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Review Article

Medicinal plants for the treatment of obesity: ethnopharmacological approach and chemical and biological studies

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Abstract: Obesity is a global epidemic that has shown a steady increase in morbimortality indicators; it is considered a social problem and entails serious health risks. One of the alternatives in the treatment of obesity is the traditional use of medicinal plants, which supports the research and development of obesity phytotherapy. In this article, we provide information about ethnopharmacological species used to treat obesity, through an electronic search of the periodical databases *Web of Science*, *Scopus, PubMed* and *Scielo*, considering the period 1996-2015 and using the descriptors "plants for obesity", "ethnopharmacology for obesity" and "anti-obesity plants" in both Portuguese and English. We analyzed and organized data on 76 plant species, cataloged per the taxonomy, geographic distribution, botanical aspects, popular use, and chemical and biological studies of the listed plants. The anti-obesity effect of the cataloged species was reported, describing actions on the delay of fat absorption, suppression of enzymatic activities, mediation of lipid levels and increase of lipolytic effects, attributed mainly to phenolic compounds. Given these findings, ethnopharmacological approaches are relevant scientific tools in the selection of plant species for studies that demonstrate anti-obesity action. Deeper botanical, chemical, pre-clinical and clinical studies are particularly necessary for species that present phenolic compounds in their chemical structure.

Keywords: Weight loss, reduction diet, anti-obesity medicines

Introduction

Obesity is a global epidemic and is recognized as an energetic imbalance caused mainly by increased consumption of high-calorie foods. Other factors include physical inactivity and socioeconomic and environmental changes, particularly rising purchasing power and education level and the influence of other individuals to increase food consumption [1-4]. Obesity is associated with dyslipidemias, diabetes, musculoskeletal disturbances, particularly osteoarthritis, and some types of cancer, such as endometrial, breast and colon cancer [2, 5].

Obese individuals also have cardiac risk factors that manifest clinically, including hypertension, insulin resistance, glucose intolerance and an elevated body mass index (BMI) [6, 7]. Since 1980, morbidity and mortality rates have increased [8, 9], becoming a social problem and the focus of institutional and government attention [10]. In 2013, around 42 million children under five years of age were obese. In 2014, more than 1.9 billion adults were overweight, of which more than 600 million were considered obese [8].

Choosing the best treatment for obesity depends on the correct diagnosis [2, 11]. There are numerous integrative and complementary practices, including dietary programs, physical activity, surgical interventions, behavioral therapy, lifestyle modification, medicinal therapies, drug addiction treatments, hypnosis, acupuncture and the use of medicinal plants [9, 10, 12-15].

Pharmacological strategies are recommended for the treatment of obesity, mainly because they are non-invasive. Recommended pharmaceuticals include sibutramine, fluoxetine, sertraline, orlistat and topiramate, among others [16]. However, these should be used with caution, especially in patients with cardiovascular disorders, because they possible may aggravate the clinical picture [2, 16, 17].

When conventional medicinal treatments are unable to address chronic diseases effectively and without eventual adversities, many people seek out non-conventional therapies. Among these therapies are plant-based medications that may contribute to satiety, increased metabolism and accelerated weight loss. Currently, obesity remedies based on dietary supplements are popular, suggesting that ethnopharmacology and phytotherapy can serve as strategies in obesity treatment and prevention [18-20].

Medicinal use of plants arises from ethnobotanical and ethnopharmacological approaches that test their therapeutic use in treating and preventing numerous diseases. These approaches include popular knowledge; thus the traditional has become something of great importance to science. These approaches also contribute to the selection of species to be studied and the development of phytotherapeutic medicines based on ethnopharmacological investigation [11, 21, 22].

In this context, plant species have become indispensable in providing extracts and isolated chemical compounds that serve as raw material for the development of obesity treatments [14, 23-25]. However, all the variables that mark a plant as alternative therapy for the treatment of diseases must be rigorously assessed to guarantee robust, safe and reliable results [26, 27]. The development of evidence-based public policies is necessary for the formulation of treatment strategies that consider the cultural, social, environmental and economic differences between countries. Translational research helps to establish parameters for that purpose, promoting the exchange of knowledge between producers, researchers, developers and companies [28].

Based on the above considerations, this study presents a compilation of plant species that have been ethnopharmacologically referenced as alternative treatments for obesity and have the pharmacological potential for the development of phytotherapeutic medicines. The intention is to guide the continuation of ethnopharmacological, pre-clinical and clinical studies in the search for therapeutic treatment alternatives and the improvement of public health.

Material and methods

Search strategy

We searched the databases *Web of Science*, *Scopus, PubMed* and *Scielo* for scientific articles published in 1996-2015, using the following descriptors: "plants for obesity", "ethnopharmacology for obesity" and "anti-obesity plants", without restriction on the language of the articles.

Inclusion and exclusion criteria

We considered only original works on medicinal plants, including those that cited the plant species referenced for obesity treatment, with botanical identification correctly described according to the Missouri Botanical Garden (http://www.tropicos.org) or the List of Species of the Brazilian Flora (http://www.floradobrasil.jbrj.gov.br/reflora).

We did not consider ethnopharmacological articles that presented possible methodological bias in terms of sample quality and authenticity of the species described in the study [26, 27]. Articles that presented a combination of more than one plant in a therapeutic formula also were not analyzed, due to a lack of attribution of pharmacological action specific to the species addressed in the article.

Data analysis

To analyze and synthesize the material, we conducted an exploratory reading of the bibliographic material, assessing the title and abstract of the work. Next, we checked the articles that appeared in the results of all the databases. After the exploratory analysis, we undertook a selective reading of the articles that included plant species with botanical records. Finally, we performed an analytical reading to summarize and rank the information contained in the consulted periodicals, thus enabling the collection of the data from the bibliographic review [29].

The botanical, ethnopharmacological, chemical and biological information of the species cited as obesity treatments were analyzed and orga-

Table 1. Distribuition of medicinal plants used for treatment of obesity

Family/Species	Popular name	Geographic distribuition	Reference
Alismataceae			
Echinodorus macrophyllus (Kunth) Micheli.	Chapéu-de-couro	Argentina, Bolivia, Brazil, Colombia, Guiana, Honduras, Nicaragua, Paraguay, Peru, Suriname, Venezuela	[68, 69]
Amaranthaceae			
Achyranthes aspera L.	Cola de zorro	Belize, Bolivia, Brazil, Buthan, Burma, Cambodia, China, Colombia, Costa Rica, Ecuador, United States, Philippines, Gabon, Guatemala, Honduras, India, Jamaica, Laos, Madagascar, Mexico, Nepal, Panama, Peru, Sri Lanka, Thailand, Vietnam	[70]
Annonaceae			
Annona montana Macfad.	Jaca-de-pobre, falsa graviola	Bolivia, Brazil, China, Costa Rica, Ecuador, United States, Guiana, French Guiana, Honduras, Panama, Peru, Suriname, Venezuela	[48]
Rollinia sylvatica Mart.	Pinha, araticum	Brazil	[11]
Apiaceae			
Foeniculum vulgare Mill.	Funcho, erva doce, anís	South Africa, Belize, Bolivia, Brazil, Canada, Chile, China, Colombia, Costa Rica, Ecuador, El Salvador, United States, Guatemala, Honduras, Mexico, Peru	[71]
Apocynaceae			
Gymnema sylvestre R. Br.	Gimena	South Africa, Madagascar	[14]
Hoodia gordonii (Masson) Sweet ex Decne.	Cacto do sul	South Africa	[72]
Hunteria umbellata (K. Schum) Hallier f.	Ghana	Gabon	[47]
Aquifoliaceae			
Ilex paraguariensis A. St.-Hil.	Erva mate, mate	Argentina, Bolivia, Brazil, Colombia, Ecuador, Peru, Paraguay, Uruguay	[11, 73-75]
Araceae			
Amorphophallus konjac K. Koch.	Konjac	China	[14, 65]
Araliaceae			
Panax japonicus (Nees) C.A. Mey.	Ginseng	Buthan, Burma, China, South Korea, China, India, Japan, Nepal, Thailand, Zambia	[24]
Asteraceae			
Achyrocline satureioides (Lam.) DC.	Marcela do campo	Argentina, Bolivia, Brazil, Colombia, Ecuador, Guiana, Paraguay, Peru, Uruguay, Venezuela	[11, 53]
Artemisia princeps Pamp.	Kui hao, yomogi	China, North Korea, South Korea, Japan	[43, 50, 66]
Baccharis articulata (Lam.) Pers.	Carquejinha, carqueja-doce, carqueja branca	Argentina	[11, 76]
Baccharis trimera (Less.) DC.	Carqueja, carqueja, amargosa	Argentina, Bolivia, Brazil, Paraguay, Uruguay	[11, 69]
Bidens bipinnata L.	Carrapicho-de-agulha, picão	Brazil, Cambodia, China, North Korea, Ecuador, United States, Laos, Madagascar, Nepal, Thailand, Venezuela	[76]
Cichorium intybus L.	Chicória	Canada, Chile, China, El Salvador, United States, Guatemala, Honduras, Madagascar, Mexico, Panama, Venezuela	[42, 45]
Cynara scolymus L.	Alcachofra	Colombia, Ecuador, United States	[11]
Hieracium pilosella L.	Erva criminosa, orelha de rato	Canada, Chile, United States	[14]
Tanacetum vulgare L.	Catinga-de-mulata, tanaceto, atanásia, erva-de-são-marcos	Argentina, Bolivia, Brazil, Canada, Kazakhstan, Chile, China, Colombia, North Korea, South Korea, Costa Rica, Ecuador, El Salvador, United States, Guatemala, Japan, Mexico, Mongolia, Peru, Russia, Venezuela	[11]

Taraxacum officinale F.H. Wigg.	Arnica, dente de leão	South Africa, Argentina, Canada, Kazakhstan, Chile, China, United States, Guatemala, Madagascar, Panama	[71]
Caricaceae			
Carica papaya L.	Mamão	Argentina, Bahamas, Belize, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, United States, Gabon, Guatemala, Guiana, French Guiana, Haiti, Honduras, Cayman Islands, Virgin Islands, Jamaica, Madagascar, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Dominican Republic, Suriname, Trinidad and Tobago, Venezuela	[14]
Celastraceae			
Tripterygium wilfordi Hook. f.	Lei gong teng	Burma, China, South Korea, Japan	[16]
Salacia reticulata Wight.	Khotala himbutu	NI	[43]
Clusiaceae			
Garcinia cambogia Desr.	Malabar tamarindo ou goraka	NI	[14, 77, 78]
Combretaceae			
Terminalia bellirica (Gaertn.) Roxb.	Pi li le, bedda castanheira	Bangladesh, Buthan, Burma, Cambodia, China, Honduras, India, Laos, Nepal, Sri Lanka, Thailand, Vietnam	[79]
Costaceae			
Costus spicatus (Jacq.) Sw.	Cana-de-macaco	Bolivia, Honduras, Mexico, Dominican Republic	[69]
Cucurbitaceae			
Cucurbita moschata Duchesne.	Jerimum	Bolivia, Brazil, Colombia, Costa Rica, United States, Ecuador, Guiana, French Guiana, Honduras, Mexico, Panama, Suriname, Venezuela	[80]
Curtisiaceae			
Curtisia dentata (Burm.f.) C.A. Sm.	Assega	South Africa	[81]
Cyperaceae			
Cyperus rotundus L.	Tiririca, junça	Afghanistan, Argentina, Australia, Belize, Bolivia, Brazil, Buthan, Burma, Kazakhstan, Chile, China, Colombia, North Korea, South Korea, Costa Rica, Ecuador, El Salvador, United States, Philippines, Gabon, Guatemala, Guiana, French Guiana, Honduras, India, Japan, Madagascar, Malaysia, Mexico, Mongolia, Nicaragua, Panama, Papua New Guinea, Pakistan, Paraguay, Peru, Sri Lanka, Suriname, Thailand, Venezuela	[82]
Dioscoreaceae			
Dioscorea nipponica Makino.	Chuan long shu yu	Chile, North Korea, Japan, Russia	[83]
Equisetaceae			
Equisetum giganteum L.	Cola de cavalo, rabo de cavalo	Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru	[11]
Euphorbiaceae			
Croton gnaphalii Baill.	Infalivina	Brazil	[11]
Erythroxylaceae			
Erythroxylum argentinum O.E. Schulz.	Cocão, fruta de pomba, baga de pomba	Argentina, Bolivia, Brazil	[11]
Fabaceae			
Abarema cochliacarpos (Gomes) Barneby & J.W. Grimes.	Barbatimão	Brazil	[76]
Acacia mearnsii De Wild.	Acácia negra	South Africa, Australia, Bolivia, Brazil, China, Ecuador, Espanha, United States, Ethiopia, India, Jamaica, Pakistan, Portugal, Quênia, Ruanda, Sri Lanka, Suíça, Taiwan, Tanzânia, Uganda, Zambia	[84]

Cassia nomame (Makino) Kitag.	Cassia	China	[50]
Phaseolus vulgaris L.	Feijão	Argentnina, Belize, Bolivia, Burma, Canada, China, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Guiana, Honduras, India, Mexico, Puerto Rico	[12]
Senna alexandrina Mill.	Sene	Brazil, Ecuador, India, Mexico, Dominican Republic	[11]
Senna corymbosa (Lam.) H.S. Irwin & Barneby.	Sena-do-campo, café-brabo, fedegoso, sena, sena-do-mato	Argentina, Brazil, United States, Uruguay	[11]
Fucaceae			
Fucus vesiculosus L.	Bodelha, fava do mar	NI	[85]
Geraniaceae			
Geranium nepalense Sweet.	Ni bo er lao guan cao	Afeghanistan, Brazil, Burma, China, United States, India, Mongolia, Laos, Pakistan, Sri Lanka, Thailand, Vietnam	[86]
Iridaceae			
Sisyrinchium vaginatum Spreng.	Canchalágua	Argentina, Bolivia, Brazil, Ecuador, Guiana, Suriname, Uruguay, Venezuela	[11]
Lardizabalaceae			
Akebia quinata (Houtt.) Decne.	Videira de chocolate	China, South Korea, United States, Japan	[46]
Lauraceae			
Cinnamomum cassia (L.) D. Don.	Cassia chinesa	China, India, Indonesia, Laos, Malaysia, Taiwan, Thailand, Vietnam	[24]
Lamiaceae			
Orthosiphon stamineus Benth.	Java	NI	[14]
Linaceae			
Linum usitatissimum L.	Linho, linhaça	Argentina, Bolivia, Canada, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Madagascar, Mexico, Nicaragua, Peru, Reino Unido, United States, Uruguay	[87]
Lythraceae			
Dioscorea *speciosa* (L.) Pers.	Rasedá gigante	Australia, Belize, China, Colombia, Costa Rica, El Salvador, United States, Philippines, Guatemala, Guiana, Honduras, India, Malaysia, Mexico, Nicaragua, Panama, Sri Lanka, Vietnam	[6, 41]
Cuphea carthagenensis (Jacq.) J.F. Macbr.	Sete sangrias	Argentina, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, United States, El Salvador, Guatemala, Guiana, French Guiana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Taiwan, Trinidad and Tobago, Venezuela	[11]
Malvaceae			
Hibiscus sabdariffa L.	Caruru-azedo, quiabo-azedo, quiabo-roxo, rosélia e vinagreira	NI	[11, 88, 89]
Luehea divaricata Mart.	Açoita cavalo	Bolivia, Brazil, Paraguay	[11]
Melastomataceae			
Leandra australis (Cham.) Cogn.	Pixirica	Brazil	[11]
Moraceae			
Morus bombycis Koidz.	Amoreira	NI	[90]
Moringaceae			
Moringa oleifera Lam.	Marango	Belize, Bolivia, Brazil, China, Colombia, Costa Rica, El Salvador, Gabon, Guiana, French Guiana, Honduras, India, Madagascar, Malaysia, Mexico, Nicaragua, Panama, Pakistan, Paraguay, Venezuela	[91]
Myristicaceae			

Myristica fragrans Houtt.	Noz moscada	China, El Salvador, Guatemala, Honduras, India, Madagascar, Malaysia, Panama, Taiwan	[92]
Myrtaceae			
Campomanesia xanthocarpa Mart. ex O.Berg.	Guabiroba	Argentina, Bolivia, Brazil, Paraguay, Uruguay	[11]
Nelumbonaceae			
Nelumbo nucifera Gaertn.	Lótus, flor-de-lótus, loto-índico, lótus-índico	Brazil, Buthan, Burma, China, North Korea, United States, Philippines, Guiana, India, Japan, Nepal, Pakistan, Russia, Sri Lanka, Suriname, Thailand, Vietnam	[45, 93, 94]
Paeoniaceae			
Paeonia suffruticosa Andrews.	Árvore peony	China	[43]
Poaceae			
Coix lacryma-jobi L.	Conta de lágrima, lágrima de nossa senhora, tsiku	South Africa, Argentina, Australia, Barbados, Belize, Bolivia, Brazil, Buthan, Burma, Chile, China, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, United States, Ethiopia, Philippines, Gabon, Guatemala, Guiana, French Guiana, Honduras, India, Jamaica, Japan, Laos, Madagascar, Mexico, Nepal, Nicaragua, Papua New Guinea, Paraguay, Peru, Puerto Rico, Sri Lanka, Suriname, Thailand, Turkey, Uruguay, Venezuela, Vietnam	[100]
Cymbopogon citratus (DC.) Stapf.	Capim-limão	Argentina, Australia, Barbados, Belize, Bolivia, Brazil, Chile, China, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, United States, Philippines, Gabon, Guatemala, Guiana, French Guiana, Honduras, India, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Suriname, Uruguay, Venezuela	[69]
Polygonaceae			
Persicaria hydropiper (L.) Spach.	Water-pepper	South Africa, Australia, Buthan, Burma, Canada, China, South Korea, United States, Japan, Mongolia, Nepal, Russia, Sri Lanka, Thailand	[44]
Plantaginaceae			
Plantago ovata Forsk.	Yuan bao che qian, plantain	NI	[14]
Piperaceae			
Piper nigrum L.	Pimenta preta	Belize, Brazil, China, Colombia, Costa Rica, Ecuador, French Guiana, Honduras, India, Peru, Sri Lanka, Venezuela	[95]
Piper mikanianum (Kunth) Steud.	Pariparoba	Argentina, Brazil, Paraguay	[11]
Rutaceae			
Aegle marmelos (L.) Corrêa.	Fruta de bael	Buthan, Cambodia, China, Honduras, India, Laos, Suriname, Vietnam	
Rutaceae			
Citrus aurantium L.	Laranja de sevilha, laranja-amarga, laranja azeda	Argentina, Belize, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, United States, Guatemala, Honduras, India, Madagascar, Mexico, Panama, Paraguay, Peru, Venezuela	[14]
Citrus decumana Murr.	Pomelo	China	[14]
Fortunella japonica (Thunb.) Swingle.	Kumkat	Honduras	[96]
Rhamnaceae			
Scutia buxifolia Reiss.	Coronilha, canela de espinho, espinho de touro	Argentina, Brazil, Paraguay, Uruguay	[11]
Rosaceae			
Rubus coreanus Miq.	Cha tian pao	China, South Korea, Japan	[86]

Salicaceae			
Casearia sylvestris Sw.	Guaçatonga, chililo	Argentina, Belize, Bolivia, Brazil, Colôbia, Costa Rica, Cuba, Ecuador, United States, El Salvador, Guatemala, Suriname, Guiana, French Guiana, Haiti, Honduras, Ilha Caiman, Virgin Islands, India, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Suriname, Trinidad and Tobago, Venezuela, Uruguay	[11]
Populus balsamifera L.	Choupo bálsamo	Bolivia, Canada, Ecuador, United States	[97]
Salix matsudana Koidz.	Han liu	Bolivia, China	[59, 86]
Sapindaceae			
Paullinia sorbilis Mart.	Guaraná	nI	[14]
Theaceae			
Camellia thea Link.	Chá da india, chá, chá verde	Laos	[14, 39, 98, 99]

nized according to the articles that met the established methodological criteria.

The scientific names, vernacular names, botanical family and geographic distribution of the species were obtained from the databases of the Missouri Botanical Garden (http://www.tropicos.org) and the List of Species of the Brazilian Flora (http://www.floradobrasil.jbrj.gov.br/reflora). Information on anti-obesity action, chemical composition, plant part used and method of extraction of active plant properties were obtained directly from the selected articles.

Results

We found 13,568 records of available publications in the databases analyzed according to the predefined descriptors. Of the total, 4,061 articles were found in *Pubmed*, 4,416 in *Web of Science,* 5,091 in *Scopus* and only 12 in *Scielo*. After the exploratory reading, we selected 1,297 manuscripts. Of this total, only 111 articles referred specifically to the plants used in the treatment of obesity. Notably, 45% of the selected articles were published in the last five years.

We found records for 76 plant species used to treat obesity through pharmacological approaches as well in as pre-clinical and clinical trials. The species were from among 52 botanical families, the most prominent being Asteraceae, with 13.16% of species, and Fabaceae, with 7.89% (**Table 1**).

In terms of geographical distribution, we found 72 countries listed among the records of plants used in the treatment of obesity (**Table 1**). These species are concentrated primarily in Asia and South America, namely Brazil (47.22%), Bolivia (37.50%) and China (50.00%). We found no record, in terms of geographical distribution of the species *Hibiscus sabdariffa* L., *Fucus vesiculosus* L., *Garcinia cambogia* Desr., *Morus bombycis* Koidz., *Orthosiphon stamineus* Benth., *Paullinia sorbilis* Mart., *Plantago ovata* Forssk. and *Salacia reticulata* Wight.

The review in this study resulted in 23 articles that reported an anti-obesity effect through *in vivo* and/or *in vitro* biological tests (**Table 2**), mainly describing the action of plant metabolites on the delayed absorption of fat, suppression of enzymatic activities, mediation of lipid levels and increase of lipolytic effects.

Phenolic compounds were presented as the main secondary metabolites responsible for anti-obesity action in 36.13% of the articles describing the identification of the chemical substances responsible for the pharmacological effect (**Table 2**).

In the analyzed articles, the plant species submitted to protocols of assessment of anti-obesity activity were tested based on the extractive solutions obtained through processes of hot maceration, cold maceration, soxhlet extraction, reflux and accelerated extraction, using leaves, seeds, rhizomes, stems, flowers, fruits and roots of these species. Solvents used in the extractive processes include water, ethanol, methanol, n-ethanol, hexane, n-butanol, dimethyl carbonate and ethyl acetate (**Table 2**).

Discussion

Interest in the subject of obesity has increased over time because it is public health problem [30], for which the use of medicinal plants is an

Table 2. Biological evidence and chemical composition of medicinal plants for the treatment of obesity

Antiobesity activity	Biological tests (*in vivo/in vitro*)	Species	Plant part	Process/Extraction method	Chemical composition	Reference
Increased gene expression related to energy expenditure on skeletal muscle and decreased fatty acid synthesis	*In vitro*	*Acacia mearnsii* De Wild.	Stalk	Extraction using water as solvent	Flavanois (flavan-3-ol e catequins)	[84]
Delay of intestinal absorption of fat in the diet by inhibition of pancreatic amylase and activity of the enzyme lipase	*In vivo/in vitro*	*Achyranthes aspera* L.	Seeds	Extraction by using 95% ethanol as the solvent	Total phenols; flavonoids; saponins	[70]
	In vivo/in vitro	*Panax japonicus* (Nees) C.A. Mey.	Rhizomes	Refluxing using methanol as solvent	Saponins	[24, 100]
Reduction of triglyceride and cholesterol levels of lipid metabolism modulation	*In vivo/in vitro*	*Aegle marmelos* (L.) Corrêa.	Leaf	Accelerated extraction using as solvents n-ethanol, hexane, n-butanol and dimethyl carbonate	Cumarins	[52]
	In vivo/in vitro	*Cucurbita moschata* D.	Stalk	Extraction by maceration using water as solvent	Terpenes	[80]
	In vivo	*Ilex paraguariensis* A. St.-Hil.	Leaf	Extraction by maceration using water as solvent	Methylxanthines (theophylline), saponins, alkaloids (caffeine and theobromine)	[73, 74]
In vitro anti-obesity effects on 3T3-1 pre-adipocyte cells	*In vitro*	*Akebia quinata* (Houtt.) Decne.	Fruit	Reflux extraction using ethanol at 70° as solvent	Phenolic compounds	[46]
	In vitro	*Artemisia princeps* Pamp.	Leaf	Reflux extraction using ethanol at 70° as solvent	Phenolic compounds	[43]
	In vitro	*Cichorium intybus* L.	Leaf	Extraction using hexane, ethyl acetate and methanol as the solvent	Tannins	[42, 45]
	In vitro	*Lagerstroemia speciosa* (L.) Pers.	Leaf	Extraction by maceration using water and methanol as solvents	Tannins	[6, 41]
	In vitro	*Persicaria hydropiper* L.	Leaf	Extraction using methanol as solvent	Flavonoids	[44]
Mediation of lipid levels based on enzymatic parameters	*In vivo*	*Achyrocline satureioides* (Lam.) DC.	Flowers	Decoction extraction using water as the solvent	Flavonoids	[53]
Reduction in lipid levels and increase in HDL-C levels	*In vivo*	*Annona montana* Macfad.	Fruit	Extraction by maceration using water as solvent	Alkaloids e terpenes	[48]
Suppression of lipogenic enzymatic activities	*In vivo*	*Artemisia princeps* Pamp.	Leaf	Extraction by maceration using 70° ethanol as solvent	Terpenes	[66]
Suppression of triglyceride accumulation in liver and adipose tissues	*In vivo*	*Artemisia princeps* Pamp.	Leaf	Extraction by maceration using 70° ethanol as solvent	Terpenes	[50]
Reduction of triglyceride levels	*In vivo/in vitro*	*Camellia thea* Link.	Leaf	Extraction by maceration using water as solvent	Phenolic compounds	[49]
Serum triglycerides and non-esterified fatty acids	*In vivo*	*Camellia thea* Link.	Leaf	Extraction by maceration using water as solvent	Flavanois (catechins), alkaloids (cafeinne)	[99]
Suppression of appetite stimulus signals in the hypothalamus	*In vitro*	*Carica papaya* L.	Leaf	Extraction by maceration using methanol as solvent	Saponins	[98]
Reduced levels of triglycerides, LDL-C E VLDL-C	*In vivo/in vitro*	*Carica papaya* L.	Fruit	Decoction extraction using water as the solvent	Alkaloids, saponins, tannins, anthraquinones, flavonoids (antocianidinas)	[14, 101]

Suppression of increased triglyceride level in the blood	*In vivo*	*Dioscorea nipponica* M.	Root	Extraction by maceration using methanol as solvent	Saponins	[83]
Decrease in plasma level of low density lipoprotein cholesterol and increase in the level of chylomicrons	*In vivo*	*Garcinia cambogia* Desr.	Seeds	Extraction by maceration using ethanol as solvent	Hydroxycitric acid	[14, 77]
Inhibition of the enzyme adenosine triphosphatasecitrato lyase blocking lipogenesis	*In vivo*	*Garcinia cambogia* Desr.	Seeds	Extraction by maceration using ethanol as solvent	Hydroxycitric acid	[78]
Inhibition of intestinal absorption and lipid biosynthesis	*In vivo*	*Hunteria umbellata* (K. Schum.) Hallier f.	Seeds	Extraction by maceration using water as solvent	Alkaloids	[47]
Protective effect against obesity induced in rats through increased expression of decoupling proteins and raised ampk phosphorylation in visceral adipose tissue	*In vitro*	*Ilex paraguariensis* A. St.-Hil.	Leaf	Decoction extraction using water as the solvent	Alkaloids (cafeinne) e saponins	[75]
Reduction of atherogenic index, reversing the hyperlipidemic effect produced by high fat diet	*In vivo*	*Moringa oleifera* Lam.	Leaf	Extraction by maceration using methanol as solvent	Fitotesrol (β-sitosterol	[91]
Increased lipolytic effects with decreased intracellular triglycerides and release of glycerol	*In vitro*	*Morus bombycis* Koidz.	Leaf	Reflux extraction using ethanol at 70° as solvent	Alkaloids	[43]
Inhibition dependent on the concentration of α-amylase and lipase activity, and over-regulated lipid metabolism and the expression regulation of gene expression in skeletal muscle	*In vivo/in vitro*	*Nelumbo nucifera* Gaertn.	Leaf	Reflux extraction using 15% aqueous ethanol as solvent	Alkaloids	[45, 94, 93]

NI: Uninformed.

alternative for its treatment and prevention. Safety measures and the processes of botanical identification and herbarium registration of these plant species must follow standard procedures from collection to identification and maintenance of the plant specimens, which are essential in scientific studies [31, 32]. The absence of botanical records for species indicated in studies of medicinal plants causes problems for ethnobotanical studies, due to the lack of specimen production and herbarium deposits and to errors in species identification procedures [33].

Considering geographic distribution, research on medicinal plants tends to be developed not only in countries where these species grow, but also by institutions and companies that dominate the industrial production and patenting of phytotherapeutic products, which may favor exploitation through "biopiracy". Therefore, legally defined intellectual protection policies for vegetation and biomes are needed [34, 35]. The high level of biodiversity in countries such as Brazil favors the study of plants for medicinal purposes [36]. For example, China offers treatment alternatives using popular plants through traditional Chinese medicine [37]. In Bolivia, the current urban phytotherapy represents an alternative medicine for the treatment of common health problems, more in alignment with the cultural and social context of Bolivian society [38].

In Central America, the most prevalent ethnopharmacologically indicated species for the treatment of obesity belong to the Asteraceae family. Conservation polices are suggested for the protection of species for which studies have indicated anti-obesity potential [39].

The *in vitro* model best suited to demonstrate anti-obesity efficacy uses preadipocytes of the cellular lineage 3T3-L1, cells originating from embryos prematurely extracted from Swiss mice [40]. The prepared plant extracts act in the cell differentiation process that forms adipose cells, inhibiting obesity [6, 41-46]. Applied *in vivo* models involve the exposure of animals to diets based on plant extracts that act mainly to support lipoprotein metabolism [47-53].

However, some studies question and invalidate the action of certain plant species characterized as useful for treatment. For example, an assessment of the efficacy of *Hoodia gordoni* (Masson) Swet. found that rats treated with the powder of this species showed no differences relative to the control animals, and that the plant is unable to inhibit appetite or treat obesity [54]; only the species diuretic action was proven [55].

Anti-obesity effects analyzed in the articles are attributed to the secondary metabolites existent and chemically characterized in the samples used in biological protocols, including saponins, polyphenols, flavones, flavanols, tannins and chalcones [14, 45, 46] (**Table 2**). Phenolic compounds (especially flavones, flavanols, flavanones, catechins, anthocyanins, isoflavones and chalcones), as well as their functional derivatives, present a variety of chemical structures and pharmacological activities, and they are constituents in fruits, legumes, nuts, beverages and medications [56]. They are predominant in the plant species *Acacia mearnsii* De Wild., *Achyranthes aspera* L., *Akebia quinata* (Houtt.) Decne., *Artemisia princeps* Pamp., *Persicaria hydropiper* L., *Achyrocline satureioides* (Lam.) DC., *Camellia thea* Link., *Carica papaya* L.-all are listed as having anti-obesity activity (**Table 1**).

These chemical compounds have become important anti-obesity substances because of their role as dietary anti-oxidants in the prevention of oxidative damage in living systems [57], acting mainly in the modulation of adipose tissue. They also act to inhibit the growth of preadipocyte cells 3T3-L1 *in vitro*, induce apoptosis of the adipocytes and inhibit lipid accumulation [58-61]; and they inhibit pancreatic lipase and the absorption of fatty acids *in vivo* [62].

Research that evaluates the level of toxicity of the extracts obtained from plant species is rarely conducted. For example, in addition to its therapeutic properties, the extract of *Tripterygium wilfordi* Hook. F. exhibits a strong cellular toxicity, presenting risk to patients' lives; its medical application is therefore prohibited. Soon, identifying active ingredients and understanding mechanisms of action may facilitate the development of highly effective drugs, but without significant toxicity [63].

This literature review is relevant to the advancement of scientific knowledge, because it synthesizes previous research, aiding in the identification of pharmacological mechanisms of action, active principles, and extraction and distribution methods of the research on previously studied species. This can direct the continuation and realization of new studies, contributing to research on natural products as well as to the assessment and validation of local pharmacopoeias, differentiating between the local and general uses of plants [64] as well as the contemporary knowledge reported in popular books and scientific literature.

Ethnopharmacological studies are necessary to prove and establish parameters for the safety, quality and efficacy of phytotherapeutic medicines and pre-clinical and clinical biological studies for the characterization of anti-obesity activity of the plants cited in this study [6, 41, 42, 44, 46, 48, 65, 66]. Attributes referenced in surveys that consult the public are not sufficient to define the use of medicinal plants as a standardized therapeutic alternative [67].

Conclusion

Ethnopharmacological approaches have increased over the years, becoming an important scientific tool in the selection of plant species for *in vitro* and *in vivo* studies that test the efficacy, safety and quality of anti-obesity pharmacological actions. These approaches should continue to be explored.

Countries of the Americas are still excellent scientific options for the study of medicinal plants, due to their high levels of biodiversity. The Asteraceae and Fabaceae families comprise the majority of plant species with pharmacognostic or biological properties that have anti-obesity action. However, botanical, chemical, pre-clinical and clinical studies must be deepened to confirm such findings.

Most studied describe phenolic compounds as the secondary metabolites in the plant species presenting the greatest evidence of effective obesity treatment, through both *in vitro* and *in vivo* studies, raising the possibility of a new application of phenolic compounds as a health supplement.

The works catalogued here represent a multifaceted approach, involving different axes of research, combining botany, phytochemistry, and biological and pharmacological aspects for indication or discovery of potentially medicinal plants. However, we observed a lack of pre-clinical and clinical studies and chemical characterization related to anti-obesity activity for most commonly used species that are reported as being therapeutic strategies for weight reduction. Experiments have yet to be conducted, providing scientific opportunities for innovative technologies aimed at research and development of phytotherapeutic medicines, with the possibility of high benefit-cost ratio, efficacy for obese patients, and improvement in the epidemiological profile of the disease among the population.

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