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Traditional Chinese medicine-based phytotherapeutics for junk food-induced obesity and metabolic dysfunction

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ABSTRACT

Obesity driven by high-sugar and high-fat dietary patterns has become a major global health challenge and is closely associated with metabolic syndrome, diabetes, and cardiovascular disorders. Growing evidence indicates that junk food disrupts lipid metabolism, alters gut microbiota, and triggers chronic inflammation, leading to systemic metabolic dysfunction. Traditional Chinese medicine (TCM), rooted in holistic regulation of organ systems, blood circulation, and energy balance, offers multi-target plant-based strategies for modulating obesity. This review summarizes key mechanisms through which Chinese medicinal plants counteract obesity, including appetite suppression, regulation of lipid metabolism, activation of thermogenesis, modulation of gut microbiota, and anti-oxidative and anti-inflammatory actions. Representative herbs such as *Panax ginseng*, *Nelumbo nucifera*, *Cinnamomum cassia*, *Gynostemma pentaphyllum*, and *Pueraria lobata* exhibit lipid-lowering, glucose-regulating, and inflammation-modulating activity in experimental and clinical studies. Overall, TCM herbal therapies provide a holistic and safe approach to correcting metabolic imbalance through multi-pathway regulation. However, standardized formulation, mechanistic validation, and large-scale clinical trials are urgently required to establish their efficacy and translational value. Future work integrating traditional knowledge with biomedical research will help position TCM-based phytotherapy as a scientifically grounded strategy for obesity prevention and management.

1 Introduction

Obesity has emerged as one of the most pressing and complex public health issues of the 21st century, affecting populations across all age groups and socioeconomic backgrounds. The World Health Organization (WHO) classifies it as a global epidemic due to its alarming increase in prevalence and its strong association with

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multiple chronic diseases, including type 2 diabetes, cardiovascular disorders, hypertension, and certain cancers [1]. Junk foods are typically rich in refined carbohydrates, saturated and trans fats, added sugars and artificial flavor enhancers, yet they are low in essential nutrients such as fiber, vitamins, and minerals. Their excessive caloric content and poor satiety value promote overconsumption and rapid accumulation of adipose tissue, particularly in visceral regions [2, 3]. Furthermore, regular consumption of such foods disrupts metabolic homeostasis, leading to insulin resistance, hyperlipidemia, oxidative stress, and chronic low-grade inflammation, key components of metabolic syndrome [4]. This syndrome not only increases susceptibility to life-threatening diseases but also accelerates physiological aging and reduces overall life expectancy. However, despite advances in pharmacotherapy and bariatric surgery, conventional interventions for obesity remain limited by side effects, high costs, and poor long-term sustainability [5]. The growing prevalence of obesity is closely linked to increased consumption of energy-dense, high-fat, and high-sugar junk foods, which disrupt appetite regulation, alter gut microbiota, and induce chronic low-grade inflammation, ultimately promoting excessive weight gain. Obesity then drives the development of metabolic syndrome through adipose tissue dysfunction, characterized by elevated inflammatory cytokines, insulin resistance, dyslipidemia, and impaired glucose metabolism. Thus, junk food acts as the primary dietary trigger for obesity, while obesity serves as the central pathological bridge leading to metabolic syndrome. Because these conditions represent a continuous metabolic disturbance rather than separate entities, understanding their interconnected mechanisms is essential. In this context, traditional Chinese medicine (TCM) offers multi-target interventions through herbal formulations, bioactive compounds, and acupuncture that may counteract diet-induced obesity and prevent its progression to metabolic syndrome [6].

In this regard, plant-based therapeutics, particularly those from TCM, have gained increasing global recognition. TCM, with a history spanning over two millennia, is founded on the principles of a holistic view of health and the balance between Yin and Yang, emphasizing the interconnection of organ systems, energy flow (Qi), and metabolic harmony [7]. Guided by these principles, TCM utilizes a variety of herbal formulations. From a modern biomedical perspective, these formulations contain diverse bioactive phytochemicals that target multiple metabolic pathways simultaneously, making them particularly suitable for addressing the multifaceted pathology of obesity [8]. Chinese medicinal plants exert anti-obesity effects through several molecular and physiological mechanisms. These include suppressing appetite via modulation of hunger-regulating hormones such as leptin and ghrelin, improving lipid metabolism by enhancing fatty acid oxidation and reducing lipogenesis, restoring gut microbiota balance and attenuating inflammatory responses that drive metabolic dysfunction [9]. Polyphenols, flavonoids, alkaloids, terpenoids, and saponins are among the primary bioactive compounds responsible for these effects. For instance, flavonoids enhance lipolysis and thermogenesis, saponins inhibit fat absorption and reduce serum lipid levels, while alkaloids modulate glucose uptake and insulin sensitivity [10].

Conversely, chronic consumption of junk foods disrupts these metabolic regulatory mechanisms. High-fat, high-sugar diets have been shown to alter gut microbial diversity, promoting the dominance of pro-inflammatory bacterial species that contribute to intestinal permeability and endotoxemia [11]. These alterations lead to persistent low-grade inflammation, oxidative stress, and abnormal triglyceride accumulation in adipose tissues, particularly in the liver and visceral fat depots. The resulting metabolic imbalance further exacerbates insulin resistance and increases the risk of developing obesity-related complications. In contrast, Chinese herbal remedies offer a promising therapeutic avenue to counteract these detrimental effects. Notably, plants such as *Camellia sinensis*, *Momordica charantia*, *Panax ginseng,* and *Coptis chinensis* have been extensively studied for their ability to reduce adiposity, regulate lipid profiles, improve glucose tolerance, and enhance overall metabolic efficiency [12]. The catechins from *Camellia sinensis* stimulate thermogenesis and energy expenditure, while charantin and polypeptide-P from *Momordica charantia* exhibit insulin-like effects that help maintain glucose homeostasis. Similarly, saponins from *Panax ginseng* activate adenosine 5'-monophosphate (AMP)-activated protein kinase (AMPK), promoting fatty acid oxidation and inhibiting adipocyte differentiation [13]. The novelty of this review lies in its focused examination of the therapeutic mechanisms of Chinese medicinal plants in managing junk food-induced obesity. By integrating traditional knowledge with emerging molecular evidence, this work highlights the synergistic potential of phytochemicals to modulate metabolic pathways, restore gut and hormonal balance, and reverse junk food-induced metabolic impairments [14]. It thereby positions plant-based interventions, grounded in traditional medicine, as safer, cost-effective, and sustainable strategies for obesity prevention and management.

2 Obesity and junk food consumption: a global epidemic

2.1 Obesity and metabolic disturbances linked to junk food consumption

The modern obesity epidemic is strongly associated with the increasing intake of processed and junk foods. Promoted for their convenience, low cost, and appealing

taste, these foods are typically energy-dense yet nutrient-poor. Their frequent consumption has emerged as a major dietary risk factor for obesity and related metabolic disorders [15]. Unlike traditional diets rich in whole grains, fruits, and vegetables, junk foods provide "empty calories" that disrupt the body's metabolic homeostasis and fuel the global obesity crisis [16]. The development of junk food-driven obesity involves multiple interconnected pathways, including excessive caloric intake, insulin resistance, gut microbiota dysregulation, and chronic low-grade inflammation. Collectively, these pathways contribute to serious complications such as cardiovascular disease, type 2 diabetes (Figure 1), and non-alcoholic fatty liver disease (NAFLD)[17].

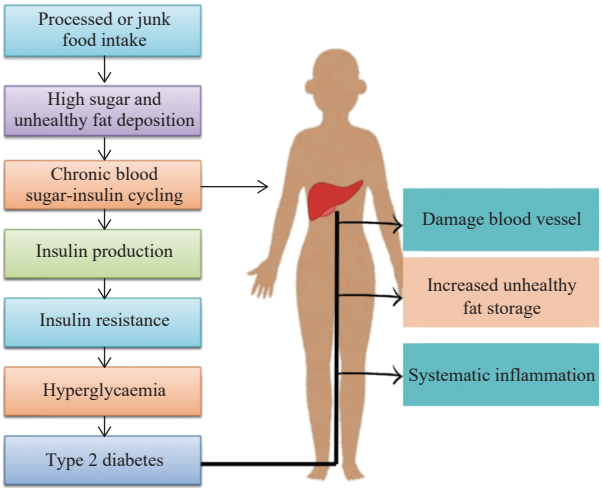

Figure 1 Pathophysiological link between junk food consumption and type 2 diabetes

2.2 Multifactorial pathology of junk food consumption

The pathology of junk food-induced obesity is multifactorial, involving intricate interactions among nutritional imbalance, metabolic dysregulation, hormonal disturbances, oxidative stress, inflammation, and gut microbiota alterations [18]. Excessive intake of refined carbohydrates and sugars leads to rapid, repeated spikes in blood glucose and insulin. This pattern promotes insulin resistance and excessive lipogenesis in adipose tissues. Similarly, high levels of saturated and trans fats elevate circulating triglycerides and low-density lipoprotein (LDL) cholesterol, contributing to hepatic steatosis and increasing cardiovascular disease risk [19]. Chronic exposure to high-fat, high-sugar diets also disrupts central appetite regulation by impairing hypothalamic signaling pathways involving leptin, ghrelin, and neuropeptide Y, resulting in overeating and a persistent positive energy balance [20]. Moreover, junk foods are typically deficient in essential micronutrients and dietary fiber, leading to poor digestive function, reduced satiety, and continuous caloric intake without meeting nutritional needs. The lack of vital nutrients, particularly antioxidants, exacerbates oxidative stress by promoting the overproduction of reactive oxygen species (ROS). ROS damage cellular components and trigger inflammatory cascades mediated by cytokines such as tumor necrosis factor (TNF)-α, interleukin (IL)-6, and C-reactive protein (CRP) [21]. This chronic low-grade inflammation contributes to adipose tissue dysfunction and insulin resistance—key hallmarks of obesity-related metabolic syndrome. Additionally, junk food consumption profoundly alters gut microbiota composition, decreasing beneficial bacterial populations such as *Bifidobacterium* and *Lactobacillus*, while promoting the growth of pathogenic species like *Firmicutes* and *Clostridium* [22]. This microbial dysbiosis increases intestinal permeability and facilitates the translocation of endotoxin into systemic circulation, further amplifying inflammation and metabolic disturbances. Furthermore, the inclusion of artificial additives, preservatives, and emulsifiers in junk foods compromises gut barrier integrity and interferes with healthy metabolic signaling [23]. Collectively, these interconnected mechanisms create a self-perpetuating cycle of excessive energy storage, hormonal dysregulation, and chronic inflammation that culminates in obesity and its associated comorbidities. Understanding this multifactorial pathology is therefore crucial for designing comprehensive prevention and therapeutic strategies that address not only caloric excess but also the underlying biochemical and molecular dysfunctions driving obesity [24].

2.2.1 Increased caloric intake Junk foods are deliberately engineered to be highly palatable and addictive, combining refined sugars, saturated fats, and salt with artificial flavor enhancers. This composition activates dopaminergic reward pathways in the brain, producing pleasurable sensations similar to the effects of addictive substances and disrupting natural satiety signals [25]. As a result, individuals consume more calories than their bodies require, leading to a sustained positive energy balance. The lack of dietary fiber, protein, vitamins, and minerals in these foods means they provide poor satiety, which encourages continuous snacking and overeating. Over time, the surplus calories are stored as triglycerides in adipose tissue, progressively leading to weight gain, obesity, and metabolic syndrome [26].

2.2.2 Insulin resistance A major metabolic consequence of junk food consumption is the development of insulin resistance, a defining feature of metabolic syndrome. Diets high in sugary beverages, fried snacks, and refined carbohydrates cause frequent and large spikes in blood glucose levels [27]. To maintain glucose homeostasis, the pancreas secretes excessive amounts of insulin. This chronic hyperinsulinemia triggers cellular insulin resistance, progressively impairing insulin signaling. As insulin effectiveness declines, the pancreas compensates by producing even more insulin, creating a vicious cycle that

ultimately leads to pancreatic β-cell dysfunction [28]. Persistently elevated glucose and insulin levels promote visceral fat accumulation, systemic inflammation, and lipid imbalances, all of which significantly raise the risk of type 2 diabetes, hypertension, and cardiovascular disease [29].

2.2.3 Altered gut microbiota The gut microbiome plays a pivotal role in regulating nutrient absorption, metabolic balance, and immune responses. Diets dominated by processed and junk foods disturb this microbial ecosystem, leading to dysbiosis, an imbalance characterized by the overgrowth of harmful bacteria and a decline in beneficial strains [30]. Dysbiosis weakens the intestinal barrier, increases gut permeability, and activates systemic inflammatory pathways. It also alters energy-harvesting mechanisms, enhancing calorie extraction and promoting fat deposition in adipose tissues [31]. Additionally, dysbiosis reduces the production of short-chain fatty acids, which are vital metabolites that regulate appetite and satiety hormones such as leptin and ghrelin. Consequently, individuals experience increased hunger and reduced fullness, perpetuating cycles of overeating (Figure 2). Thus, gut microbiota imbalance acts as both a cause and consequence of obesity, firmly linking diet quality to metabolic health [32].

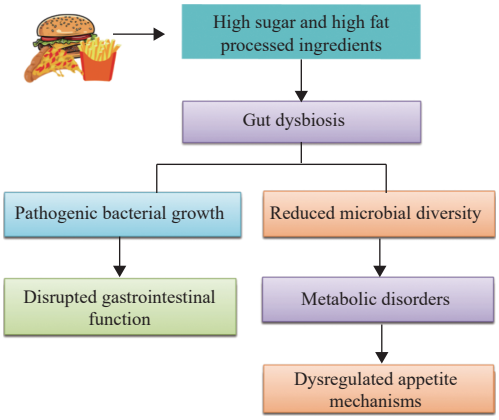

Figure 2 Mechanistic pathway of gut dysbiosis induced by high sugar and high fat diets

2.2.4 Chronic inflammation A hallmark of junk food-induced obesity is chronic low-grade inflammation (Figure 3). Processed foods containing trans fats, refined sugars, preservatives, and excess sodium trigger inflammatory pathways and oxidative stress [33]. While acute inflammation is protective, chronic systemic inflammation compromises metabolic tissues and vascular function. Continuous inflammatory signaling interferes with insulin activity, exacerbating insulin resistance and promoting the progression of type 2 diabetes [34]. It also injures blood vessel walls, encouraging atherosclerosis, which increases the risk of heart attacks and strokes. Moreover, inflammatory stress on the liver facilitates the onset of NAFLD, a rapidly rising obesity-associated condition worldwide [35, 36].

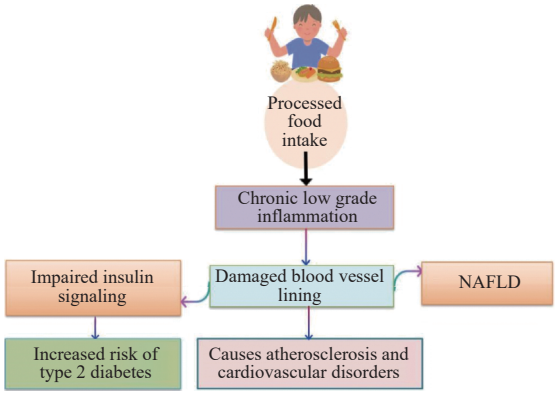

Figure 3 Pathophysiological pathways linking processed food intake to chronic diseases

3 Mechanisms of Chinese medicinal plants in obesity management

3.1 Molecular mechanisms of TCM-based anti-obesity actions

Chinese medicinal plants combat obesity through a spectrum of biological mechanisms that restore metabolic balance and promote overall metabolic health (Figure 4). Key mechanisms include appetite regulation, modulation of lipid and glucose metabolism, activation of thermogenesis, restoration of gut microbiota composition, and attenuation of inflammatory and oxidative stress responses. These multi-targeted approaches collectively reduce excess fat accumulation, improve energy utilization, and prevent obesity-related complications.

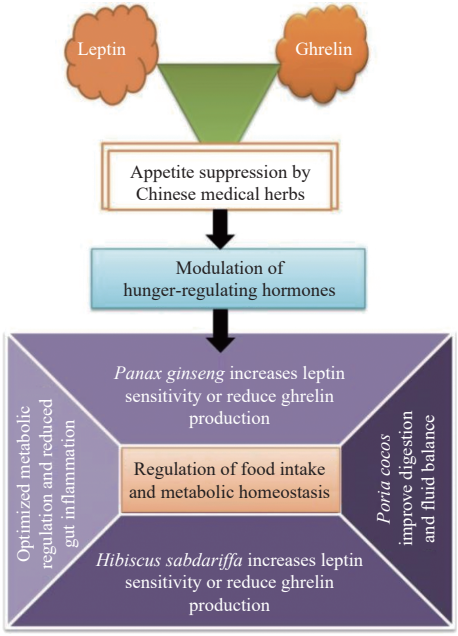

Figure 4 Role of Chinese medical herbs in appetite and hunger hormone regulation

TCM interprets obesity as a manifestation of internal imbalance involving disrupted energy metabolism, poor digestion, and impaired circulation (Table 1). Over the centuries, numerous medicinal plants have been used to restore physiological harmony, many of which are now scientifically validated for their anti-obesity properties [41]. These plants act through multiple molecular pathways that regulate appetite, lipid metabolism, thermogenesis, and glucose homeostasis. For instance, the bioactive compound epigallocatechin gallate (EGCG) activates the AMPK signaling pathway, a key energy sensor that enhances fatty acid oxidation and inhibits lipogenesis [42]. Additionally, EGCG suppresses catechol-O-methyltransferase (COMT) activity, thereby prolonging the action of norepinephrine and stimulating thermogenesis in brown adipose tissue (BAT). Together, these mechanisms increase energy expenditure and reduce fat accumulation, supporting the role of bitter melon and Poria mushroom as effective and sustainable agents for long-term weight management [43].

Panax ginseng and its active constituents, ginsenosides, exhibit strong metabolic regulatory effects that contribute to obesity management. Mechanistically, ginsenosides enhance insulin receptor substrate (IRS)-mediated signaling and promote glucose transporter type 4 (GLUT4) translocation, thereby improving cellular glucose uptake and enhancing insulin sensitivity [44]. They also activate key metabolic regulators such as peroxisome proliferator-activated receptor gamma (PPARγ) and AMPK, which together stimulate fatty acid oxidation and inhibit adipocyte differentiation. Through these mechanisms, *Panax ginseng* effectively reduces visceral fat accumulation, improves metabolic flexibility, and provides protection against obesity-related complications, including type 2 diabetes and hepatic steatosis. Similarly, *Momordica charantia* exerts multiple anti-obesity actions through insulin-mimetic and lipid-lowering pathways. Its major bioactive compounds, charantin and polypeptide-P, mimic insulin activity by stimulating glucose uptake via the phosphatidylinositol 3-kinase/protein kinase B (PI3K/Akt) signaling pathway. Additionally, *Momordica charantia* enhances the expression of carnitine palmitoyltransferase-1 (CPT-1), promoting mitochondrial β-oxidation of fatty acids, while downregulating sterol regulatory element-binding protein (SREBP)-1c, thereby suppressing *de novo* lipogenesis [45]. These coordinated molecular actions lead to reduced visceral adiposity, improved glycemic control, and better lipid metabolism. Collectively, bioactive compounds from these Chinese medical plants act on multiple, interconnected molecular networks that regulate energy balance, lipid metabolism, and adipogenesis. Unlike conventional single-target pharmacological agents, these multi-target mechanisms offer a more balanced, synergistic, and sustainable approach to the long-term management of obesity and its metabolic complications [46].

Salvia miltiorrhiza traditionally used to enhance circulation, supports liver function and lipid metabolism. It promotes the breakdown of fats, prevents hepatic lipid accumulation and contributes to cardiovascular protection, which is an essential aspect of obesity management [47]. Similarly, *Astragalus membranaceus* enhances mitochondrial function, stimulates energy expenditure, and balances glucose and lipid metabolism, thereby reducing visceral fat and improving overall energy balance. In the category of thermogenic herbs, *Citrus*

Table 1 Chinese medicinal plants with documented anti-obesity properties

Latin name	English name	Key compound	Anti-obesity/metabolic effect	Reference
Camellia sinensis	Green tea	Catechins, caffeine	Enhances fat oxidation	[11]
Panax ginseng	Ginseng	Ginsenosides	Suppresses appetite, improves lipid metabolism, and boosts energy	[12]
Ananas comosus	Pineapple	Bromelain	Improves fat digestion	[13, 14]
Crataegus pinnatifida	Hawthorn	Flavonoids	Regulates lipid metabolism	[37, 38]
Lycium barbarum	Wolfberry	Polysaccharides	Enhances antioxidant and supports metabolic balance	[39]
Angelica sinensis	Angelica	Ferulic acid	Enhances blood circulation	[40]
Nelumbo nucifera	Lotus leaf	Alkaloids, flavonoids	Reduces fat accumulation and improves lipid profile	[41]
Jasminum sambac	Jasmine tea	Flavonoids	Promotes fat oxidation	[42]
Momordica charantia	Bitter melon	Charantin	Improves glucose metabolism	[43]
Poria cocos	Poria mushroom	Triterpenes	Enhances diuretic and digestive support	[44]
Citrus reticulata	Tangerine peel	Flavonoids	Stimulates lipid metabolism	[45]
Mangifera indica	Mango seed	Polyphenols	Reduces fat storage	[46]
Cinnamomum verum/ *cassia*	Cinnamon	Cinnamaldehyde, polyphenols	Improves insulin sensitivity	[47]
Gynostemma pentaphyllum	Gynostemma	Gypenosides	Enhances fat oxidation	[48]
Pueraria lobata	Kudzu	Isoflavones (puerarin)	Reduces adipogenesis	[49]

aurantium is particularly notable. Its primary active compound, synephrine, increases metabolic rate, enhances fat oxidation, and suppresses appetite. Due to these effects, bitter orange is commonly included in contemporary weight-loss formulations [48]. In contrast, *Rheum palmatum* primarily supports digestive regulation. Its mild laxative properties aid in bowel regularity, enhance gastrointestinal function, and help prevent fat buildup by modulating nutrient absorption and lipid metabolism. *Ephedra sinica*, one of the most potent yet controversial Chinese medical plants, has been traditionally used to enhance thermogenesis, fat oxidation, and energy expenditure, while suppressing appetite [49]. However, due to its strong stimulant properties and potential cardiovascular risks, its use requires medical supervision and is restricted in many countries. Collectively, the evidence from these Chinese medicinal plants demonstrates that effective obesity management goes beyond weight reduction by addressing metabolic imbalances. Through appetite control, thermogenesis stimulation, lipid metabolism enhancement, and digestive support, they provide a holistic and multi-targeted strategy for weight regulation. These mechanisms underscore their potential as safe, effective, and sustainable alternatives to conventional anti-obesity drugs [50, 51].

3.2 Pathways of Chinese medicinal plants in obesity management

3.2.1 Appetite regulation A fundamental mechanism through which Chinese medicinal plants combat obesity is the regulation of appetite and energy intake. These herbs modulate key hunger-regulating hormones: leptin, secreted by adipose tissue, signals satiety to the hypothalamus and suppresses food intake; ghrelin, produced in the stomach, stimulates hunger during energy deficiency [52]. The dysregulation of these hormones promotes overeating and weight gain. By enhancing leptin sensitivity or inhibiting ghrelin secretion, bioactive phytochemicals in certain herbs effectively restore appetite balance and reduce caloric intake. For example, *Panax ginseng* and *Hibiscus sabdariffa* are known to suppress appetite and improve metabolic signaling, thereby contributing to reduced food consumption and improved energy balance [53].

3.2.2 Fat metabolism and lipid regulation Another critical mechanism involves the modulation of lipid metabolism. Several Chinese medicinal plant extracts enhance lipolysis and inhibit lipogenesis, thereby preventing the excessive accumulation of adipose tissue [54]. These actions lead to a reduction in visceral fat, which is closely associated with insulin resistance, cardiovascular disease, and type 2 diabetes. *Camellia sinensis*, rich in catechins such as EGCG, promotes fat oxidation and increases energy expenditure. Similarly, *Gynostemma pentaphyllum* and *Zanthoxylum bungeanum* activate key enzymes involved in lipid catabolism and regulate adipogenic transcription factors, thus shifting the metabolic balance from lipid storage toward utilization [55, 56].

3.2.3 Thermogenesis activation Thermogenesis, the process of heat generation in the body through calorie expenditure, represents a key anti-obesity mechanism. Bioactive compounds from herbs like *Cinnamomum cassia* and *Zingiber officinale* stimulate BAT, which dissipates energy as heat instead of storing it as fat [57]. This BAT activation increases the resting metabolic rate and promotes energy expenditure even at rest. Moreover, *Panax ginseng* enhances mitochondrial biogenesis and function, thereby improving cellular energy production and facilitating gradual fat reduction over time [58].

3.2.4 Gut microbiota modulation The gut microbiota plays a central role in regulating metabolism, nutrient absorption, and immune responses. Dysbiosis, microbial imbalance in the gut microbial community, is often linked to obesity through mechanisms involving increased energy extraction from food, inflammation, and altered lipid metabolism [59]. Chinese medicinal plants restore microbial homeostasis by enriching beneficial bacteria and suppressing pathogenic strains. *Dioscorea opposita* provides prebiotic fibers that serve as fermentable substrates for beneficial gut bacteria, while *Astragalus membranaceus* promotes microbial diversity and reduces intestinal inflammation. This restoration of a healthy gut microbiota enhances digestion, glucose metabolism, and overall metabolic efficiency [60, 61].

3.2.5 Anti-inflammatory and antioxidant effects Chronic low-grade inflammation and oxidative stress are hallmark features of obesity and its comorbidities [62]. Many Chinese medicinal plants contain phytochemicals with potent anti-inflammatory and antioxidant properties that counteract these pathological processes. *Curcuma longa* inhibits pro-inflammatory cytokines in adipose tissue, thereby improving insulin sensitivity. *Lycium barbarum* exhibits strong free radical-scavenging activity, protecting cellular components from oxidative damage. Additionally, *Panax ginseng* modulates immune pathways, reducing obesity-induced inflammation and oxidative stress. Collectively, these effects prevent metabolic dysfunction, protect tissues from oxidative injury, and promote overall metabolic health [63, 64]. The anti-obesity mechanisms of Chinese medicinal plants are multi-targeted and synergistic, addressing both the symptoms and root causes of metabolic imbalance. Unlike conventional single-pathway drugs, these plant-based interventions promote long-term metabolic stability through integrated regulation of appetite, lipid metabolism, gut microbiota, and inflammation, thereby offering a sustainable and holistic approach to long-term obesity management [65].

4 Clinical studies and evidence on Chinese medicinal plants in obesity management

4.1 Chinese medical plants in obesity management

Over the last two decades, a growing body of clinical and experimental research has highlighted the therapeutic potential of medicinal plants. These botanicals serve as valuable adjuncts in preventing and managing obesity and its associated metabolic complications (Figure 5 and Table 2). Various botanicals long used in traditional medical systems, including Ayurveda, TCM, and other indigenous practices, have now been systematically evaluated in clinical trials for their ability to modulate appetite regulation, lipid metabolism, glucose homeostasis, and energy expenditure [66]. Among these, *Camellia sinensis* has emerged as one of the most extensively researched plants. Numerous randomized, double-blind, placebo-controlled clinical trials have demonstrated that supplementation with *Camellia sinensis* extract significantly reduces body weight, body mass index (BMI), and waist circumference in overweight and obese individuals. A notable study published in the *American Journal of Clinical Nutrition* reported that consumption of a catechin-rich *Camellia sinensis* extract for 12 weeks led to a mean body weight reduction of 1.3 kg and a decrease in waist circumference by 1.8 cm [67]. These effects are primarily attributed to EGCG, the major catechin responsible for enhancing thermogenesis, promoting fat oxidation, and increasing overall energy expenditure. Participants also exhibited improved fat oxidation during exercise and reduced visceral fat accumulation [68].

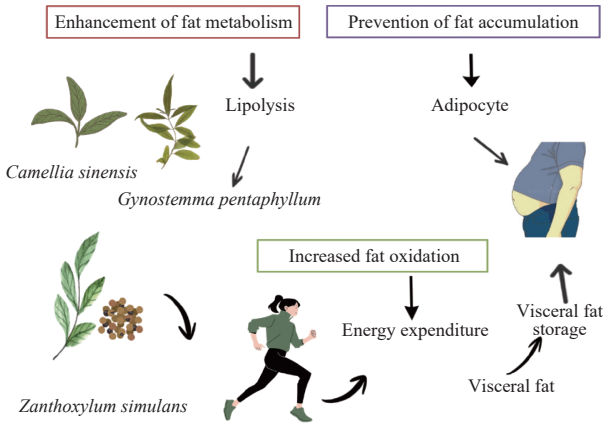

Figure 5 Role of medicinal plants in regulating fat metabolism and preventing obesity

Similarly, *Panax ginseng* has been widely studied for its metabolic and adaptogenic properties. The ginseng supplementation can enhance insulin sensitivity, regulate lipid metabolism, and reduce body fat percentage. An 8 week RCT involving obese women found that daily administration of 8 g of ginseng extract resulted in a 3% reduction in total body fat and a 15% decrease in the homeostatic model assessment for insulin resistance (HOMA-IR), indicating markedly improved insulin sensitivity [69]. Additional studies reported that ginseng not only decreases fasting glucose and triglyceride levels but also improves appetite control and overall energy metabolism. These metabolic benefits are attributed mainly to ginsenosides, which enhance insulin receptor activity, stimulate glucose uptake in peripheral tissues, and inhibit adipocyte differentiation. Interestingly, the most pronounced fat loss occurred in visceral depots, which are strongly correlated with elevated cardiometabolic risk [70]. However, clinical outcomes have been inconsistent. Some trials report metabolic improvements without substantial changes in body weight. These variable results may stem from factors such as trial duration, the ginsenoside profile of the extracts used, and interindividual differences in gut microbiota that affect the biotransformation and bioavailability of active compounds [71].

Another promising medicinal plant with anti-obesity potential is *Momordica charantia*, traditionally employed for its antidiabetic and hypolipidemic properties. Both preclinical and clinical studies have demonstrated that *Momordica charantia* extract exerts beneficial effects on body fat distribution, lipid metabolism, and glucose utilization. A randomized, placebo-controlled clinical study reported that administration of 2 g/d of *Momordica charantia* extract for 12 weeks led to a 5% reduction in visceral fat area and a 0.8 kg reduction in body weight compared with placebo, accompanied by significant improvements in serum triglycerides and fasting glucose levels [72]. The bioactive components, including

Table 2 Clinical evidence on medicinal plants for obesity management

Medicinal plant	Study design & population	Intervention	Key finding	Reference
Panax ginseng	Rondomized controlled trial (RCT), overweight adults	Ginseng extract	Reduced weight, improved insulin sensitivity	[66, 67]
Nelumbo nucifera	Clinical trial, obese subjects	Lotus leaf tea/extract	Decreased fat accumulation, improved lipid profile	[68, 69]
Cinnamomum cassia	Double-blind RCT, type 2 diabetics	Cinnamon extract/powder	Lowered glucose, improved BMI	[70, 71]
Gynostemma pentaphyllum	Clinical study, overweight adults	Gynostemma extract	Enhanced fat metabolism, weight reduction	[72, 73]
Pueraria lobata	Pilot clinical trial	Pueraria isoflavone supplement	Improved lipid metabolism, reduced adiposity	[74, 75]

charantin, polypeptide-P, and vicine, are known to enhance the activity of AMPK, thereby stimulating fatty acid oxidation, suppressing lipogenesis, and improving insulin signaling. Although some studies have reported only moderate, statistically non-significant reductions in body weight, the overall metabolic benefits, particularly the reduction of visceral adiposity and improved insulin sensitivity, are noteworthy. These findings position *Momordica charantia* as a dual-action agent against obesity and metabolic syndrome [73].

When clinically compared, *Camellia sinensis* demonstrates the most consistent evidence for weight reduction in short- to medium-term trials (8 – 12 weeks), whereas *Panax ginseng* exhibits stronger metabolic effects on improving glucose and lipid profiles, even without significant weight loss. *Momordica charantia* shows synergistic anti-obesity and antidiabetic activity, with particular efficacy in reducing visceral fat. Importantly, all three botanicals have demonstrated excellent safety profiles with minimal adverse effects, indicating their suitability as natural adjuncts in obesity management [74]. Nevertheless, the current evidence is limited by several factors: small sample sizes, short study durations, variability in extract composition, and a lack of standardized dosing protocols. These limitations collectively hinder the reproducibility and large-scale clinical translation of the findings. Collectively, the data underscore the therapeutic potential of these medicinal plants particularly *Camellia sinensis*, *Panax ginseng,* and *Momordica charantia* as complementary interventions. Their pleiotropic mechanisms, which target appetite, thermogenesis, lipid metabolism, and glucose metabolism, represent a multifaceted strategy against the complex pathophysiology of obesity. Future research should prioritize long-term, multicentric RCTs that include standardized phytochemical characterization, mechanistic biomarker evaluation, and comparative efficacy analysis to establish these botanicals as scientifically validated components of integrated obesity care [75].

4.2 Synergistic effects of multi-herb formulations in obesity management

Beyond single-herb interventions, multi-herbal formulations have gained increasing scientific attention due to their synergistic potential in modulating multiple metabolic pathways associated with obesity (Figure 6 and Table 3). The rationale for multi-herb therapy stems from the complementary and additive interactions of diverse bioactive phytoconstituents, which collectively target interrelated mechanisms such as appetite regulation, lipid metabolism, glucose homeostasis, and inflammation control. For instance, a clinical study on a polyherbal formulation comprising *Camellia sinensis*, *Panax ginseng,* and *Garcinia cambogia* reported significantly greater reductions in body weight and fat percentage after 12 weeks compared with placebo [76]. The outcomes were attributed to the combined thermogenic effects of *Camellia sinensis* catechins, the insulin-sensitizing action of ginsenosides, and the appetite-suppressing property of hydroxycitric acid from *Garcinia cambogia*. Similarly, experimental studies on traditional Chinese prescriptions such as Linggui Zhugan Decoction (苓桂术甘汤) and Qingre Huatan Formula (清热化痰方) demonstrated enhanced AMPK activation, adiponectin upregulation, and suppression of lipogenic gene expression, leading to improved lipid profiles and reduced adiposity in obese animal models [77]. These findings underscore that multi-herb formulations can act synergistically to correct the multifactorial metabolic dysregulation underlying obesity. Multi-herbal combinations can thereby yield broader and more sustained therapeutic effects than single-compound interventions by simultaneously influencing several molecular targets, including insulin resistance, mitochondrial efficiency, oxidative stress, and inflammatory signaling. However, despite promising preclinical and limited clinical evidence, the standardization, pharmacokinetic profiling, and safety validation of complex herbal mixtures present critical challenges for their clinical translation [78].

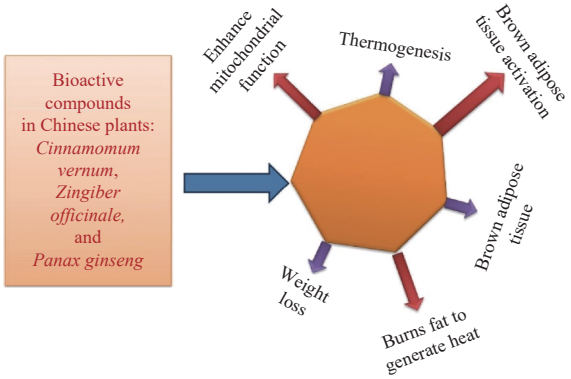

Figure 6 Bioactive compounds in Chinese medicinal plants promoting thermogenesis and fat burning

Table 3 Integrating medicinal plants into obesity treatment

Strategy	Role of medicinal plant	Outcome	Reference
Appetite regulation	Suppress hunger, enhance satiety	Reduced food intake	[76]
Lipid metabolism	Regulate fat synthesis and breakdown	Improved lipid profile	[77]
Insulin sensitivity	Enhance glucose uptake	Better glycemic control	[78, 79]
Gut microbiota	Restore microbial balance	Improved digestion, reduced inflammation	[80, 81]
Anti-inflammatory	Reduce chronic inflammation	Lower metabolic complications	[82, 83]

4.3 Safety and clinical considerations of Chinese medicinal plants in obesity management

Medicinal plants hold remarkable therapeutic potential for obesity management. However, their safety, efficacy, and clinical reliability must be carefully evaluated before routine use. The bioactive compounds in these plants often exhibit complex pharmacodynamic profiles, which can influence physiological parameters such as blood glucose, blood pressure, and hepatic function [79]. In some cases, certain botanicals may interact with prescription medications, altering drug metabolism and potentially causing adverse effects. While most medicinal plants are considered safe within the recommended limits, mild adverse effects such as allergic reactions, nausea, and gastrointestinal discomfort may occasionally occur. Hence, consulting a healthcare professional is strongly recommended before initiating any herbal regimen, particularly for individuals with pre-existing health conditions, those on antihypertensive, antidiabetic, anticoagulant medications, and lactating women [80].

Furthermore, although numerous short-term clinical studies have confirmed the beneficial effects of plant-based therapies on weight loss and metabolic regulation, there remains a critical need for long-term, large-scale RCTs. Such studies are essential to determine standardized dosages, treatment duration, bioavailability, toxicity profiles, and potential herb-drug interactions [81, 82]. Establishing these parameters will provide the scientific validation needed to ensure the safe integration of medicinal plants into mainstream obesity management. Among the most promising medicinal plants are *Camellia sinensis*, *Panax ginseng*, and *Momordica charantia*, which have demonstrated notable efficacy as complementary or adjunct therapies for obesity. When combined with comprehensive lifestyle modifications, including balanced nutrition, regular physical activity, stress management, and behavioral modification, these plant-based remedies can significantly enhance weight reduction, improve metabolic homeostasis, and reduce the risk of obesity-associated disorders, such as diabetes, hypertension, and cardiovascular disease [83, 84].

5 Lifestyle and integrated interventions

5.1 Physical activity and exercise

Physical activity is a fundamental component of effective and long-term weight management, playing a central role in regulating energy balance, improving metabolic efficiency, and enhancing overall health. When combined with medicinal plants, the benefits of physical activity can be significantly amplified due to the synergistic actions of plant-derived bioactive compounds [85]. Phytochemicals such as capsaicin, curcumin, catechins, and ginsenosides are known to stimulate thermogenesis, increase fat oxidation, and boost energy expenditure, thereby supporting more efficient weight reduction during physical exercise. These compounds also exhibit strong anti-inflammatory and antioxidant properties, which help reduce exercise-induced oxidative stress and muscular inflammation. As a result, individuals experience faster recovery, reduced muscle soreness, and improved post-exercise performance [86]. This enhancement in comfort and recovery often leads to better long-term adherence to exercise routines, an essential factor for sustainable weight loss. Furthermore, by improving endurance and metabolic flexibility, these bioactive compounds assist the body in maintaining a higher level of physical activity over time, reinforcing the overall effectiveness of weight management strategies [87].

5.2 Stress management

Psychological stress is an important, yet frequently overlooked, contributor to obesity. Chronic stress triggers emotional eating, disrupts hormonal balance, and increases preference for calorie-dense foods. Prolonged elevation of cortisol, the primary stress hormone, promotes lipogenesis, increases abdominal fat deposition, and alters appetite-regulating pathways. Adaptogenic herbs, including *Withania somnifera*, *Rhodiola rosea, Ocimum sanctum*, and *Panax ginseng* play a key role in mitigating these effects [88]. These plants help regulate cortisol secretion, modulate the hypothalamic-pituitary-adrenal (HPA) axis, and restore physiological homeostasis. By reducing stress, they effectively curb stress-induced cravings and improve overall dietary discipline. Importantly, adaptogens also enhance sleep quality, which is a crucial factor in weight regulation since inadequate sleep is strongly associated with increased hunger, reduced metabolic rate, and impaired glucose metabolism. Through these combined actions, stress-modulating medicinal plants support healthier eating behaviors, reduce the likelihood of emotional overeating, and contribute to long-term, sustainable weight management [89].

5.3 Lifestyle integration of herbal remedies for long-term metabolic health

Integrating medicinal plants into daily life offers a practical, sustainable, and culturally adaptive approach to managing obesity (Figure 7). When combined with balanced nutrition, routine exercise, and healthy lifestyle habits, these plants can support long-term metabolic health and weight control. Beyond their nutritional value, medicinal plants contribute bioactive phytochemicals that regulate appetite, modulate lipid metabolism, and promote fat oxidation [90]. One of the most accessible and effective methods to incorporate these plants is through herbal teas. Green tea, rich in catechins such as EGCG,

has been extensively documented to stimulate metabolism, enhance thermogenesis, and increase fat oxidation. Consuming 2 – 3 cups daily, particularly before exercise, can help maximize fat oxidation and increase energy expenditure. Similarly, bitter melon tea provides bioactive compounds that help regulate lipid metabolism, stabilize blood glucose levels, and reduce visceral fat accumulation [91]. Another effective dietary approach involves functional foods, in which medicinal plant extracts are incorporated into regular meals or supplements. Turmeric, ginger, and cinnamon, for instance, possess bioactive compounds that enhance insulin sensitivity, promote thermogenesis, and optimize fat metabolism [92]. Additionally, smoothies and juices enriched with powdered herbs such as matcha, turmeric, and cinnamon provide concentrated sources of antioxidants and anti-inflammatory compounds, promoting both metabolic and immune health. In addition, TCM offers centuries of empirical knowledge through herbal formulations developed for managing obesity and related metabolic disorders. However, due to the inherent complexity of such formulations, they must be used under professional supervision to ensure correct dosage and prevent herb-drug interactions [93].

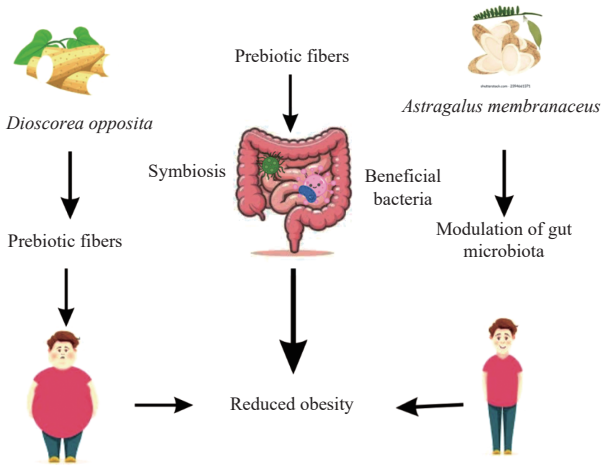

Figure 7 Lifestyle incorporation of Chinese medicinal plants for sustained weight management and metabolic health

TCM and conventional therapies differ in their therapeutic strategies and outcomes for obesity management. Conventional approaches primarily rely on pharmacological agents that target specific physiological pathways, including appetite suppression, inhibition of fat absorption, and regulation of glucose metabolism [37]. Although these medications often produce rapid and measurable reductions in body weight, their effects are typically transient, and discontinuation frequently results in weight regain. Moreover, adverse effects such as gastrointestinal disturbances, hypertension, and mood alterations can restrict their long-term applicability. In contrast, TCM adopts a holistic and multi-targeted approach that addresses not only body weight but also the underlying metabolic dysregulation associated with obesity [38]. Herbal formulations and plant-based therapies within TCM have been shown to modulate lipid and glucose metabolism, improve gut microbiota composition, reduce oxidative stress, and restore hormonal balance. Studies involving herbs such as *Panax ginseng*, *Cinnamomum cassia*, and *Nelumbo nucifera* have demonstrated gradual yet sustained weight reduction, enhanced insulin sensitivity and improved overall metabolic homeostasis. While TCM treatments are generally safer and better tolerated, challenges remain regarding the standardization of herbal composition and dosage consistency [39]. Despite these challenges, by promoting systemic equilibrium and long-term wellness, TCM offers more sustainable benefits compared to conventional single-target interventions. Therefore, integrating both modalities —utilizing modern pharmacotherapy for short-term outcomes and TCM for long-term metabolic regulation— may represent a comprehensive and effective strategy for holistic obesity management [40].

6 Limitations and future prospects

Despite promising findings, existing studies on the efficacy of TCM in obesity management present several limitations. Many clinical trials are characterized by small sample sizes, short intervention durations, and inadequate control groups, which restrict the generalizability and reproducibility of the results. Additionally, variability in herbal composition, extraction methods, and dosage standardization complicates cross-study comparisons and limits the ability to establish consistent therapeutic outcomes [94]. In some cases, contradictory findings have been reported regarding the magnitude of weight loss, lipid regulation, and improvements in insulin sensitivity. These discrepancies may arise from differences in study design, population diversity, and concurrent lifestyle interventions. Furthermore, long-term safety data and mechanistic insights remain insufficient, as most available studies focus on short-term metabolic responses rather than sustained physiological effects [95]. There is also a lack of integration between TCM diagnostic frameworks and modern biomedical parameters, leading to challenges in interpreting outcomes within a standardized scientific context. Addressing these gaps through large-scale, randomized controlled trials, mechanistic investigations, and standardized formulations is essential to validate the clinical potential and ensure the safe, evidence-based application of TCM in obesity management [96, 97].

Medicinal plants hold great promise for obesity management. However, their integration into mainstream practice faces significant challenges (Table 4). A primary issue is the standardization of plant extracts and the determination of appropriate dosages [98]. Phytochemical

concentrations can vary with the plant source, preparation method, and storage conditions, leading to inconsistent therapeutic effects. Establishing standardized extracts with uniform levels of active compounds is therefore essential to ensure safety and efficacy. Another major hurdle is the limited bioavailability of many plant-derived compounds. Combining certain herbs with bioavailability enhancers, such as piperine from black pepper, can significantly improve their absorption [99]. Advanced formulation technologies, including nanoencapsulation and controlled-release systems, can further enhance the delivery and therapeutic efficacy of herbal treatments. However, safety remains paramount, as certain herbs like *Ephedra sinica* carry cardiovascular risks and should be used only under strict medical supervision. Personalizing plant-based interventions based on individual sensitivities is essential to ensure both safety and effectiveness [100].

Table 4 Future prospects in medicinal plant-based obesity management

Aspect/challenge	Explanation	Future prospect	Reference
Standardization & dosage	Variable potency in no dosage standards	Standardized extracts and dosage guidelines	[85]
Lack of clinical evidence	Few large human trials	More robust clinical studies	[86]
Bioavailability issues	Poor absorption and stability	Advanced delivery systems	[87]
Mechanistic insights	Limited pathway understanding	Omics-based research	[88, 89]
Drug interactions	Possible interactions with drugs	Detailed herb drug studies	[90]
Regulation & quality	Inconsistent quality standards	Strong global regulations	[91]
Public awareness	Low knowledge of uses/risks	Awareness and education programs	[92, 93]
Cultural acceptance	Resistance to herbal therapy	Integrative healthcare approaches	[94, 95]
Cost & accessibility	High cost, limited access	Affordable production methods	[96, 97]
Long-term safety	Limited long-term data	Extended safety studies	[98]
Environmental concerns	Overharvesting, ecosystem impact	Sustainable cultivation and conservation	[99, 100]

7 Conclusion

Obesity has become a major global health concern, largely driven by the over consumption of junk foods. These highly processed, calorie-dense products rich in sugars, unhealthy fats, and additives contribute not only to excessive weight gain but also to serious comorbidities, including cardiovascular disease, type 2 diabetes, and NAFLD. Addressing this epidemic requires approaches that move beyond conventional pharmacological treatments toward safe, plant-based, and holistic solutions. TCM constitutes a valuable resource for plant-based therapeutics that has long been applied to correct metabolic imbalances. Medicinal plants such as *Panax ginseng*, *Nelumbo nucifera*, *Cinnamomum cassia*, *Gynostemma pentaphyllum*, and *Pueraria lobata* exhibit multi-targeted effects, including appetite regulation, modulation of lipid and glucose metabolism, energy expenditure enhancement, gut microbiota balance improvement, and chronic inflammation reduction. Such properties position them as promising agents for counteracting junk food-induced obesity. This review underscores the therapeutic potential of these plants, both as standalone remedies and as components of synergistic TCM formulations. While preclinical and limited clinical evidence is encouraging, further research must prioritize large-scale, randomized controlled trials and detailed mechanistic studies to firmly establish their safety, efficacy, and long-term benefits in humans. Integrating traditional wisdom with modern scientific research offers a sustainable and effective pathway for combating obesity and its complications related to junk food consumption.

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Competing interests

The authors declare no conflict of interest.

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中医药植物疗法治疗垃圾食品诱导的肥胖和代谢紊乱

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【摘要】肥胖是由高糖高脂饮食驱动的全球性健康问题，与代谢综合征、糖尿病及心血管疾病密切相关。现代研究表明，垃圾食品通过影响脂肪代谢、肠道菌群及炎症等途径引发代谢紊乱。中医药秉持整体观念，强调脏腑功能与气血平衡，其药用植物中含有多类活性成分，具有调节能量代谢和改善代谢失衡的潜力。本综述系统总结了中草药调控肥胖的主要作用机制，包括抑制食欲、调节脂代谢、促进产热、改善肠道菌群以及抗炎、抗氧化等。在实验及临床中人参、荷叶、葛根、桂皮、绞股蓝等代表性药材具有调脂、降糖和改善炎症反应的作用。总体而言，中医药植物疗法通过多途径调节来纠正代谢失衡是一种整体和安全的方法。然而，还需要通过标准化配方、机制验证和大规模临床试验来确定其疗效和转化价值。未来将传统知识与生物医学研究相结合有助于中医药植物疗法形成科学性的肥胖预防和管理策略。

【关键词】中医药；药用植物；活性成分；垃圾食品；肥胖；代谢紊乱；肠道菌群调节；炎症调控