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An Investigative Study of Medicinal Herbs for Anti-obesity Potential: (A-Review)

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ABSTRACT

Obesity is stated to be a notable concern for public health and plays a significant role in the development of numerous non-communicable diseases (NCDs), including conditions affecting the heart, metabolism, and the nervous system. The use of medicinal plants to maintain normal weight and excellent health has been researched for a very long time. However, sufficient empirical data are still lacking to support the scientific notion of the use of herbal products for weight management. Obesity has traditionally been treated with herbal remedies from both domestic and international sources, including Ayurveda (Indian Traditional Medicine System). This article provides a brief overview of obesity-related disorders and their epidemiology, then discusses the potential anti-obesity effects of plants including *Salvia plebian, Glycine max, Curcuma longa, Camellia sinensis, Moringa citrifolia*, and others using validated tested animal models. It also focuses on the active phytochemical components that give these substances their anti-obesity properties, such as daidzein, ginsenosides, curcuminoids, zingiberene, curcumene, and ellagitannin. The paper was compiled after going through marketed formulations used worldwide, clinical trials and patents based on herbal products for obesity. This review can assist numerous researchers in conducting additional research on exploring the potential.

Keywords: Benefits of anti-obesity medicinal herbs on molecular level.

INTRODUCTION

Obesity, a chronic medical condition characterized by excessive or abnormal fat accumulation in the body result in adverse metabolic, biomechanical and psychosocial health consequences. In simple words, it is a disease when a person carries excess body fat that might affect

their health. In the world the issue of obesity and overweight is increasing day by day. The person if having obesity or not can be gauged by using a parameter termed "body mass index (BMI). BMI of an individual can be calculated by dividing the weight by square of body's height expressed as kg/m^2. A BMI of 30 or above suggests that a person suffers from obesity[1]. Obesity is the major cause of many diseases like diabetes, heart diseases, reproductive diseases, liver diseases, hypertension, and high blood pressure[2]. According to WHO, the main cause of death is linked to overweight and obesity in the world. In 2016, in world around 11% men and 15% women are obese, which in total is about 13% of the world population. About 41 million of the children under the age of 5 were found obese. India is behind the United State & China among the top 10 countries of obesity patients[3].

Obesity is associated with the consumption of energy-dense foods rich in fat, lipids and by a reduction in physical activity due to increase in urbanization. Studies have noted that in terms of physical inactivity, working in an office environment predisposes to more obesity due to less energy expenditure and more time spent sitting[4]. In those pregnant, obesity also predisposes to gestational DM which can cause various adverse effects including prematurity and fetal death[5]. Many drugs are available in the market viz orlistat, cetilistat, rimonabant, sibutramine, lorcaserin, metformin, phentermine, bupropion, diethylpropion, dinitrophenol but these drugs cause severe adverse effects like liver damage, heart attack, insomnia, myocardial infarction, nausea, tachycardia, diarrhea, neuropathy, and muscle problem[6]. The drugs with their side effects are mentioned in Table 1.

Table 1: Drug/s with their mechanism of action and side effects

S. No	Drug/s name	Trade/brand name	Manufacturing company	Mechanism of action	Side effects
1	Orlistat	Xenical	Roche	Inhibit pancreatic lipase[7]	Steatorrhea[7]
2	Lorcaserin	Belviq	Arena pharmaceuticals	Selective serotonin 2C receptor (5-HT2C) agonist[8]	Hypoglycemia, headache, dizziness, and constipation[8]
3	Phentermine -Topiramate	Qsymia	Sun Pharmaceuticals Industries Ltd (phentermine), Ortho-McNeil Pharmaceutical (Topiramate)	Sympathomimetic amine (phentermine)[9], Gamma -aminobutyric acid (GABA) modulator[10]	Paresthesia, dizziness, dry mouth, constipation[11]
4	Naltrexone -Bupropion	Contrave	Orexigen Therapeutics, Inc.	Antagonist of the opioid receptor (naltrexone), reuptake inhibitors of dopamine and norepinephrine (bupropion)[12]	Vomiting, diarrhoea, constipation, dry mouth, nausea[13]
5	Liraglutide	Saxenda	Novo Nordisk	Glucagon-like peptide-1 receptor (GLP-1) agonist[14]	Decreased appetite, dyspepsia, fatigue, nausea ,hypoglycemia, dizziness, increased lipase activity[14]
6	Sibutramine	Meridia	Abbott laboratories	Sympathomimetic amine[15]	Hypertension, serotonin syndrome, dry mouth, insomnia[16]
7	Metformin	Glucophage	Bristol-Myers Squibb	Reduce appetite by attenuating hypothalamic (5' adenosine monophosphate-activated protein kinase) AMPK activity[17]	Lactic acidosis, gastrointestinal upset.[17]
8	Exenatide	Byetta	Amyla pharmaceuticals	Long-acting analogue of hormone GLP-1[18]	Severe nausea[18]
9	Pramlintide	Symlin	Amyla pharmaceuticals	Inhibits hepatic gluconeogenesis by inhibiting glucagon synthesis[19]	Pain at injection site, hypoglycemia, vomiting, stomach pain and exhaustion.[19]
10	Rimonabant	Acomplia	Sanofi-Aventis	Cannabinoid1 receptor antagonist[20]	Severe depression and predisposes to neurons related diseases.[21] neuron-related
11	Phendimetrazine	Adipost	Elite Pharmaceuticals	Sympathetic agonist[22]	Interstitial nephritis and cardiac ischemia.[22]

Due to above-fore said side effects of drugs, we selected those plants where validated model studies were known to be conducted. So this review paper focuses on epidemiology aspects of obesity as well as the validated herbs which have been demonstrated scientifically for obesity.

Methodology

The herbal plants chosen were thoroughly researched through a database along with the validated animal models. Different keywords were entered into the search engines like Pubmed, Google Scholar, ScienceDirect to search for the secondary data. Some of the examples are "herbal plants for obesity", "obesity role in different diseases", "obesity in children", "drugs use in obesity treatment". Animal studies reports were simultaneously being studied for the chosen plants using key words like "pre-clinical" or "non-clinical".

Obesity and other diseases

Obesity is a chronic condition marked by excessive body fat. Obesity is defined by a body mass index (BMI) which is determined by dividing weight in kg by height in m^2 (kg/m^2). Persons are classified in three categories on basis of BMI. Underweight or normal weight is 25 kg/m^2, followed by overweight (25 to 30 kg/m^2), moderate obesity (30 to 35 kg/m^2), and severe obesity (BMI 35 kg/m^2).[23] In recent decades, the prevalence of obesity has risen rapidly in both Western societies and the developing world[24]. As per previous studies in 2014, the number of obese people in the world increased upto 641 million out of which 266 million are men and 375 million are women as compared to the year 1975 [105 million total adults out of which 34 million are men and 71 million are women]. If this trend continues, worldwide obesity prevalence is anticipated to reach 18% in men and 21% in women by 2025[25]. Overall, obesity is a chronic recurring and increasing disease[26] and a prominent possible risk for global fatalities. Furthermore, significant weight increase tendencies have been recorded for children and adolescents, weakening the present and future health status of the community[27-30]. The World Health Organization (WHO) labelled obesity a global epidemic to emphasize the threat to public health, yet it remains an under-recognized public health problem in many areas[23,31,32].

Obesity, depending on the degree and length of weight gain, can induce and/or exacerbate a wide range of co-morbidities, including type 2 diabetes mellitus (T2DM), cardiovascular disease, some types of cancer, and cognitive issues, among others Figure 1.

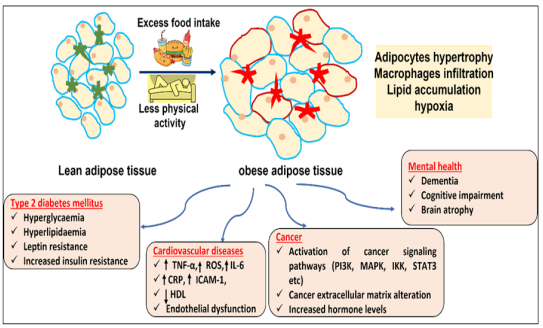

Fig. 1. Obesity-induced co-morbidities

Epidemiology of obesity

Obesity & Diabetes mellitus

The risk of having type II diabetes due to excess weight rises by a factor of 3 and obesity by a factor of 7 relative to average weight. Childhood and adolescence overweight and weight gain through early to middle-aged age are high-risk factors for diabetes[33]. Obesity itself increases the possibility of diabetes even in the absence of other metabolic disorders[34].

Obesity & cardiovascular diseases

Excess body weight is an accepted possibility for heart disease and ischemic stroke, along with the common history of dyslipidemia and hypertension[35]. Due to obesity, metabolic fat associated with visceral obesity is thought to play a major role in the process of cardiovascular disease. Several studies have revealed a decrease in life expectancy among fat people. The primary cause of excess mortality in obesity was usually found to be a cardiovascular disease as compared to normal weight[36].

General obesity and fat distribution were related to increase incidence of elevated blood pressure in a study. Obesity usually reveals much about the level of blood pressure relative to the distribution of weight. In the prospective study, the baseline BMI and the subscapular folding thickness of the skin were reported to be independent of the hypertension predictors, with an average total odds ratio of 3.85 and 3.75 for the top vs. the lowest quintile, respectively[37].

Obesity & Cancer

As per US cancer risk statistics data around the world 4.7% men (every 37, 670 new cases) and 9.6% women (every 74,690 new cases) have arisen due to obesity[38]. Diabetes being a significant risk factor for obesity, which is already a potential risk for most cancers, it has been known that obesity is associated with an increased risk of, postmenopausal, endometrial esophageal, colon, pancreatic and renal cancer[39]. A meta-analysis study found that the risk of gallbladder cancer among those overweight and obese was 15 per cent and 66 per cent higher than those of average weight, respectively. In women, the correlation between obesity and gallbladder cancer was greater than in men[40]. Excess body weight can be a risk factor for leukaemia according to cohort meta-analysis. Findings demonstrate that overweight and obese individuals are 14 per cent and 39 per cent higher than non-overweight individuals, respectively. Obesity was directly associated with both female and male leukaemia and all subtypes of leukaemia. Obesity has also been linked with a high risk of leukaemia mortality[41].

In retrospective study, the chances of patients with severe obese trauma were at least 30 per cent more likely to die and about twice as likely to have serious problems compared to non-obese patients. Several obese patients have a two-to four-fold higher risk of acute renal failure, a double higher risk of sepsis, and an elevated risk of bedsore up to eight-fold[42]. Patients with obesity have impaired respiratory physiology associated with decreased lung volume and hypoxaemic compliance, due to a limited ability to compensate this impact will be exacerbated by trauma. Patients with obesity have chances of more chest injuries, including rib fractures and contusions[43]. The implications of an epidemic of worldwide obesity may not only be a greater burden on obese chronic and infectious diseases, but it is also a higher risk of infectious diseases due to obesity[44].

Obesity & mental health

Elderly people with higher adiposity are at higher risk of brain atrophy and therefore dementia. Elderly participants were affected by obese-associated brain atrophy and confirmed to be clinically unstable for at least five years after baseline testing. The findings suggest that individuals may have greater brain atrophy due to obesity or factors influencing obesity and this atrophy may, in effect, predispose them to potential cognitive impairment and dementia[45]. Obesity has been associated with a lesser proportion of gray matter orbital cortex, including reduced efficiency in some regions of executive function in children and adolescents (aged 9 years)[46]. The risk of Alzheimer's disease raises mid-life overweight, vascular dementia or any degenerative disease by 35 per cent, 33 per cent and 26 per cent respectively; and increased risk of obesity reported[47].

Medicinal plants with anti-obesity activity

Over the years, several drugs were used to treat obesity, but most of them have now been taken off due to dangerous side effects[48]. Orlistat is the only FDA-approved long-term obesity treatment. Steatorrhea is a digestive side effect of this medication. Sibutramine, another anti-obesity medicine, was discontinued globally due to increased significant, non-fatal cardiovascular events. Pharmacotherapy failures highlight the need for further obesity treatments[49,50].

Natural products are widely used in healthcare and as dietary supplements[51]. Dietary phytochemicals have recently sparked significant interest as possible therapeutic agents for health promotion and alleviation of obesity and related diseases[52]. Plant products have long been a fruitful source for the discovery of new medications, and these are used in the most prevalent naturopathy systems due to their chemical richness and aptitude to work on numerous biological targets[53]. A diverse range of medicinal plants and their active constituents can produce beneficial anti-obesity effects such as Curcuminoids (Curcumin), Lignans (Podophyllotoxin), flavones (Apigenin, Luteolin), phenolic acids (o-Coumaric acid, chlorogenic acid), flavanols (Quercetin), phytosterols (Diosgenin, Brassicasterol, β-sitosterol), alkaloids (Caffeine), Resins (Capsaicin), Pigments (Malvidin, Pelargonidin)[54].

Few of the most famous traditional medicinal plants for the treatment/prevention of obesity as well as substitutes to synthetic drugs in obese models are discussed below and in Table 2 and depicted in Figure 2.

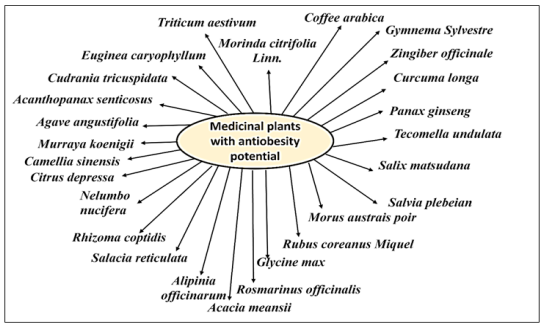

Fig. 2. Medicinal plants with anti-obesity potential

***Curcuma longa* L.** (f. Zingiberaceae) is also known as turmeric which is used as a spice mainly. It is used traditionally as Ayurvedic, Unani and Homeopathic medicine[55]. It is the plant which works against many diseases like cancer, neurological, autoimmune, cardiovascular, metabolic disorders, lung, and liver diseases. Curcuma longa contains carbohydrates, fat, minerals, and moisture also in different proportions[56].

Carbohydrate consumption is related to weight gain[57]. By elevating the adipose tissue expression of GLUT4 (Glucose transport type 4) the uptake of glucose increases. It is described that down-regulation and overexpression of GLUT4 elevate the sensitivity and glucose intolerance[58]. Curcumin by the phosphoinositide phospholipase C-phosphoinositide 3-kinase (PLC-PI3K) pathway enhances the expressions of GLUT4 through glucose uptake by skeletal muscle. Thus it helps in the management of obesity by elevating calories consumption by improving glucose utilization[59].

Panax ginseng C. A. Mey (f. Araliaceae) The root of *P. ginseng* is mainly used for treatment of different diseases like nervous disorders, anemia, overfatigue, lack of sexual desire, heart pain, nausea, shortness of breath, tuberculosis, diabetes, amnesia, and disorder of liver, kidney and heart[60]. It mainly contains vitamins, proteins, carbohydrates, niacin, calcium, iron and phosphorus[61]. The main active constituents of *P. ginseng* are saponins and polysaccharide.

The possible mechanism for lowering of reactive oxygen species (ROS) and lipid accumulation production is via the initiation of CCAAT/enhancer-binding protein-homologous protein10 (C/EBP), as it diminishes fat accumulation and down regulates the protein level of nicotinamide adenine dinucleotide phosphate (NADPH) oxidase 4[62]. Lin. *et al.,* found that when panaxoside Rb1 was given by intraperitoneal injection for 3 weeks in diet-induced obese mice, its body weight, food consumption and blood lipid profile decreased[63].

Tecomella undulata (f. Bignoniaceae) This is found in the north-west and western parts of India, as well as in the outer Himalayas. It is usually referred to as Rohitaka. It is used in the treatment of leucoderma, spleen, syphilis, spleen, skin disease, and liver disease[64]. It mainly contains alkanes, alkanols and β-sitosterols and undulatosides A & B, tecomelloside and tecoside (iridoid glucosides)[65].

Alvala, R. *et al.,* established that a dose-dependent decrease in cellular triglyceride is caused by consumption of *T. undulata*. Targets of sirtuin 1 (SIRT1) like peroxisome proliferator-activated receptor-gamma (PPAR-γ) and C/EBP which are the master regulators of adipogenesis are also reduced. The level of leptin fatty acid synthase (FAS), lipoprotein lipase (LPL), E2F1 and protein are also decreased. While the level of adiponectin is increased. *T. undulata* also inhibits lipogenesis by the activation of SIRT1[66].

Salvia plebeia (f. Lamiaceae) The genus Salvia includes more than 1000 distinct types of crops that grow extensively in hotter and tepid areas. There're around 100 species of Salvia in China, many of which are found in the southwest[67]. Steroids, phenolic acids, terpenoids and flavonoids were revealed to be the main constituents of this genus, showing comprehensive biological activities including antioxidant, antimicrobial, anti-HIV and cytotoxic activity[68].

In a study on mice Choi, SI *et al.,* reported that *Salvia plebeia* extract (SPE) therapy reduced serum, body weight, and fat accumulation levels in the tissues. SPE therapy also led in mRNA transcriptional changes in genes linked to obesity in liver tissue, epididymal adipose tissue (AT), and subcutaneous AT. In the SPE-treated group of liver and fat tissues, transcriptions of C/EBP mRNA and PPARγwere inhibited significantly. Additionally, mRNA transcription of γP2, LPL, FAS, sterol regulatory element-binding protein (SREBP-1c) and hormone-sensitive lipase (HSL) genes were

suppressed by SPE therapy. PPARγ is distributed mainly in ATs, where it controls the development of fat in cells[69].

Glycine max (f. Fabaceae) is commonly known as soybean. Soybean is indigenous to East Asia, primarily China, Korea and Japan, and later began to be cultivated in Europe, America and all across the world[70]. Dry soybean comprises 36 per cent protein, 19 per cent fat, 35 per cent carbohydrate (17 per cent of which are dietary fibres), 5 per cent minerals and many other ingredients, including vitamins, isoflavones and saponins[71,72]. According to their respective types of aglycon soy saponins are divided into three groups, soyasapogenol A, B and E. The component of saponin A and AB protects the damaged liver from oxidation and increases lipid metabolism[73].

Daidzein (Dzd) is also a chemical constituent of Glycine max which is found to have anti-obesity activity. Dzd therapies considerably decreased plasma total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), and free fatty acids (FFA). Naaz. *et al.,* also reported a slight reduction in high-density plasma lipid-cholesterol (HDL-C) levels in mice model. These findings suggest that the rise in TC by eating a high-lipid diet is due to an increase in LDL-C concentrations. As a result, the effect of Dzd was primarily expressed in the reduction of LDL-C. Dzd increased lipolysis by activating the hormone-sensitive lipase[74].

Camellia sinensis (f. Theaceae) is commonly known as Green Tea in which two different types of tea exist in the south and south-east Asia, including Malaysia and Australia. *C. sinensis*. var. sinensis is widely grown in China, Japan, and Taiwan, while in the south and south-east of Asia, Australia, and other regions of China, *C. sinensis* var. assamica (Assam tea) is in the majority in the south and southeast Asia, including Malaysia[75]. Important compounds of leaf buds and very young leaves are amino acids, carbohydrates, polyphenols, proteins, chlorophyll, volatile organic compounds, fluoride, alkaloids, aluminium, minerals and trace elements[76,77]. Many evidence have shown that green tea seems to have an anti-proliferation effect on hepatoma cells and hypolipidemic activity in hepatoma treated rats, as well as hepatoxicity and post-initiation preventive measures for mammalian cancer[78,79]. Green tea catechins may also serve as anti-tumour agents[80].

In the regulation of lipolysis and energy consumption, sympathetic nervous system (SNS) performs a vital role. Some substances that induce or delay the production of norepinephrine (NE), a significant mediator of SNS activity, can induce energy usage and promote fat oxidation. Caffeine, found naturally in green tea, also affects SNS effect by reducing phosphodiesterase, an enzyme that rapidly degrades intracellular cyclic adenosine monophosphate (cAMP) as a signal provided by NE reactions. It is possible that when taken together, green tea catechins (GTCs) and caffeine function synergistically, resulting in major effects on the SNS and thus on energy consumption and lipolysis. Another possible mechanism through which GTCs cause anti-obesity effects may be linked to improvements in fatty acid oxidation and metabolism because of NE and SNS. They facilitate lipolysis in peripheral tissues, further release the free fatty acids into circulation and increase lipid metabolism. It has also been observed that *C. sinensis* inhibits catechol-o-methyltransferase (COMT) and phosphodiesterase, which further potentially induce lipid oxidation[81].

Rubus coreanus Miquel (f. Rosaceae) is a deciduous tree with broad-leaf found in China and Korea. The fruits are frequently referred to as bokbunja in South and North Korea. It is found to constitute multiple bioactive phenolic compounds such as tannins, quercetin, flavonoids, anthocyanins, minerals, vitamins, etc. The unripe fruit is used in traditional Korean herbal medicine for the treatment of diseases like diabetes, asthma, enuresis, and allergy-related diseases[82,83].

The ripe fruits of plant have elevated anthocyanin content. The color of the plant is darker than most other berries. They possess high-quality phenolic compounds like protocatechuic acid, ellagic acid, gallic acid, H-4 blood, H-6 blood, 23-hydroxytormentic acid, and nigaichgoside[84]. The effects which were reported are anti-bacterial, anti-fatigue, anti-cancer, antihemolytic, anti-oxidant and anti-inflammatory[85-90].

The unripe *Rubus coreanus Miquel* (uRCB) butanol fraction and its five active chemical constituents (erycibelline, 4-hydroxycoumarin 5-hydroxy 2-pyridinemethanol, m-hydroxyphenylglycine and ellagic acid) have been found to prevent adipocyte heterogeneity by suppressing transcriptional

factors, including PPARγ, C/EBP and SREBP-1c, adipogenesis-related genes (acetyl-CoA carboxylase) and enzymes (fatty acid synthase). In fact, uRCB decreased body weight, fatty tissue weight (epididymal and persistent fat pad) and serum TC/TG (Triglyceride), glucose and LDL-C levels in high fat-induced (HFD) obese mice[91].

***Morinda citrifolia* Linn**. (f. Rubiaceae) a small tree or shrub native to southern Asia, which grows in the tropic areas and it, is also known as noni[92]. Many secondary metabolites are found in the different parts of the plant. They include glycosides like iridoid and triterpenoids, ursolic acid, ketones, lignans, nucleoside, sterols which are the most important components of the fruit, and several anthraquinones which accumulate primarily in the roots, but which are also found in fruit in trace amounts[93].

***Morinda citrifolia* Linn**. (f. Rubiaceae) fruit extracts have shown *in-vitro* potential for anti-obesity effects. *M. citrifolia* leaf extract (MLE) modulates adipocytic process by means of leptin like activity to demonstrate anti-obesity characteristics[94]. M. citrifolia specifically, by inhibiting LPL activity may help change TG metabolism. This may be caused due to synergistic impacts of catechin with the other phytochemicals present in the MLE and M. citrifolia fruit extract (MFE)[95]. This is endorsed by literature reporting that several flavonoids had stronger synergistic impacts than that demonstrated by a single flavonoid[96].

Zingiber officinale (f. Zingiberaceae) is known as ginger commonly, is native of Asia but is now cultivated in West India, Africa, India and other tropical areas. For ginger preparations, the underground stem (rhizome) can be obtained for white-brown colours, depending on how the surface is scrapped and how it is originally handled. This rhizome can be turned into a paste, drink, volatile oil and milk[97]. Ayurvedic Pharmacopoeia of India advocates use of dried rhizomes for dyspepsia, decreased appetite, rheumatism, tympanitis, anaemia, coughing and dyspnoea, fresh rhizomes for stomach problems, colic, oedema and mouth infections. It is often used as a postoperative antiemetic, for prevention of motion sickness, anorexia, pregnancy vomiting and bronchitis. It contains alkaloids, flavonoids, glycosides, saponins, terpenoids, tannins, polyphenols (gingerenone A) and phlobotanins, although steroids are not present[98].

The oral supplementation of ginger has significantly prevented and improved obesity from HFD triggered energy metabolism restoration, and increased gene-and protein-related browning, both in white and brown adipose tissue. Furthermore, ginger may control the cycle pathway of glycolysis/ gluconeogenesis- Tricarboxylic acid cycle (TCA) and stimulate the SIRT1/AMPK/PGC-1 (Peroxisome proliferator-activated receptor gamma coactivator 1-alpha) pathway[99]. In another study, with ginger consumption the level of interleukin-6 (IL-6) and tumor necrosis factor-α(TNF-α) in the serum and macrophage infiltrations in the epididymal white adipose tissue (eWAT) and liver of the HFD-G decreased substantially. Additionally, the addition of ginger has shown positive impacts on enhanced insulin sensitivity, insulin resistance and glucose tolerance[100]. By decreasing hypertrophy and inhibiting macrophage infiltration, gingerenone-A suppressed the growth of obesity and adipose tissue inflammation. This information collectively supports the use of gingerenone A in obesity prevention and its problems[101].

Murraya koenigii (f. Rutaceae) It is an aromatic shrub, more or less a tree up to 6 meters, reaching up to 1,500 m height in India. It is cultivated for its leaves. Plants grow best in sunny to semi-shaded sites in tropical and subtropical climates[102]. The main chemical constituents are carbazole alkaloids, coumarin glucoside and scopolin. Curry leaves decrease the amount of blood glucose significantly in diabetic patient's diet[103].

In a study, the fruit juice of M. koenigii reduced body weight as noted in medium and high dosages groups, due to loss of subcutaneous fats and blood glucose levels[104]. In another study, *M. koenigii* leaves extract-treated HFD rats lead to a time-dependent decrease in bodyweight and cholesterol, TG, reflecting anti-obesity and hypoglycemic activity in *M. koenigii*. The plant can be used as insulin-sensitive measures to achieve anti-diabetic and anti-obesity effects[105].

Table 2 illustrates some important natural anti-obesity agents and their details such as their

biological source, part used and parameters checked during their biological evaluation.

Ayurvedic formulations with their composition available in market

The market's anti-obesity products contain food ingredients, herbal compounds, and other functional supplements. The functional supplement market's most popular segment is food-based supplements. Customers prefer products manufactured from fruits (citrus, melons and berries), grains (brown rice, fermented wheat, soybean), vegetables (celery, radish, leafy greens), or drinking liquids (tea leaves). Traditional Chinese medicine uses herbal combinations including turmeric (Curcuma longa) and mulberry leaf to cure obesity (Morus alba). Asian and Western herbal medicines are common. Herbal remedies may be effective anti-obesity treatments. Probiotics and calcium supplementation are also anti-obesity. Novel anti-obesity treatments must include citrus fruits. Citrus peels and pulp contain triterpenoids, flavonoids, and alkaloids. Citrus fruit extracts lower body weight and white adipocytes weight in cell and animal tests[143]. Citrus fruit consumption decreased leptin, an important hormone produced by adipocytes which controls appetite and energy expenditure. This hormonal change is needed for citrus-based anti-obesity treatment. Methoxylated phenolic acids and flavanone glycosides in citrus fruits may impact plasma leptin levels. Green tea based anti-obesity products are also prominent in functional food. Up to 35% of green tea's dry weight includes polyphenols, which include flavanols, flavones, and flavan-3-ols. Catechins (270 to 1200 mg/day) have been demonstrated to reduce body weight, leptin levels, and fatty acid absorption in clinical trials. Tea, other medicinal components component of tea leaves, affects visceral nervous system activity and promotes energy intake and fat burning synergistically with catechins[144]. Here in the below mentioned table few marketed antiobesity products with their constitutional composition mentioned.

Clinical trials and Patents on herbal formulation for obesity treatment

Apart from the above said herbal formulations, medicinal herbs have been used in different other ways for treatment of obesity. Many plant species, probiotic microorganisms, and their combinations have been described as potential anti-obesity medications. These have many mechanisms to fight fat. Lipase enzyme inhibitors, adipogenesis modulators and adipogenic factors, appetite suppressors, and miscellaneous are the principal modes of action of these antiobesity drugs[145].

Arvind Kumar in 2009 has reported that dyeing of vastra with the specific medicinal herbs for specific dosha (vata, pitta, kapha) is presented in Ayurveda. When vastra exposed to skin, the herbs absorbed into the body through vastra and this works as a means of providing Ayurvedic treatment for a variety of disorder and diseases including obesity, which was confirmed with experimental research on medicinal plant pigment dyeing of organic natural fibres[146]. Kim and Su in 2005 have made a composition of weight loss regimen termed chegameuiintang for the treatment of obesity, which comprises varied %weights of mixture of Rehmanniae Radix preparata, Coixlacryma-jobi var. ma-yuen, Stephania tetrandra, Glycyrrhiza glabra, Akebia quinata, Polyporus umbellatus, Alisma canaliculatum, kaphanus sativus, Morus alba, Angelica gigasnakai, Lycium chinese miller, Cornus officinalis, Cnidium officinale, Carthamus tinctorius, Sinapis alba and Sisyrin chium angustifolium. It was found that the regime combined with low calorie diet contributed to reduction in the total fat mass[147].

Chung and Ju in 2008 has identified an inexpensive and safe composition comprising medicinal herbs for treating abdominal obesity and constipation, which comprises varied %weights of mixture of adlay, Atractylodis rhizoma, Aloe arborescens, Rheum palmatum, honey and propolis[148]. Kim and Yeong in 2003 has made an extract of medicinal herbs for obesity treatment and for diet, which comprises varied %weights of mixture of ginseng, Astragalus membranaceus, Imperata cylindrical, Pinellia ternate, Semen coicis, Ganoderm lucidum, Poria cocos, lotus leaves, Lonicera japonica with purified water[149]. Cheong and Hee in 2013 has made an excellent therapeutic composition to prevent and treat obesity, which comprises varied %weights of crude drug mixture of Ephedrae herb, Pinellae tuber, Rhei rhizome, Sinomenii caulis rhizoma, Gypsum natriisulfas, Persicae semen, Ponciri fructus, Magnoliae cortex, Poria cocos, Atracylodis rhizoma, Zingiberis rhizome, Grdeniae fructus, Forsythiae fructus, Arctium lappa, Glycyrrhiza radix, Scutellariae radix, mehthae herba, Schizonepeta tenuifolia and Aurantii nobilis pericarpium[150]. Other patents related to effect of medicinal plants and herbs in obesity treatment discussed in Table 4.

Table 2: Herbs with their Chemical Constituents, Extract, and Animal Models for Treatment of Obesity

Plant name	Common Name	Family	Plant part used	Chemical constituent	Model used	Parameters checked	References
Curcuma longa	Turmeric	Zingiberaceae	Rhizomes	Carbohydrates, protein, curcuminoides, fat, essential oils	HFD induced obese mice	Insulin, adiponectin in plasma, leptin level, serum TG and cholesterol levels	[106,107,108]
Panax ginseng	Korean ginseng	Araliaceae	Whole plant	Ginsenosides, alkaloids, glucosides, glucosides, phenolic acid, saponins and polysaccharides.	Male leptin-deficient (B6.VLepob, 'ob/ob') mice	Bodyweight, food intake, blood glucose, tissue PPAR-γ and LPL mRNA expression, and tissue GLUT4 and IR mRNA expression	[109,110]
Tecomella undulata	Rohida	Bignoniaceae	Bark	Iridoid glucoside, naphthoquinone, phytosterols, fatty alcohol, flavonoid glycoside, flavonol, fatty acid and triterpenoids	HFD induced obese mice	LDL, HDL, Cholesterol, TG, VLDL	[66]
Salvia plebeian	Sage weed	Lamiaceae	Leaves	Flavonoids, monoterpenoids, sesquiterpenoids, diterpenoids, triterpenes, volatile oil and phenolic acids.	HFD induced obese mice	Leptin, adiponectin, glucose, alanine aminotransferase, aspartate aminotransferase, TG, total count, HDL-C, VLDL-C	[69,112]
Glycine max	Soybean	Fabaceae	Seeds	Isoflavones, lignans, & coumestans. Major bioactive isoflavones are genistein & daidzein	ICR mice	Plasma total count, LDL-C, HDL-C, FFA	[74,113-114]
Camellia sinensis	Tea plant	Theaceae	Leaves	Polyphenols, alkaloids and caffeine, Catechins	Diet rich in fat-induced zebrafish	Bodyweight, body fat volume, fatty acid oxidation activity enzyme activity	[115-118]]
Rubus coreanus Miquel	Korean blackberry	Rosaceae	Fruit	Phenolic acids, triterpenosides, flavonoids, and ellagitannin	HFD induced obese mice	Bodyweight, fatty tissue weight, serum total count/triglyceride, glucose, LDL-C	[119-120]
Morinda citrifolia Linn.	Indian mulberry	Rubiaceae	Leaves	Iridoid glycosides, Fatty acid, Flavonol glycosides, sterol derivatives and volatile oil	HFD induced obese rats	Bodyweight, BMI, body fat, VLDL & HDL	[121,122]
Zingiber officinale	Ginger	Zingiberaceae	Dried rhizomes	$\gamma\beta$-sesquiphellandrene, $\gamma\beta$-bisabolene, ar-curcumene, $\gamma\alpha$-zingiberene, gingerols, shogaols & ketone derivative	HFD induced obese	Serum level of triacylglycerol & total count, liver lipids, TG levels, alanine aminotransferase, aspartate aminotransferase, HDL-C, LDL-C	[123,124]

Murraya koenigii	Curry leaf tree	Rutaceae	Leaves	Carbazole alkaloids, coumarin glycosides, scopoline, limonene, and linalool	HFD rats	Total cholesterol, TG, glycemia, bodyweight	[125,126]
Acacia meansii	Black Wattle	Mimosaceae	Bark	Polyphenols-catechins	HFD induced obese mice	Body weight, insulin levels, adiponectin levels	[127]
Triticum aestivum	Wheat	Poaceae	Sprout	Glycolipids, alkaloids, carbohydrates, saponins,proteins, flavonoids	HFD induced obese mice	Serum Cholesterol, body weight, LDL	[128]
Salix matsudana	Chinese Willow	Salicaceae	Leaves	Apigenin-7-o-D-glucoside	HFD induced obese mice	TG, total cholesterol	[129]
Acanthopanx senticosus	-	Araliaceae	Whole plant	Carnitine, Chiisanoside, Saponins-lupane type triterpene triglycosides	HFD induced obese mice	LDL-Cholesterol, TG	[130]
Alipinia officinarum	Galangal	Zingiberaceae	Rhizome	3-methylethergalangin, 5-hydroxy-7-(4'-hydroxy-3'-methoxyphenyl_-1-phenyl-3-heptanone	HFD induced obese mice	Pancreatic lipase, TG	[131]
Nelumbo nucifera	Lotus	Nymphaeceae	Leaves	Phenolic compounds, Flavonoids	HFD induced obese mice	Total cholesterol, TG, LDL	[132]
Salacia reticulata	Saptarangi	Celastraceae	Roots and stem	Mangiferin, (-)-epicatechin, (-)-epigallocatechin	HFD induced obese mice	Body weight, fact accumulation	[133]
Rhizoma coptidis	Huang Lian	Ranunculaceae	Dried powder	Berberine	HFD induced obese mice	Adipose weight, lipid levels, blood glucose levels	[134]
Citrus depressa	Shiikuwasa	Rutaceae	Fruits	Flavonoids	HFD induced obese mice	Body weight, TG, leptin levels	[135]
Rosmarinus officinalis	Rosemary	Lamiaceae	Leaves	Carnosic acid, carnosol	HFD induced obese mice	Body weight, TG, Cholesterol, Insulin, pancreatic lipase	[136]
Cudrania tricuspidata	Cudrang	Moraceae	Leaves	Anthocyanins, polyphenolic pigments	HFD induced obese mice	Body weight, TG	[137]
Morus austrais poir	Mulberry	Moraceae	Fruits and leaves	Rutin, resveratrol, anthocyanin and deoxynojirimycin	HFD induced obese mice	Body weight, blood glucose levels, TG, total cholesterol	[138]
Agave angustifolia	Narrow-leaf century plant	Asparagaceae	Leaves	Agavins, Fructan	HFD induced obese mice	Body weight, TG, GLP-1 levels	[139]
Coffee arabica	Coffee	Rubiaceae	Beans (seeds)	Alkaloids-Caffeine, polyphenols	HFD induced obese mice	Leptin level, IL-6 and TNF-$\alpha\gamma$ expression	[140]
Gymnema sylvestre	Gurmar	Apocynaceae	Leaves	Deacetyl gymnemic acid, catechins, polyphenols, flavonoids (theaflavin and thearubigins)	HFD induced obese mice	Body weight, Total cholesterol, TG, LDL, VLDL	[141]
Euginea caryophyllum	Clove	Myrtaceae	Flower bud	Eugenol, acetyl eugenol, caryophyllene, humulene	HFD induced obese mice	Body weight, Lipid levels, TG, LDL-C Level	[142]

Table 3: Ayurvedic formulations with their composition available in market

S. No	Name of formulation	Composition of formulation
1	Normact Tablet	Arjuna *(Terminalia arjuna)*, Upakunchika *(Nigella sativa)*, Lasuna *(Allium sativum)*, Sigru *(Moringa oleifera)*, Draksha*(Vitis vinifera)*, Sarpagandha *(Rauwolfia serpentina)*, Gandira *(Coleus Sp.)*
2	Dhootapapeshwar Kanchanar guggul	Kanchanar Twak *(Bauhinia variegate)*, Pippali *(Piper longum)*, Haritaki *(Terminalia chebula)*, Amalaki *(Phyllanthus emblica)*, Shunthi *(Zingiber officinale)*, Varun Twak *(Crataeva nurvula.Linn.)*,Tamalpatra *(Cinnamomum tamala)*, Dalchini *(Cinnamomum verum)*, Maricha *(Piper nigrum)*, Ela *(Elettaria cardamomum)*, Bibhitak *(Terminalia bellirica)*, Triphala Vishesh and Shodhit Guggul *(Commiphora wightii)*
3	Mustharishtam	Nut grass *(Cyperus Rotundus)*, gur *(jaggery)*, Dhataki Flower *(Woodfordia Fruticosa)*, Carom Seeds *(Trachyspermum Ammi)*, ginger rhizome *(Zingiber Officinale)*, black pepper *(Piper Nigrum)*, clove *(Syzygium Aromaticum)*, fenugreek *(Trigonella Foenum)*, chitrakmool *(Plumbago Zeylanica)*, cumin seeds *(Cuminum Cyminum)*
4	Obloz capsules	Guggulu *(Commiphora mukul)*, vrikshamla *(Garcinia gummi-gutta)*, lashuna *(allium sativum)*, chitraka *(plumbago zeylanica)*
5	Medohar gugglu	Black pepper *(Piper nigrum)*, ginger *(Zingiber officinale)*, pipali *(Long pepper)*, mustak *(Nut grass)*, chitrakmool *(Plumbago zeylanica)*, haritaki *(Terminalia chebula)*, vibhitaki *(Terminalia bellirica)*, amla *(Emblica officinalis)*, vaividang *(Embelia ribes)*, castor oil *(Errand tel)*
6	Vyodhari gugglu	Ginger *(Zingiber officinale)*, agni *(Plumbago zeylanica)*, haritaki *(Terminalia chebula)*, pepper *(Piper nigrum)*, gugglu *(Cammiphora mukul)*, pipali *(Long pepper)*, musta *(Cyprus rotundus)*, vidanga *(Embelia ribes)*, vibhitaki *(Terminalia bellirica)*, amla *(Emblica officinalis)*
7	Navaka gugglu	Ginger *(Zingiber officinale)*, pepper *(Piper nigrum)*, pipali *(Long pepper)*, vibhitaki *(Terminalia bellirica)*, amla *(Emblica officinalis)*, agni *(Plumbago zeylanica)*, musta *(Cyprus rotundus)*, haritaki *(Terminalia chebula)*, vidanga *(Embelia ribes)*, gugglu *(Cammiphora mukul)*
8	Garcinia Combogia extracts tablets	Garcinia cambogia *(Garcinia gummi-gutta)*, Green coffee bean (coffea arabica), Green tea *(Camellia sinensis)*, Capsicum *(Capsicum annuum)*
9	Green tea and Garcinia Combogia capsules	Garcinia Combogia HCA *(Garcinia gummi-gutta)*, Green coffee bean CGA *(Coffea arabica)*, Black pepper *(Piper nigrum)*
10	Triphala churna	Vibhitaki *(Terminalia bellirica)*, Haritaki *(Terminalia chebula)*, amla *(Emblica officinalis)*

Table 4: Herbs/herbal combination-based patents for obesity treatment

S. No	Year of Patent	Patent No.	Inventor/ Applicant Details	Details	References
				Enzyme inhibition for anti-obesity activity	
1	2010	United States patent (US7816342B2)	Bailly *et al.,*	A formulation consisting of both orlistat and glucomannan, specifically derived from konjac flour, was developed to mitigate the adverse effects linked to orlistat usage, such as occurrences like oily spotting, stools with excess fat content, urgent bowel movements, increased frequency of defecation, and loss of control over bowel movements. The formulation contained a range of 0.1% to 10% of orlistat's weight and 20% to 75% of glucomannan's weight. Glucomannan powder, a polysaccharide from of *Amorphophallus konjac* cultivated in Japan. Lipase inhibitor-orlistat and konjacflour were individually given orally with a 2-hour interval, and this process was repeated 2 to 3 times a day.	[151]
2	2010	Japanese patent JP2010265182A	Ikemoto A, Sakamoto K,	Lipase inhibition derived from the outer layer of plants belonging to the Lardizabalaceae family. This botanical family encompasses *A. quinata, A. trifoliata, A. pentaphylla, S. mube*.	[152]
3	2013	Japanese patent (JP5309292B2)	Kamada *et al.,*	A mixture with the capacity to hinder lipase activity was formulated using a blend of *P. cuspidatum, P. vulgaris, C. pulcherrima, S. samarangense, F. microcarpa, A. zerumbet, H. littoralis*, *K. pinnata, B. balsamifera, N. domestica, C. tinctorius, C. glauca*, *T. catappa*, and *P. luchuensis*. These combinations exhibited a range of lipase inhibition percentages, spanning from 48.63% to 98.18%.	[153]
4	2013	US patent (US8420131B2)	Smith *et al.,*	In the work by CA Smith, reference was made to pharmaceutical formulations containing extracts from *R. rosea* and *L. speciosa*, combined with apple polyphenols, *Gardenia fructus*. These formulations were explored for their potential in inhibiting α-glucosidase and lipase activities. The findings suggested that the supplements given to the participants had the potential to lead to decreases in weight, blood cholesterol levels, and blood glucose levels.	[154]
5	2012	United States patent (US9504725B2)	Kim *et al.,*	A formula for addressing obesity through both curative and preventive approaches employs the butanol and ethyl acetate fractions derived from the rhizomes of *P. cuspidatum*. This formulation includes an active ingredient, which is the *P. cuspidatum* extract fraction, constituting 0.1–99.9% of the total weight, alongside suitable pharmaceutical vehicle, excipients, like starch, $CaCO_3$, lactose, gelatin. Notably, butanol extract and resveratrol present in the *P. cuspidatum* demonstrated IC_{50} values 15.8±2.6 µg/mL and 124±6.7 µg/mL, respectively.	[155]
6	2017	Chinese patent (CN106962933A)	Fang *et al.,*	The formulation is comprised of extracts from *F. nelumbinis* and *N. nucifera* (leaf), *C. sinensis* (leaf), *C. obtusifolia* (seed), and V. vinifera (seed). This blend exhibited anti-obesity properties through the inhibition lipase (PL), contributing to weight reduction and the control of lipid metabolism, intestinal flora.	[156]
7	2018	Korean patent (KR20180039418A)	Noh S, Mirae S	The Industry-Academic Collaboration Foundation of Daegu Haany University revealed an antiobesity formulation incorporating *D. kaki* and *C. unshio*. This composition demonstrated the ability to decline lipid level by inhibiting of pancreatic lipase activity.	[157]

				Blocking adipogenesis and suppressing adipogenic factors	
1	2010	United States patents (US20100203078A1 & US9345732B2)	Gokaraju G, Gokaraju R, Golakoti T, *et al.,*	The dried leaves of *Holoptelea integrifolia* exhibited anti-obesity effects by impeding adipogenesis and lipolysis. Studies were conducted using 3T3-L1 cell lines, revealing that the composition's mode of action involves inhibiting adipogenesis and enhancing the process of lipolysis.	[158,159]
2	2010	Korean patent (KR100799116B1)	Kim *et al.,*	It was asserted that *Cordyceps sinensis* demonstrated antiobesity effects by damaging CCAAT enhancer binding protein alpha and Peroxisome proliferator- activated receptor gamma activities, thereby restraining the transformation of fibroblast cells into adipocytes and the synthesis triglycerides.	[160]
3	2010	A United States patent (US20100247691A1)	Kim JD.	The formulation comprises extracts of *P. semen, S herba*, and *C. fructus* in varying proportions. Notably, the combination group displayed weight reduction effects, with P semen, S herba, and C fructus contributing to reductions in body weight 27.1%, 34.1%, and 23.5%, respectively.	[161]
4	2013	United States patent (US20130102554A1)	Lee *et al.,*	The application of hydroalcoholic extracts from bran of wheat for an antiobesity formulation. Extract derived from bran of wheat consists of 9,12,13-trihydroxy-10(E)-octadecenoic acid, which effectively restricted expression of PPAR-γ, C/EBRγ, and ADD1/SREBP1c.	[162]
5	2013	United States patent (US8501249B2)	Liu *et al.,*	The formulation contained *Alpinia* galangal roots or stems and *Zingiber zerumbet* in ratios of 1:3 and 3:1. On an individual basis, these botanicals curbed the fat storage processes in adipocytes. However, their combined usage demonstrated inhibitory impacts on adipogenesis and lipid accumulation in 3T3-L1 cells.	[163]
6	2014	United States patent (US20140371326A1)	Lee KW, Seok SJ.	Gingerenone A exhibited the ability to suppress several transcription factors, including CEBPγand PPARγ, which play crucial roles in the differentiation of adipocytes.	[164]
7	2014	United States patent (US20140037678A1)	Ramazanov Z.	A formulation consisting of a beneficial quantity of fucoxanthin, both individually and in conjunction with pomegranate seed oil.	[166]
8	2015	World patent WO2015198346A1	Gokaraju G, Gokaraju. R, Gokaraju V	It comprised *Alangium salvifolium* rich in terpenes, which exhibited actions promoting lipolysis and hindering adipogenesis, leading to the reduction of obesity. The formulation improved various biological markers, including Peroxisome proliferator- activated receptor gamma, adipose differentiation related protein, CEBPA/B, CD-36, OxLDL, aP2 FABP4/A-FABP.	[167]
				Appetite suppressants	
1	2012	World patent (WO2012083414)	Foll B, Strat Y.	Formulation derived from Cannabis (C sativa, C indica/afghanica, C ruderalis) containing cannabinoids, their end product, suppress the appetite	[168]
				Miscellaneous synergistic mechanism	
1	2010	Japanese patent (JP4432069B2)	Yamashita, Takashita T.	A formulation involving *Pleurotus* species, acetone extract from *A. purpurata* containing bergenin, capsicum containing astilbin, and C forskohlii containing forskolin, possess repressive effects on adipogenesis.	[169]
2	2013	United States patent (US8563051B2)	Samuel P	A formulation for weight management using herbal components has been unveiled. The formulation consisted of extracts sourced from 3900 mg of Garcinia fruit rind, 650-700 mg of green tea leaves, 400-450 mg of green coffee beans, and 120-150 mg of leaves of banaba.	[170]
3	2015	Chinese patent (CN104757535A)	Chunhua G.	Formulation is employed as slimming pouches. This mixture suppressed the activity of vascular endothelial cells to fight obesity. The components of the formulation included Black Wolfberry, polyphenol, Japanese apricot, sodium alginate.	[171]
4	2017	United States patent (US20170042957A1)	Sybille BW	The application of *Magnifera indica*, commonly known as mango, for addressing obesity. The utilization of Magnifera extract activated the sirtuin-1 gene, which contributed to lowering the susceptibility to obesity induced cardiovascular diseases.	[172]
5	2017	South Korea patent (KR101745597B1)	*Hyun et al.,*	A formulation created utilizing active components derived from aqueous extracts of persimmon. The fermentation process involved the use of *Pediococcus acidilactici or Pediococcus pentosaceus* to ferment the persimmon and mulberry leaf extracts. The resulting extract showcased a lipolysis inhibition rate of 37.77% (with a predicted lipolysis rate of 37.62%). Additionally, approximately 1.66% of the mulberry leaf extract was obtained after a period of 40.39 hours at a temperature of 36.44°C.	[173]

6	2017	Chinese patent (CN106728464A)	Crystal *et al.,*	A formulation consists of extract powder from *C. sinensis* in the range of 10–35%, N nucifera extract powder in the range of 10–30%, and TCM plant extract ranging from 20–75%, such as *M. charantia, R. Glycyrrhizae*, and *P. grandifloras*. This composition demonstrated the ability to restrain the differentiation of pre-adipocytes while enhancing lipid absorption.	[174]
7	2017	Russian patent (RU2623872C1)	Vadimovich KB, Vladimorovih GB	A formulation designed to hypertension, hyperglycemia, obesity, elevate good cholesterol levels is comprised of red grapefruits and *G. procumbens* leaves.	[175]
8	2013	US patent (US8541383)	Gokaraju *et al.,*	A formulation containing curcuminoids, *M. olefera*, and *M. koenigii* was effective in diminishing serum cholesterol levels and TG. The study investigates inhibition and accumulation of lipids within adipocytes.	[176]
9	2014	World patent (WO2014133286A1)	Chang-gyu *et al.,*	The patented formulation comprised *A. iwayomogi* and *C. longa*, offering benefits in eliminating natural fats while also reducing levels of LDL and serum cholesterol.	[177]
10	2015	US patent (US9155773B2)	Kim *et al.,*	The antiobesity formulation incorporates extracts from M folium, Psyllium husk, hemicellulose, crystalline cellulose, pectin, alginic acid, guar gum, arabinogalactan, inulin, and indigestible maltodextrin.	[178]
11	2011	World patent (WO2011112067A1)	Zhari BI, Khalid H.	A formulation was designed utilizing nanoparticles (NPs) derived from Piper sarmentosum, including such as rutin, pellitorine, *sarmentosine*, polyphenols, flavonone, and their modified forms.	[179]
12	2014	Chinese (CN104304540A)	Wu Shaozheng	A blend of lotus leaf, Hawthorn, Gingko, and orange unveiled. This blend was employed as a tea beverage, comprising the principal raw materials like lotus leaf, hawthorn, coix seed, ginkgo leaf, dried orange peel, and green tea. The presence of flavones in Gingko leaves facilitated the dissolution of cholesterol, whereas the orange peel contained 0.15% synephrine.	[180]
13	2019	Japanese patent (JP2019014761A)	Dong Pharm Co.	A formulation derived from the root of *P. longum* was developed for addressing obesity. It has been established to stimulate the γβ-AR receptors found within both brown and white adipose tissue. Primary alkaloid piperanine, a significant component in P. longum, was identified as the agent responsible for its anti-obesity effects.	[181]
14	2018	Korean patent (KR20180132208A)	Gye-man *et al.,*	Cocktails like bitter melon and a blend of fruit and vegetables employed for their anti-obesity properties. The mixture was subjected to fermentation with the involvement of *Lactobacillus plantarum* and *L. brevis*.	[182]
15	2020	United States patent (US20200061132A1)	Kim *et al.,*	A formulation aimed at combating obesity, containing a combination of *Lactobacillus* and *Streptococcus*. The components were suggested for its potential as appetite suppressants.	[183]
16	2012	Chinese patent (CN102318697A)	Minsheng L.	The formulation comprised lotus leaves, seeds of Cassia, dried tangerine, and green tea, exhibiting antiobesity properties.	[184]
17	2016	Chinese patent (CN104435068A)	Junping *et al.,*	The formulation utilizing *Eucommia* ulmoides containing derivatives of flavonoids that contributes to body-weight management.	[185]
18	2017	World patent (WO2017064530A1)	Leal et al.	It is asserted that derivatives of saponins of Agavaceae family exhibit anti-obesity effects by diminishing blood sugar level, insulin resistance, adipocyte accumulation, fatty liver, and overall bodyweight.	[186]
19	2018	Korean patent (KR1020160099136A)	Kim T, Kim T	An anti-obesity formulation was created utilizing substances sourced from the ethyl acetate fraction of Ainsliaea acerifolia. However, specific information about the plant part employed to obtain the ethyl acetate fraction was not specified.	[187]
20	2012	United States patent US8163312B	Krishnan GG	Polyphenols like chlorogenic acid, catechin, epicatechin, and procyanidins present in apple extracts display the ability to inhibit over 70% of lipase enzyme activity. Another well-known polyphenol found in turmeric rhizome (Curcuma longa), curcumin, hails from regions including Southeast Asian countries. Lipid accumulation and fat buildup hinders Curcumin. It influences the transcription factors crucial in adipogenesis and lipogenesis, thereby impacting the differentiation of adipocytes.	[188]

CONCLUSION

Medicinal plants are one of the most essential components of complementary medicines. There are several studies that have shown the role of several herbs in obesity and overweight. The plants listed above have been considered for their potential behavior and some preliminary investigations have been carried out by the researchers on various animal models like high-fat diet rats and mice. The mechanisms of specific phytochemical constituents of plants through which bodyweight can be reduced such as curcumin enhances the expression of GLUT4 by PLC-PI3K pathway and diadzein by activating hormone-sensitive lipase enhanced lipolysis have been also discussed. This explores the chemical, pharmacological and therapeutic effects of plants as a potential herbal medication due to its health and efficacy.

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Conflict of Interest

There are no conflicts of interest declared by the author(s).

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