ± 5.77
E	800 ± 14	Magnesium	255.00 ± 0.69
C	66000 ± 141	Sodium	2200.00 ± 1.15
B_{12}	5355 ±7.10	Potassium	413.00 ± 1.45
Folic acid	20600± 42.43	Iron	98.00 ± 0.23
		Zinc	120.00 ± 1.15
		Manganese	156.00 ± 0.33
		Copper	32.00 ± 1.85

In numerous studies, at least three different groups of constituents found in all parts of bitter gourd have clinically shown the hypoglycemic properties (blood sugar lowering) or other actions of potential benefit against diabetes mellitus. These hypoglycemic chemicals include a mixture of steroidal saponins known as charantins, insulin-like peptides, and alkaloids. The hypoglycemic effect is more pronounced in the fruit part where these chemicals are in greater abundance [9].

Some of the pytochemicals in bitter gourd have been clinically demonstrated to inhibit the enzyme guanylate cyclase that is thought to be linked to the cause of psoriasis and also necessary for the growth of leukemia and cancer cells. In addition, a protein found in bitter gourd, momordin, has clinically been proven as an anti-cancerous substance against Hodgkin's lymphoma in animal models. Other proteins such as α- and β-momorcharin and cucurbitacin B have also been tested for the possible anti-cancerous effects. A chemical analog of these proteins was developed, patented, and named as "MAP-30"; its developers reported that it was able to inhibit prostate tumor growth significantly. Two of

these proteins- α- and β-momorcharin have also been reported to inhibit HIV virus based on *in vitro* studies. In one study, HIV-infected cells treated with α- and β-momorcharin showed a nearly complete loss of viral antigen while healthy cells were largely unaffected. The inventor of MAP-30 filed another patent which stated it was "useful for treating tumors and HIV infections." Another clinical study showed that MAP-30's antiviral activity was also relative to the herpes virus *in vitro*.

The proximate composition of leaf, fruit and seeds of bitter gourd are given in Table-2. Bitter gourd being rich in all the essential vitamins and minerals, especially vitamin A, B_1, B_2, C and iron (Table-3), its regular use can prevent hypertension, eye complications, neuritis and defective metabolism of carbohydrates [10].

4. Use as a Folk Medicine

Medicinally, the plant has a long history of use by the indigenous people of the Amazon. A leaf tea is employed for diabetes; as a carminative for colic; topically for sores, wounds, and infections; internally and externally for worms and parasites; as an emmenagogue; and as an antiviral for measles, hepatitis, and feverish conditions. It is antidotal, antipyretic tonic, appetizing, stomachic, anti-bilious and laxative [11]. It is also used in native medicines of Asia and Africa particularly for enhancing the digestion, metabolism, blood circulation, immunity and robustness. According to *Ayurveta*, and Indian system of medicine, bitter guard causes *vatta*, reduces *kuph* and *pitta* and controls fever, blood impurities and jaundice. Moreover, this vegetable is beneficial in curing liver diseases, skin ailments and other windy complaints [12].

Folk wisdom has it that bitter gourd helps to prevent or counteract type-II diabetes. A scientific study at the Jawaharlal Institute of Postgraduate Medical Education and Research, India, proved that consumption of bitter gourd could significantly increase the insulin sensitivity. In 2007, Department of Health, Philippine stated that bitter gourd is one of the best scientifically validated herbal plant for lowering the elevated blood sugar levels [13]. In this study, a dose of 100 mg per kilo dose per day was comparable to 2.5 mg of the anti-diabetes drug, glibenclamide, taken twice per day. Bitter gourd is sold in the Philippines as a food supplement and marketed under the trade name Charantia. Charantia capsules and tea are being exported to the United States, Canada, Europe, Mexico, Japan, Korea, and parts of the Middle East.

Bitter gourd has been used in various Asian traditional medicine systems for a very long time and traditionally it is being believed that bitter gourd stimulates digestion and also this can be helpful in people with sluggish digestion, dyspepsia, and constipation, it can sometimes make heartburn and ulcers worse [14]. The fact that bitter gourd is also a demulcent and at least a mild inflammation modulator, however means that it rarely does have these negative effects, based on clinical experience and traditional reports.

Traditional medicine of Brazil believes that bitter gourd is used for treating tumors, wounds, rheumatism, malaria, leucorrhea, inflammation, menstrual problems, diabetes, colic, fevers, worms, and also used as an abortions inducer as well as an aphrodisiac agent [15]. It is also employed topically for skin problems, vaginitis, hemorrhoids, scabies, itchy rashes, eczema, and leprosy. In Mexico, the entire plant is used for controlling diabetes and dysentery. In Peruvian herbal medicine, the leaf or aerial parts of the plant are used to treat measles, malaria, and all types of inflammation. In Nicaragua the leaf commonly is used for stomach pain, diabetes, fevers, colds, coughs, headaches, malaria, skin complaints, menstrual disorders, aches and pains, hypertension, infections, and as an aid in childbirth.

The bitter gourd is specifically used as a folk medicine for the management of diabetes. Studies have shown that it contains a hypoglycemic or insulin-like principle, designated as 'plant-insulin', which has been found highly beneficial in lowering the blood and urine sugar levels [16]. It should, therefore, be included liberally in the diet of the patients suffering from diabetes. For better results, these patients should take the juice of about four or five fruits every morning, on an empty stomach or alternatively the seeds of bitter gourd can be supplemented in food formulations in the powdered form. They can also use bitter gourd in the form of decoction by boiling the pieces in water or in the form of dry powder. The juice of fresh leaves of bitter gourd is valuable in treating piles problems. 3 teaspoonfuls of leaf juice mixed with a glassful of buttermilk should be taken every morning for about a month in this condition. A paste of the roots of bitter gourd plant can also be applied over piles with beneficial results. Bitter gourd is highly beneficial in the treatment of blood disorders like blood boils, scabies, itching, psoriasis, ring-worm and other fungal diseases. A cupful of fresh juice of bitter gourd mixed with a teaspoonful of lime juice should be taken, sip by sip, on empty stomach daily for four to six months in these conditions. Its regular use in endemic regions of leprosy acts as a preventive medicine.

The roots of this plant were used in folk medicine against respiratory disorders from ancient times [17]. A teaspoonful of the root paste mixed with an equal amount of honey or basil leaf (tulsi) juice, given once every night for a month acts as an excellent medicine for asthma, bronchitis, pharyngitis, colds and rhinitis. Leaf juice is beneficial in the treatment of alcoholism, and as an antidote it ameliorates the liver damage caused by alcohol intoxication. Fresh juice of leaves of bitter gourd is also an effective medicine in early stages of cholera and other types of diarrhea during summer. Two teaspoonfuls of this juice mixed with an equal part of white onion juice and a teaspoonful of lime juice should be given in these conditions. Though it has been claimed that bitter gourd's bitterness comes from quinine, no evidence could be located supporting this claim. Bitter gourd is traditionally regarded by Asians, as well as Panamanians and Colombians, as useful for preventing and

treating malaria. Ethnobotanical uses of different of parts of bitter guard and their medicinal application are given in table-4.

Table 4. *Ethnobotanical uses of Bitter gourd [64].*

Plant Part	Ethnobotanical uses	Type of extract
Leaf	Purgative in children Anti-helmintic, Treatment of leprosy, piles and jaundice; treatment of ringworm, bowel movement, cough, congestion and chest pain.	Leaves or Oral Hot water extract
Vein and shoots	Emmenagogue; shoots used to treat pneumonia and leucorrhagia	Hot water extract
Root	Used as an abortifacient, Root paste administered in milk to reduce the scars in small pox	Decoction
Fruit	Used for jaundice, piles, leprosy, rheumatism, gout, diabetes, hydrophobia; treatment of malarial fevers Anti-helminthic	Fruit juice
Seed	Seeds are boiled and the extremely bitter effusion is said to produce instantaneous vomiting and used to reduce fat	Hot water extract or oral

5. Culinary Practices

Bitter gourd is often used in Chinese cooking for its bitter flavor, typically in stir-fries (often with pork and douchi), soups, and also as tea. It is very popular throughout India, where it is often prepared with potatoes and served with yogurt on the side to offset the bitterness, or used in sabji. It is stuffed with spices and then fried in oil, which is very popular in Punjabi cuisine. It is a popular food in Tamil Nadu and in the South Indian state of Kerala. They use it for making a dish called *thoran* mixed with grated coconut, *theeyal* and *pachadi.* This is one of the common medicinal foods for patients with diabetes. Popular recipes include curry, deep fry with peanuts (ground nuts), and *'Pachi Pulusu'* a kind of soup made up of boiled bitter gourd, fried onions and other spices [18].

In Pakistan, bitter gourd is available in the summertime, and is cooked with lots of onions. A traditional way to cook bitter gourd curry is to peel off the skin and cut into thin slices. It is salted and exposed to direct sunlight for few hours to reduce its bitterness. After a few hours, its salty, bitter water is reduced by squeezing out the excess by hand followed by rinsing with water and frying in cooking oil along with onion. After further frying of the onions and bitter gourd, red chili powder, turmeric powder, salt, coriander powder, and a pinch of cumin seeds are also added. A little water can be sprinkled while frying the spices to prevent burning. A good amount of tomato is added to the curry, with green chilies, followed by heating. After half an hour or so, the curry is ready to serve, with soft hot flatbreads and yogurt chutney. Another dish in Pakistan calls for whole, unpeeled bitter gourd to be boiled and then stuffed with cooked ground beef. In this dish, it is recommended that the bitter gourd be left 'debittered'. It is served with hot tandoori bread, naan, chapati, or with khichri (a mixture of lentils and rice) [19].

Bitter gourd is rarely used in mainland Japan, but is a primary component of Okinawan cuisine, and is credited with Okinawan life expectancies being higher than already long Japanese ones [20]. In Indonesia, bitter gourd is prepared in various dishes, such as stir fry, cooked in coconut milk, or steamed. In Vietnam, raw bitter gourd slices consumed with dried meat floss and stuffed to make bitter gourd soup with shrimp are popular dishes. Bitter gourds stuffed with ground pork are served as a popular summer soup in the South. It is also used as the main ingredient of "stewed bitter gourd". This dish is usually cooked for the Tết holiday as its name: "bitter" reminds people not to forget or disrespect the poor living conditions experienced in the past. Vietnamese names for the plant include 'muop dang' (mướp đắng) in the North and 'kho qua' (khổ qua) in the South.

It is prepared in various dishes in the Philippines, where it is known as *Ampalaya* [21]. *Ampalaya* may also be stir-fried with ground beef and oyster sauce, or with eggs and diced tomato. A very popular dish from the Ilocos region of the Philippines, pinakbet, consists mainly of bitter gourds, eggplant, okra, string beans, tomatoes, lima beans, and other various regional vegetables stewed with a little bagoong-based stock. The young shoots and leaves may also be eaten as greens; in the Philippines, where bitter gourd leaves are commonly consumed, called *dahon* (leaves) *ng ampalaya*.

In Nepal, bitter gourd is prepared in various ways. Most prepare it as fresh *achar* (a type of pickle). For this the bitter gourd is cut into cubes or slices and sautéed covered in little oil and a sprinkle of water. When it is softened and reduced, it is minced in a mortar with a few cloves of garlic, salt and a red or green pepper. Another way is the sautéed version. In this, bitter gourd is cut in thin round slices or cubes and fried with much less oil and some salt, cumin and red chili. It is fried until the vegetable softens with hints of golden brown. It is even prepared as a curry on its own, or with potato; and made as stuffed vegetables.

In Panama, bitter gourd is known as *Balsamino*. The pods are smaller and bright orange when ripe with very sweet red seeds, but only the leaves of the plant are brewed in hot water to create a tea to treat malaria and diabetes. The leaves are allowed to steep in hot water before being strained thoroughly so that only the remaining liquid is used for the tea.

6. Pharmacological and Medicinal Uses

Several medicinal properties of the bitter gourd have been studied by various researchers that include anti-diabetic [22-24], anti-ulcerogenic [25], anti-mutagenic [26], anti-oxidative [27], anti-tumour [28], immune-modulatory acivities [29] etc. *In vitro* studies reveals that the bitter gourd proteins (α -and β-monorcharin) have inhibitory effect

against human immune deficiency virus (HIV). Leaf extracts have demonstrated broad-spectrum anti-microbial activities against *E. coli*, *Staphylococcus*, *Pseudomonas, Salmonella, Streptobacillus* and *Streptococcus* [30]. Further, it has been reported to possess anti-lipolytic, analgesic and abortifacient, [31].

6.1. Anti-Tumor Properties

Some researchers have found that Thai bitter gourd fruit contained anti-carcinogens or chemopreventive agent [32-33]. Several *in vivo* studies have demonstrated the anti-tumorous activity of the entire plant of bitter gourd. In one study, a water extract blocked the growth of rat prostate carcinoma; another study reported that a hot water extract of the entire plant inhibited the development of mammary tumors in mice. Numerous *in vitro* studies have also demonstrated the anti-cancerous and anti-leukemic activity of bitter gourd against numerous cell lines, including liver cancer, human leukemia, melanoma and solid sarcomas [34-35]. The other realm showing that bitter gourd is as an effective immunomodulator. However, one clinical trial found very limited evidence that bitter gourd might improve immune cell function in people with cancer, but this needs to be verified and amplified in other research [36].

6.2. Anti-Inflammatory Properties

Wild species of bitter gourd (WBG) is considered to be more potent in disease prevention than the cultivable species. A study on the anti-inflammatory effect of WBG on lipopolysaccharide (LPS)-stimulated RAW 264.7 macrophages suggested that WBG is beneficial for reducing LPS-induced inflammatory responses by modulating NF-kB activation. In this study, among the hot water, 95% ethanol, and ethyl acetate extracts of WBG, the ethanol extract showed a peak reduction of LPS-induced nitric oxide (NO) and prostaglandin E_2 (PGE_2) production and inducible nitric oxide synthase (iNOS) and pro-interleukin-1 β expression. LPS-induced cyclooxygenase-2 expression was not affected by WBG extracts. Compared to WBG, the extracts of normal bitter gourd showed a lesser inhibition on LPS-induced events. Electrophoretic mobility shift assay further showed that both the hot water and the ethanol extracts of WBG inhibited NF-kB activation. Although information is lacking on the bioactive components of WBG, the phenolic compound contents of each extract significantly paralleled its anti-inflammatory ability [37].

6.3. Anti-oxidant Properties

Wu and Ng (2007) found that extracts of wild bitter gourd grown in Taiwan, possessed higher antioxidant and free radical-scavenging activities than the normal ones [38]. Kubola et al. (2008) investigated the antioxidant activity of the water extract of leaf, stem and fruit fractions by several *in vitro* systems of assay, viz. DPPH radical-scavenging activity, hydroxyl radical-scavenging activity, β-carotene- linoleate bleaching assay, ferric reducing/antioxidant power (FRAP) assay and total antioxidant capacity [39]. Total phenolic content was measured by Folin-Ciocalteu reagent. The extracts of different fractions were found to have different levels of antioxidant activity in the systems tested. The leaf extract showed the highest value of antioxidant activity, based on DPPH radical-scavenging activity and ferric reducing power, while the green fruit extract showed the highest value of antioxidant activity, based on hydroxyl radical-scavenging activity, β-carotene- linoleate bleaching assay and total antioxidant capacity. The predominant phenolic compounds were gallic acid, followed by caffeic acid and catechin. The study demonstrated that the water extract fractions of bitter gourd have different responses with different antioxidant methods. Total phenol content was shown to provide the highest association with FRAP assay.

In a study conducted on bitter gourd and its fractions, total phenolics and total flavonoids were found to be in positive correlations with antioxygenic activities determined by the β-carotene-bleaching, ammonium thiocyanate and DPPH radical-scavenging methods [40]. For the pulp sample, the correlations between total phenolics and the β-carotene bleaching and DPPH radical-scavenging methods were significant, while for seed samples the correlations between total phenolics and the ammonium thiocyanate and DPPH radical scavenging methods were also significant

In fruit, the pulp portion showed higher anti-oxygenic activity compared than seeds, which may be ascribed to their different phenolic and flavonoid compositions [39]. Ethanol/water extracts of both pulp and seed powders exhibited higher anti-oxygenic activities compared with other solvent extracts when evaluated for anti-oxygenic activity by any of the methods.

6.4. Anti-Viral Properties

Bitter gourd, like several of its isolated plant chemicals, has also been documented with *in vitro* anti-viral activity against numerous viruses, including Epstein-Barr, herpes, and HIV viruses. In an *in vivo* study, the leaf extract showed an increased resistance to viral infections and had an immunostimulant effect as well in humans and animals, and also increased the interferon production and natural killer cell activity. Since the anti-viral compounds of bitter gourd mostly are of proteins or glycoprotein (lectins) in nature, the oral intake of bitter gourd may not slow down the HIV multiplication in infected people due to its poor absorption. Oral ingestion of bitter gourd could offset the negative effects of anti-HIV drugs, if the test tube studies can be translated into clinical applications. In one preliminary clinical trial, an enema form of a bitter gourd extract showed some benefits in people infected with HIV [41]. However, more research is necessary before this could be recommended.

Various extracts of the leaves have demonstrated *in vitro* anti-bacterial activities [42] against *E. coli, Staphylococcus, Pseudomonas, Salmonella, Streptobacillus* and *Streptococcus*. An extract of the entire plant was shown to have anti-protozoal activity against *Entamoeba histolytica* [43]. The

fruit and fruit juice have demonstrated the same type of anti-bacterial properties and, in another study, a fruit extract demonstrated activity against the stomach ulcer-causing bacteria *Helicobacter pylori*.

6.5. Hypolipidemic Properties

In an *in vivo* study, the elevated cholesterol and triglyceride levels in diabetic rats were returned to normal value after 21 days of administration of bitter gourd fruit and/or seeds [22]. Noguchi et al. (2001) evaluated the effects of bitter gourd oil (BGO) on the blood and liver lipids of rats [44]. Fatty acid analysis from this study showed the presence of (cis) 9, (*trans*) 11 and (n3)18:3 in the liver of rat group treated with BGO diets, on the contrary this conjugated linoleic acid (CLA) isomer was almost absent in the liver of rats fed with control diet. Furthermore, dietary BGO decreased the concentration of 18:2 (n-6), increased the concentration of 22:6 (n-3), and also affected the levels of plasma hydroperoxides.

6.6. Anti-Diabetic Properties

To date, more than 100 *in vivo* studies have demonstrated the blood sugar-lowering effect of this bitter fruit. The fruit has also shown the ability to enhance cells' uptake of glucose, to promote insulin release, and to potentiate the effect of insulin. The bioactive compounds present in bitter gourd activate a protein called AMPK (AMP-activated protein kinase α), which is well known for regulating fuel metabolism and enabling glucose uptake processes which are impaired in patients with diabetes. A study by Virdi et al (2003) observed that extract or powder of fresh and dried whole fruit remarkably lowered the blood sugar in diabetic rats [45]. Batran et al. (2006) further reported that bitter gourd extracts has anti-diabetic, hepato-renal protective and hypolipidemic effects in alloxan-induced diabetic rats [1]. Recently, Wehash et al. (2012) reported that bitter melon appears to be exerting in reducing capillary permeability than the fenugreek extract. In general, the increase in capillary permeability is a sign of microvascular dysfunction at the arteriolar and capillary level, which is a common and severe complication of diabetes [46]. More recently, a detailed anti-diabetic mechanism has been reviewed by Joseph and Jini, 2013 [47].

Lectin of bitter gourd has insulin-like activity and which is due to its linking together of 2 insulin receptors. This lectin lowers blood glucose concentrations by acting on peripheral tissues and, similar to insulin's effects in the brain, suppressing appetite. Lectin is likely a major contributor to the hypoglycemic effect that develops after eating bitter gourd and it may be a way of managing adult-onset diabetes. Lectin binding is non-protein specific, and this is likely why bitter gourd has been credited with immunostimulatory activity - by linking receptors that modulate the immune system, thereby stimulating said receptors.

Vijayalakshmi et al. (2009) studied the changes in glycol-conjugate metabolism during the development of diabetic complications and their modulation by feeding bitter gourd and spent turmeric as a fiber-rich source [48]. Treatment resulted in decreased level of total sugar content in liver, spleen, and brain while an increase in amount was observed in heart and lungs. Uronic acid content got decreased in liver, spleen and brain, and a marginal increase was also observed in testis. Amino sugar content decreased in liver, spleen, lungs and heart in patients with diabetes. Decrease in sulfation of glycoconjugates was observed in liver, spleen, lungs and heart during diabetes and this effect was significantly ameliorated by treatment with bitter gourd and spent turmeric, except in brain tissues. Protein content decreased in liver, while higher level was observed in brain. The studies clearly showed the ameliorative properties by slowing down the release of glucose from fiber in the gastrointestinal tract (GI) and short-chain fatty acid production from fiber by colon microbes.

Effect of bitter gourd on streptozotocin-induced diabetic rats with particular emphasis on kidney heparin sulfate (HS) was studied by Sureshkumar et al. [49]. This Study showed a partial reversal of all the diabetes induced effects by bitter gourd. Increase in the components of glycol-conjugates during diabetes was significantly decreased by the feeding of bitter gourd. Diabetes associated elevation in the activities of enzymes involved in the synthesis and degradation of glycosaminoglycans (GAGs) were significantly lowered by bitter gourd supplementation. GAGs composition revealed decrease in amino sugar, and uronic acid contents during diabetes and bitter gourd feeding was effective in countering this reduction. Decrease in sulfate content in the GAGs during diabetes was also ameliorated by the intake of bitter gourd. HS treatment resulted in 43% reduction of diabetic rats whereas bitter gourd feeding to diabetic rats showed 27% reduction. These results clearly indicated the beneficial role of bitter gourd in controlling glyco-conjugate and heparin sulfate related kidney complications during diabetes thus prolonging late complications of diabetes.

A study [50] in mice revealed that lipid and saponin extracts of melon are more effective in lowering glycated haemoglobin levels and excessive body weight gain than the hydrophilic extract or the whole fruit. White bitter gourd varieties were found to contain significantly lower saponin concentrations (0.25%) compared to green varieties (0.67%). The lipid extract contained higher amounts of conjugated linoleic and linolenic acids i.e up to 65.89%.

Charantin is one of the hypoglycemic compounds consisting of a mixture of (1:1) sitosteryl glucoside ($C_{35}H_{60}O_6$) and stigmasteryl glucoside ($C_{35}H_{58}O_6$), belongs to steroidal saponins. Lolitkar and Rao (2010) have shown that charantin when taken either orally or intravenously in rabbits, it produces hypoglycemic effects [51]. Protein P- insulin is an another hypoglycemic agent of polypeptide in nature with the molecular weight of about 11,000 Da and consists of 166 amino acids. Clinical study revealed that the polypeptide-p-ZnCl2 produced blood sugar lowering effect. Khanna and Mohan (1973) reported that besides the fruits, p- insulin was also found in seeds and tissue cultures of bitter gourd [52].

According to Dutta et al. [53] and Barron et al. [54] the seeds of bitter gourd contain pyrimidine nucleoside, vicine which has been found to induce hypoglycemia in rats, when administered intraperitonially. Charantin-rich extract is a potential agent for increasing insulin-sensitivity in type 2 diabetic (T2D) patients [55]. Recently, 8 new cucurbitane-type glycosides were isolated by bioactivity-guided fractionation that also exhibited a hypoglycemic effect *in vitro* [56].

7. Current Practical Uses

Over the years scientists have verified many of the traditional uses of this bitter plant that continues to be an important natural remedy in herbal medicine systems. Although bitter gourd has medicinal uses as discussed above, the available scientific data are not sufficient to recommend its usage in treating these ailments, in the absence of careful supervision and monitoring. Investigation of the traditional uses of this plant in India revealed as one of the most important plants for ethnobotanical practices. Bitter gourd products are employed by natural health practitioners for treating diabetes, virus infections, colds and flu, cancer and tumors, hypercholesterolemia and psoriasis. However, more clinical studies are warranted in order to support the morale of the practitioners' and the users.

8. Bitter Gourd Supplements/Products

Bitter gourd based supplements are prepared using the whole herb/vine powders and concentrated fruit and seed extracts and are becoming more widely popular in many countries. Bitter Melon Extract-Solaray (500 mg capsule with 15% charantin) is marketed for hypoglycemic effect in blood. The other marketed products include Himalaya Bitter Melon capsule, Nature's Goodness Australia Bitter Melon 500mg, Puritan's Pride bitter melon capsules, ampalaya tea etc [57]. But the claims of these products have not been evaluated by the Food and Drug Administration and therefore needs further validation.

9. Conclusion and Future Prospects

Over all, most of the scientific studies suggest that a regular consumption of bitter gourd certainly can circumvent various health related problems either by its prophylactic or therapeutic actions. There is a wide scope in the processing sectors for the development of food products by using isolated compounds or crude extracts. However, currently only fewer items like concentrated fruit, seed extracts in the form of capsules and tablets, herb/vine powders are available and therefore further studies are needed to increase the products numbers in the global market. Moreover, nanoencapsulation of active ingredients using various biocompatible polymers is also required as an emerging and promising strategy to increase its sustained release property as well as enhanced bioavailability.

References

[1] Batran, SAES, El-Gengaihi SE, & El-Shabrawya OA. Some toxicological studies of Momordica charantia L. on albino rats in normal and alloxan diabetic rats. J Ethnopharmacol. 2006; 108: 236-242.

[2] Kirtikar KR, & Basu BD. In: E. Blatter, J. F. Caius, K. S. Mhaskar (2ndEds.), Indian medicinal plants (Vol. 2). Allahabad, India: Lalit Mohan Basu; 1993. p 1182

[3] Bown D. The Herb Society of America Encyclopedia of Herbs & Their Uses. (1st ed.,) Dorling Kindersley Publishing Inc, New Yark.1995; p:135.

[4] Hooker JD. The Flora of British India. (Vol. 2). Reeve & Co Ltd. The Oast House, Brook, NR.Asford. Kent, England; 1961.

[5] Alessandra B, Tiziana S, Manuela DA, & Maria PG. Chemical composition and antimicrobial activity of Momordica charantia seed essential oil. Fitoterapia. 2008; 79: 123-125.

[6] Budrat P, & Shotipruk A. Enhanced recovery of phenolic compounds from bitter melon (*Momordica charantia*) by subcritical water extraction. Sep Purific Technol. 2009; 66:125-129.

[7] Yuwai KE, Rao KS, Kaluwin C, Jones GP & Rivett DE. Chemical composition of *Momordica charantia* L. fruits. J Agric Food Chem. 1991; 39: 1762-1763.

[8] Li QY, Chen HB, Liu ZM & Wang B. Cucurbitane triterpenoids from *Momordica charantia*. Chinese Chemical Lett. 2007; 18: 843-845.

[9] Chopra RN, Nayar SL, & Chopra IC. Glossary of Indian Medicinal Plants. NISCAIR, (7th ed). CSIR, New Delhi; 2006.p. 151-152.

[10] Baldwa VS, Bhandari CM, Pangaria A, Goyal RK.. Clinical trial in patients with diabetes mellitus of an insulin-like compound obtained from plant source. Upsala J Med Sci, 1977; 82: 39-41.

[11] Nadkarni KM. In: Indian Materia Medica (2007) Vol. II. Popular Prakashan, Mumbai., 296.

[12] Satyavati GV, Raina MK, Sharma M. Medicinal Plants of India. Vol I, ICMR, New Delhi, India; 1987. p. 317-320.

[13] Kumar DS, Sharathnath KV, Yogeswaran P, Harani A, Sudhakar K, Sudha P & Banji D. A medicinal potency of *Momordica charantia.* International Journal of Pharmaceutical Sciences Review and Research. 2010; 1(2): 95-100.

[14] Leslie Taylor: In: Herbal Secrets of the Rainforest, 2nd edition, Sage Press, Inc., 2002

[15] Maiti R, Satya P, Rajkumar D& Ramasamy A. Crop plant anatomy.2012.CPI Group (UK) Ltd, Croydon,CRO 4YY.

[16] Abascal K & Yarnell E. Using bitter gourd to treat diabetes. Altern Complemen Ther. 2005; 11(4): 179-184.

[17] Bhakru HK. Foods that heal (The natural way to good life). Orient paperback.New Delhi.1st Edition, 1990.

[18] The wealth of India. Vol. 6. Publication and Information Directorate. CSIR, New Delhi; 1962. p. 411.

[19] http://www.medicalhealthguide.com/articles/ampalaya.htm

[20] Lim TK. Edible Medicinal And Non-Medicinal Plants: Volume 2, Fruits. Springer Science and Business Media BV.2012.

[21] Rashmi T, Wadher KJ, Taksande JB, Umekar MJ. Bitter melon: A Bitter body with a sweet soul. International Journal of Research in Ayurveda and Pharmacy. 2011; 2(2): 443-447.

[22] Ahmed I, Adeghate E, Sharma AK, Pallot, DJ, & Singh, J. Effects of *Momordica charantia* fruit juice on islet morphology in the pancreas of the streptozotocin-diabetic rat. Diabetes Res Clin Pract. 1998; 40:145-151.

[23] Matsuda H, Li Y, Yamahara J & Yoshikawa M. Inhibition of gastric emptying by triterpene saponin, momordin Ic, in mice: roles of blood glucose, capsaicin-sensitive sensory nerves, and central nervous system. J Pharmacol Exp Ther. 1999; 289:729- 34.

[24] Raza H, Ahmed I, John A & Sharma AK. Modulation of xenobiotic metabolism and oxidative stress in chronic streptozotocin-induced diabetic rats fed with *Momordica charantia* fruit extract. J Biochem Mol Toxicol. 2000;14:131-139.

[25] Gürbüz I, Akyüz C, Yesilada E, & Sener B.. Anti-ulcerogenic effect of *Momordica charantia* L. fruits on various ulcer models in rats. J Ethnopharmacol. 2000; 71; 77-82

[26] Guevara AP, Lim-Sylianco C, Dayrit F, & Finch P. Antimutagens from *Momordica charantia*. Mutat Res. 1990; 230:121-126.

[27] Scartezzini P & Speroni E. Review on some plants of Indian traditional medicine with antioxidant activity. J Ethnopharmacol. 2000; 71: 23-43.

[28] Lee-Huang S, Huang PL, Chen HC, Huang PL, Bourinbaiar A, Huang HI, & Kung HF. Anti-HIV and anti-tumor activities of recombinant MAP30 from bitter melon. Gene, 1995; 161(2):151-6.

[29] Spreafico F, Malfiore C, Moras ML, Marmonti L, Filippeschi S, Barbieri L, Perocco P & Stirpe F. The immunomodulatory activity of the plant proteins Momordica charantia inhibitor and pokeweed antiviral protein. Int J Immunopharmacol. 1983; 5:335-343.

[30] Patil SA & Patil SB. Toxicological studies of *Momordica charantia* Linn Seed extracts in Male Mice. Int J Morphol. 2011; 29(4):1212-1218.

[31] Singh A, Singh PS & Bamezai R. Momordica charantia L. (Bitter Gourd) peel, pulp, seed and whole fruit extract inhibits mouse skin papillomagenesis. Toxicol Letters. 1998; 94: 37-46.

[32] Kusamran WR, Tepsuwan A & Kupradinun P. Antimutagenic and anticarcinogenic potentials of some Thai vegetables. Mutat Res. 1998; 402: 247-258.

[33] Yasui Y, Hosokawa M, Sahara T, Suzuki R, Ohgiya S, Kohno H, Tanaka T & Miyashita K. Bitter gourd seed fatty acid rich in 9c, 11t, 13t-conjugated linolenic acid induces apoptosis and up-regulates the GADD45, p53 and PPARγ in human colon cancer Caco-2 cells. Prostaglandins, Leukotrienes and Essential Fatty Acids. 2005;73 (2): 113-119.

[34] Fang EF, Zhang CZY, Wong JH, Shen JY, Li CH, Ng TB .The MAP30 protein from bitter gourd *Momordica charantia* seeds promotes apoptosis in liver cancer cells *in vitro* and *in vivo*. Cancer Letters. 2012; 324(1): 66-74.

[35] Grover JK &Yadav SP. Pharmacological actions and potential uses of *Momordica charantia* : A review. *Journal of Ethnopharmacology.* 2004; 93(1): 123-132.

[36] Pongnikorn S, Fongmoon D, Kasinrerk W& Limtrakul PN. Effect of bitter melon (*Momordica charantia* Linn) on level and function of natural killer cells in cervical cancer patients with radiotherapy. J Med Assoc Thai. 2003; 86(1): 61-8.

[37] Lii CK, Chen HW, Yun WT & Liu KL. Suppressive effects of wild bitter gourd (*Momordica charantia* Linn. Var. abbreviate ser.) fruit extracts on inflammatory responses in RAW 264.7 macrophages. J Ethnopharmacol. 2009; 122: 227-233.

[38] Wu SJ & Ng LT. Antioxidant and free radical scavenging activities of wild bitter gourd (*Momordica charantia* Linn. var. abbreviata Ser.) in Taiwan. LWT-Food Science and Technol. 2008; 41:323-330.

[39] Kubola J & Siriamornpun S. Phenolic contents and antioxidant activities of bitter gourd (*Momordica charantia* L.) leaf stem and fruit fraction extracts in vitro. Food Chem, 2008; 110: 881-890.

[40] Padmashree A, Sharma GK, Semwal, AD & Bawa AS. Studies on the antioxygenic activity of bitter gourd (*Momordica charantia*) and its fractions using various in vitro models. J Science Food Agric. 2011; 91: 776-782.

[41] Zhang QC. Preliminary report on the use of *Momordica charantia* extract by HIV patients. J Naturopath Med. 1992; 3: 65-69.

[42] Mwambete KD. The *in vitro* antimicrobial activity of fruit and leaf crude extracts of *Momordica charantia*: a Tanzania medicinal plant. Afr Health Sci. 2009; 9(1):34-9.

[43] Gupta S, Raychaudhuri B, Banerjee S, Das B, Mukhopadhaya S & Datta SC. Momordicatin purified from fruits of *Momordica charantia* is effective to act as a potent antileishmania agent. Parasitol Int. 2010; 59(2):192-7.

[44] Noguchi R, Yasui Y, Suzuki R, Hosokawa M, Fukunaga K, & Miyashita K. Dietary effects of bitter gourd oil on blood and liver lipids of rats. Arch Biochem Biophys. 2001; 396: 207-212.

[45] Virdi J, Sivakami S, Shahani S, Suthar AC, Banavalikar MM & Biyani MK. Antihyperglycemic effects of three extracts from *Momordica charantia*. J Ethnopharmacol. 2003; 88: 107-111.

[46] Wehash FE, Abo-Ghanema I & Saleh RM. Some physiological effects of Momordica charantia and Trigonella foenum-graecum extracts in diabetic rats as compared with Cidophage®World. Academy of Science, Engineering and Technology. 2012; 64: 1206-1214.

[47] Joseph B, & Jini D. Antidiabetic effects of *Momordica charantia* (bitter melon) and its medicinal potency, Asian Pac J Trop Dis, 2013; 3: 93-102.

[48] Vijayalakshmi B, kumar SG & Salimath PV. Effect of bitter gourd and spent turmeric on glycoconjugate metabolism in streptozotocin-induced diabetic rats. J Ethanopharmacol. 2003; 11: 276-283.

[49] Sureshkumar G, Shetty AK & Salimat PV. Modulatory effect of bitter gourd (*Momordica charantia* Linn.) on alterations in kidney heparin sulfate in streptozotocin-induced diabetic rats. J Ethnopharmacol. 2003;115: 276-283.

[50] Habicht D, Kind V, Rudloff S, Borsch C, Mueller AS, Pallauf J, Yang R, & Krawinkel MB. Quantification of antidiabetic extracts and compounds in bitter gourd varieties. Food Chem. 2011; 126: 172-176.

[51] Lolitkar MM, Rajarama-Rao MR.. Pharmacology of a hypoglycaemic principle isolated from the fruits of *Momordica charantia*. Linn. Ind J Pharmacy. 1966; 28: 129-133.

[52] Khanna P, & Mohan S. Isolation and identification of diosgenin and sterols from fruits and in vitro cultures of *Momordica charantia* Linn. Ind Journal Exp Biol. 1973; 11: 58-60.

[53] Dutta PK, Chakravarty AK, Chowdhury US, Pakrashi SC.. Vicine, a favism-inducing toxin from *Momordica charantia* Linn. Ind Journal Chem. 1981; 20B: 669-667.

[54] Barron D, Kaouadji M, & Mariotte AM. Etude comparative de deux cucurbitacees a usage medicinal. Planta Medica. 1982; 46: 184-186.

[55] Wang H, Kan W, Cheng T, Yu S, Chang L & Chuu J. 2014. Differential anti-diabetic effects and mechanism of action of charantin-rich extract of Taiwanese *Momordica charantia* between type 1 and type 2 diabetic mice. Food and Chemical Toxicology, 69, 347-356.

[56] Zhang L, Liaw C, Hsiao P, Huang H, Lin M, Lin Z, Hsu F, Kuo Y. Cucurbitane-type glycosides from the fruits of *Momordica charantia* and their hypoglycaemic and cytotoxic activities. Journal of Functional Foods. 2014; 6: 564-574.

[57] Husain J, Tickle IJ, & Wood SP. Crystal structure of momordin, a type I ribosome inactivating protein from the seeds of *Momordica charantia*. FEBS Lett. 1994; 342: 154-158.

[58] Xie H, Huang S, Deng H, Wu Z & Ji A. Study on chemical components of *Momordica charantia*. Zhong Yao Cai. 1998; 21: 458-459.

[59] Yuan YR, He YN, Xiong JP & Xia ZX. Three-dimensional structure of beta-momorcharin at 2.55A resolution. Acta Crystallographica Section D Biological Crystallography. 1999; 55: 1144-1151.

[60] Parkash A, Ng TB, Tso WW. Purification and characterization of charantin, a napin-like ribosomeinactivating peptide from bittergourd (*Momordica charantia*) seeds. J Peptide Res. 2002;59: 197-202.

[61] Murakami T, Matsuda EA & Yoshikawa M. Medicinal foodstuffs. Part XXI. Structures of new cucurbitane-type triterpene glycosides, goyaglycosides-a, -b, -c, -d, -e, -f, -g, and -h, and new oleanane-type triterpene saponins, goyasaponins I, II, and III, from the fresh fruit of Japanese *Momordica charantia* L. Chem Pharm Bull (Tokyo). 2001; 49(1): 54-63.

[62] Zhao G, Liu J, Deng Y, Li H, Chen J, Zhang Z, Zhou L & Qiu M. Cucurbitane-type triterpenoids from the stems and leaves of *Momordica charantia*. Fitoterapia. 2014; 95: 75-82.

[63] Yuwai KE, Sundar RK & Kaluwin CJ. Chemical composition of *Momordica charantia* L. fruits. J Agric Food Chem. 1991; 39: 1762-1763.

[64] Paul A & Raychaudhur SS. Medicinal Uses and Molecular Identification of Two *Momordica charantia* Varieties – a review. Electronic J Biol. 2010; 6: 43-51.

[65] Bakare RI, Magbagbeola OA, Akinwande AI, & Okunowo OW. Nutritional and chemical evaluation of *Momordica charantia*. J Medicinal Plants Res. 2010; 4:2189-2193.