Journal of Apitherapy and Nature
e-ISSN: 2667-4734
JAN (2026) 9(1): 144-151 doi: 10.35206/jan.1908389 Research Article

The potential of *Barbarea* species in the management of obesity, hyperlipidemia, and diabetes

Merve BADEM*[1], Şeyda KANBOLAT[1], Ali KANDEMİR[2], Ayşe Aleyna ÖZTÜRK[1], Hayrünnisa TOPÇU[1]
[1]*Karadeniz Technical University, Faculty of Pharmacy, Department of Biochemistry, 61080, Trabzon*
[2]*Erzincan University, Faculty of Arts and Sciences, Department of Biology, Erzincan, 24002, Türkiye*

• **Received: 13.03.2026** • **Accepted: 11.06.2026**

Abstract
Barbarea species belonging to the Brassicaceae family contain glucosinolates, flavonoids, phenolic acids, saponosides, fatty acids, and other bioactive compounds. These compounds are reported to exhibit antioxidant, antimicrobial, antimutagenic, antiproliferative, and herbicidal effects, as well as beneficial effects on metabolic diseases. In particular, organosulfur and polyphenolic compounds have been reported to exhibit inhibitory effects on enzymes such as cyclooxygenase, lipoxygenase, nitric oxide synthase, pancreatic lipase, lipoprotein lipase, and glucosidase. In this study, the inhibitory activities of methanol extracts, chloroform, ethyl acetate, and remaining aqueous subfractions obtained from the aerial parts of *B. auriculata* var. *paludosa* Coode& Cullen and *B. plantaginea* DC on pancreatic lipase, cholesterol esterase, and *α*-glucosidase enzymes were investigated for the first time. When the results obtained in the study are evaluated, the ethyl acetate subfraction of *B. plantaginea* exhibited the strongest pancreatic lipase and cholesterol esterase inhibitory activities, with IC_{50} values of 111.687 ± 1.291 µg/mL and 10.718 ± 0.308 µg/mL, respectively. For *α*-glucosidase inhibition, the methanol extract of *B. auriculata* subsp. *paludosa* demonstrated the highest activity with an IC_{50} value of 135.207 ± 0.136 µg/mL. it is seen that the ethyl acetate subfraction of both species has stronger cholesterol esterase inhibitory effects, moderate lipase and glucosidase inhibitory effects.

Keywords: *Barbarea*, Glucosidase, Lipase, Cholesterol esterase

1. INTRODUCTION

The coexistence of interrelated metabolic disorders such as obesity, hypertension, dyslipidemia, and hyperglycemia is clinically defined as metabolic syndrome. The prevalence of metabolic syndrome, which has become a global health problem, is increasing, and it has been reported to affect more than a quarter of adults today (O'Neill, 2015; He et al., 2026). Obesity is related to many chronic diseases such as diabetes, hypertension, cardiovascular diseases, and cancer, and constitutes a significant global burden (Aktar et al., 2017; Hruby and Hu, 2014). It has been reported that obesity could affect approximately 20% of the world's population by 2030 (Subaş et al., 2026). The body mass index (BMI), which is accepted as an international standard for classifying thinness, overweight, and obesity in adults, is defined by the World Health Organization (WHO) as a simple and widely used measure calculated by dividing an individual's body weight in kilograms by their height in meters squared (kg/m²). The literature indicates that increasing BMI levels have been shown to increase the risk of insulin resistance development, thereby creating an important basis for type 2 diabetes mellitus (T2DM), and are associated with dyslipidemia, including increased total cholesterol, triglyceride, and LDL cholesterol levels, and decreased HDL cholesterol levels (Kahn et al., 2006). The treatment of obesity can involve various strategies such as reducing energy expenditure, decreasing lipid absorption, suppressing lipogenesis, and limiting adipocyte differentiation and proliferation (Patra et al., 2015; Yun et al., 2010). Among the approaches to reducing lipid absorption, pancreatic lipase testing, a lipolytic

*Merve BADEM; mervecolakoglu@ktu.edu.tr

enzyme synthesized and secreted from the pancreas that catalyzes the hydrolysis of triacylglycerols into monoacylglycerols and free fats, holds an important place (Seyedan et al., 2015; Lowe, 2002). Currently, orlistat, which reduces fat digestion, has been registered as a pharmacological agent used in the treatment of pathological obesity (Bray and Tartaglia, 2000). However, the side effects on the gastrointestinal system and the disease do not negatively affect patient compliance. This situation has increased interest in safer and naturally derived alternatives in different directions (Kang et al., 2017).

Cholesterol esterase is a reversible enzyme that hydrolyzes cholesterol fatty acid esters and other sterols, and can also synthesize these molecules (Hui and Howles, 2002). Inhibition of pancreatic cholesterol esterase activity limits the bioavailability of dietary cholesterol. Therefore, it has attracted attention in recent years as a potential treatment avenue for atherosclerosis and hypercholesterolemia (Sakunpak et al., 2021; Wei et al., 2014). In recent years, studies have focused on the potential roles of phenolic and polyphenolic compounds in obesity management. These compounds appear to induce apoptosis in pre-adipocyte and adipocyte appearances, and lipids can be stored in products where they are present. Furthermore, phenolic compounds are reported to suppress food intake and lipogenesis, increase lipolysis, limit adipocyte differentiation and restriction, mitigate inflammatory responses, and reduce oxidative stress (Rodríguez Pérez et al., 2019).

Polyphenolic compounds can have positive effects on blood glucose control and body weight management by inhibiting digestive enzymes such as lipase, glucosidase, and protease, thereby regulating lipid metabolism. Polyphenol-rich extracts are reported to lower blood glucose, triglyceride, and LDL levels; It increases fat oxidation and energy consumption and breaks down fat accumulation, occurring in various plants (Ercan and El, 2014).

Plants belonging to the Brassicaceae family contain glucosinolates, which are sulfur-containing anionic secondary metabolites responsible for beneficial effects on human health (Agerbirk and Olsen, 2015). These compounds and hydrolysis products have been reported to have antioxidant, antifungal, antibacterial, antimutagenic, antiproliferative, herbicidal, antithrombotic, hypoglycemic, and lipid-lowering effects, as well as inhibitory effects on cyclooxygenase, lipoxygenase, and nitric oxide synthase enzymes (Al-Shehbaz, 2007; Vig et al., 2009; Cartea and Velasco, 2008).

There are 14 species and 19 taxa belonging to the genus *Barbarea*, 10 of which are endemic (Bağcı and Sayfa, 2012; Akkemik and Yılmaz, 2016). Previous studies have reported that *Barbarea* species contain glucosinolates and their hydrolysis products (Bianco et al., 2014; Agerbik and Olsen, 2015; Badem et al., 2021), flavonoids (Senatore et al., 2000; Dalby-Brown et al., 2011; Badem et al., 2021), saponosides (Kuzina et al., 2011; Khakimov et al., 2016), phenolic acids (Fraisse et al., 2007; Badem et al., 2021), fatty acids, protein, sugar, and sugar nutrients (Andersson et al., 1999). In addition, *Barbarea* species exhibit antithyroid, anticancer, tyrosinase inhibitor, antifungal, antineurodegenerative, and anti-inflammatory activities (Senatore et al., 2000; Kuzina et al., 2011; Badenes Perez et al., 2014; Pedras et al., 2015). Some *Barbarea* species have been reported to be used in traditional medicine for wound healing, expectorant, and diuretic purposes, as well as being consumed as food (Bayto, 1984; Senatore et al., 2000).

This study aims to determine the antihyperlipidemic, anti-obesity, and antidiabetic effects of *B. auriculata* var. *paludosa* (endemic) and *B. plantaginea*, based on their phytochemical content and information obtained from the literature. The inhibitory effects of extracts obtained with different solvents of the aerial parts of these species on pancreatic lipase, cholesterol esterase, and α-glucosidase enzymes will be evaluated for the first time.

2. MATERIAL AND METHODS

2.1. Chemicals

The chemical materials used in extraction and biological activity studies, ethanol, methanol, ethylacetate, chloroform, hydrochloric acid (HCl), taurochoic acid, simvastatin *p*-nitro phenyl butyrate (*p*-NPB), orlistat, 4-nitrophenyl-*β*-d-glucuronide (PNPG), glutathione, acarbose, cholesterol esterase enzyme (Cholesterol Esterase from porcine pancreas, EC 3.1.1.13, 35 U/mg) α-glucosidase (from *Saccharomyces cerevisiae*, EC 3.2.1.20, ≥100 units/mg protein), and pancreatic lipase enzyme (Crude porcine PL type II, EC 3.1.1.3, 200 U/mL), were purchased from Sigma-Aldrich.

In this study, a magnetic stirrer (Heidolph MR), refrigerator (Arçelik), evaporator (Heidolph), precision balance (Ohaus Pioneer), incubator (Memmert), pH meter (Hanna), centrifuge (Elektromag), spectrophotometer (BMG Labtech Spectrostar Nano), vortex (Heidolph Reax Top Vortex Mixer), freeze dryer (Christ), microwave oven (START SYNTH), and ultrasonic water bath (Isolab) were used.

2.2. Plant material and extraction

B. auriculata var. *paludosa* Coode & Cullen was collected from Mount of Pöske in Erzincan, Türkiye, at an altitude of 2100 m, and *B. plantaginea* DC was collected from Çimen village of Kelkit (Gümüşhane), Türkiye, at 1750 m. The identification of the species was carried out by Prof. Dr. Ali Kandemir, and the voucher specimens have been stored in the Herbarium of the Department of Biology, Erzincan Binali Yıldırım University, Türkiye (Kandemir 10863 and 10864). The aerial parts of the plants, dried and ground into powder, are stored under appropriate conditions.

The powdered aerial parts of the plants (min. 100 g) were extracted with 250 mL of methanol in a shaker incubator (30 °C for 8 h×2) and filtered. The combined filtrates were concentrated under pressure to obtain the methanol extracts. These extracts were suspended in 200 mL water: methanol (9:1, v/v) and subjected to liquid-liquid partitioning with chloroform and ethyl acetate, respectively (applied twice successively). The chloroform and ethyl acetate fractions were concentrated to dryness under pressure, while the remaining aqueous fraction was lyophilized. The dried crude methanol extract and its fractions were further evaluated for their *in vitro* enzyme inhibitory activity studies.

2.3. Enzyme inhibitory activity studies

Antihiperlipidemic and antidiabetic activities of the extracts were analyzed by evaluating the inhibition of pancreatic lipase, cholesterol esterase, and α-glucosidase.

2.3.1. Pancreatic lipase inhibition

The pancreatic lipase inhibitory activity of the samples was measured spectrophotometrically (Bustanji et al., 2011). The extracts (12.5-2000 µg/mL), orlistat (positive control, 12.5-200 µg/mL), and lipase enzyme were dissolved in Tris-HCl buffer (pH 8, 0.1 mM). p-NPB (10 mM) in acetonitrile was used as substrate solution. After the samples and enzyme solution were added to the wells, the plates were incubated at 37 °C for 15 minutes. At the end of incubation, substrate solution was added and incubated again at 37 °C for 10 minutes. The lipase inhibition was determined by measuring the absorbance at 405 nm.

2.3.2. Cholesterol esterase inhibition

The cholesterol esterase inhibitory activity was determined using a modified method (Zor et al., 2022). The samples (5-160 µg/mL), cholesterol esterase enzyme (1 µg/mL), and taurochoic acid (12 mM) were dissolved in phosphate buffer (0.1 M NaCl, pH 7). p-NPB (10 mM) was used as substrate. Simvastatin (5-160 µg/mL) was used as a positive control. The samples, taurocholic acid solution, buffer, and substrate solution were added to the wells and incubated at 37 °C for 10 minutes. At the end of incubation, enzyme solution was added to all wells and incubated at 37 °C for 25-30 minutes. The cholesterol inhibition was determined by measuring the absorbance at 405 nm.

2.3.3. α-Glucosidase inhibition

The α-glucosidase inhibitory activity was determined using a modified method (Palanisamy et al., 2011). The samples (125-2000 µg/mL), α-glucosidase enzyme (0.4 U/mL), and glutathione (1 mM) were dissolved in phosphate buffer (pH 6.8). PNPG solution (3 mM) was used as substrate. Acarbose (125-2000 µg/mL) was used as a positive control. The sample, glutathione, α-glucosidase, buffer, and substrate solution were added to the wells and incubated at 37 °C for 15 minutes. The reaction was stopped by adding sodium carbonate (0.2 M). α-glucosidase inhibition was determined by measuring the absorbance at 400 nm.

The pancreatic lipase, cholesterol esterase, and α-glucosidase inhibition rate was calculated using the formula: Inhibition rate (%) = [(ΔAcontrol - ΔAsample)/ ΔAcontrol] × 100.

The inhibitory concentrations (IC_{50}) were calculated from the graphs plotted with the logarithmic concentrations of the extract versus inhibition rate (%).

2.4. Statistical analyses

In the *in vitro* studies, each sample was studied in triplicate. In the enzyme inhibition assays, IC_{50} values of the samples were found with the help of the graphs drawn with the calculated % inhibition data and the logarithmic concentrations of the samples using Microsoft Excel. Experimental results were given as means ± standard deviation (SD). Statistical differences were assessed using one-way ANOVA, followed by Tukey's multiple comparisons test, using GraphPad Prism 8.0.2 (GraphPad Prism Software, San Diego, CA, USA).

3. RESULTS AND DISCUSSION

The inhibitory effects on pancreatic lipase, cholesterol esterase, and α-glucosidase of methanol extract and ethyl acetate, chloroform, and residual aqueous subfractions obtained from *B. auriculata* var. *paludosa* and *B. plantaginea* are presented in Table 1. All statistical analyses were performed using GraphPad Prism 8.0.2. Before applying One-Way ANOVA, the normality of the data distribution was assessed using normality and lognormality tests (Shapiro-Wilk test), and the suitability of the data was confirmed. A p-value of < 0.05 was considered statistically significant. The calibration graphs of orlistat, simvastatin, and acarbose, used as positive controls, are given in Figure 1.

Table 1. The results of the enzyme inhibitory activities carried out on *Barbarea* species

Samples		Pancreatic Lipase Inh.	Cholesterol Esterase Inh.	*α*-Glucosidase Inh.
		IC_{50} values (µg/mL)		
B. plantaginea	**Methanolic extract**	350.802 ± 5.549^{h}	16.439 ± 1.165^{a}	278.736 ± 44.129^{b}
	Aqueous subfraction	197.743 ± 3.256^{e}	28.725 ± 2.403^{b}	269.569 ± 12.575^{b}
	Chloroform subfraction	160.824 ± 4.028^{d}	23.466 ± 5.556^{b}	307.737 ± 34.551^{b}
	Ethylacetate subfraction	111.687 ± 1.291^{b}	10.718 ± 0.308^{a}	279.241 ± 12.551^{b}
B. auriculata	**Methanolic extract**	131.586 ± 2.132^{c}	14.214 ± 1.618^{a}	135.207 ± 0.136^{a}
subsp. *paludosa*	**Aqueous subfraction**	204.694 ± 1.861^{f}	14.512 ± 4.395^{a}	264.990 ± 23.362^{b}
	Chloroform subfraction	155.730 ± 0.985^{d}	42.623 ± 1.691^{c}	345.446 ± 14.348^{b}
	Ethyl acetate subfraction	238.573 ± 3.112^{g}	19.591 ± 3.584^{b}	453.420 ± 20.233^{c}
PC		40.584 ± 0.542^{a}	13.981 ± 2.367^{a}	424.644 ± 17.692^{c}

PC: Positive control (orlistat for lipase, simvastatin for cholesterol esterase, acarbose for α-glucosidase. Different letters (a>b>c>d) in the same column indicate significant differences ($p<0.05$)

The highest lipase and cholesterol esterase inhibition activity among the samples was observed in the ethyl acetate subfraction of *B. plantaginea* (111.687 ± 1.291 µg/mL; 10.718 ± 0.308). The highest lipase and cholesterol esterase inhibition activity among the samples was observed for α-glucosidase inhibition; the strongest activity was observed in the methanol extract of *B. auriculata* subsp. *paludosa* (135.207 ± 0.136 µg/mL). In general, methanol extracts and ethyl acetate subfractions showed stronger enzyme inhibitory activities depending on solvent polarity.

In our previous studies on *Barbarea* species by HPLC analysis, p-OH benzoic acid was identified in *B. plantaginea,* while vanillic acid, syringaldehyde, coumaric acid, sinapic acid, and benzoic acid were identified in *B. auriculata* var. *paludosa* (Badem et al., 2020). Although *B. auriculata* var. *paludosa* was found to be richer in phenolic compounds, a comparison of the carried enzyme inhibition activities in this study showed that *B. plantaginea* exhibited a stronger inhibitory effect. This suggests that total phenolic content is not the sole determinant of enzyme inhibition activity, and that the type, structure, and synergistic interactions of phenolic compounds may play a more significant role in biological activity.

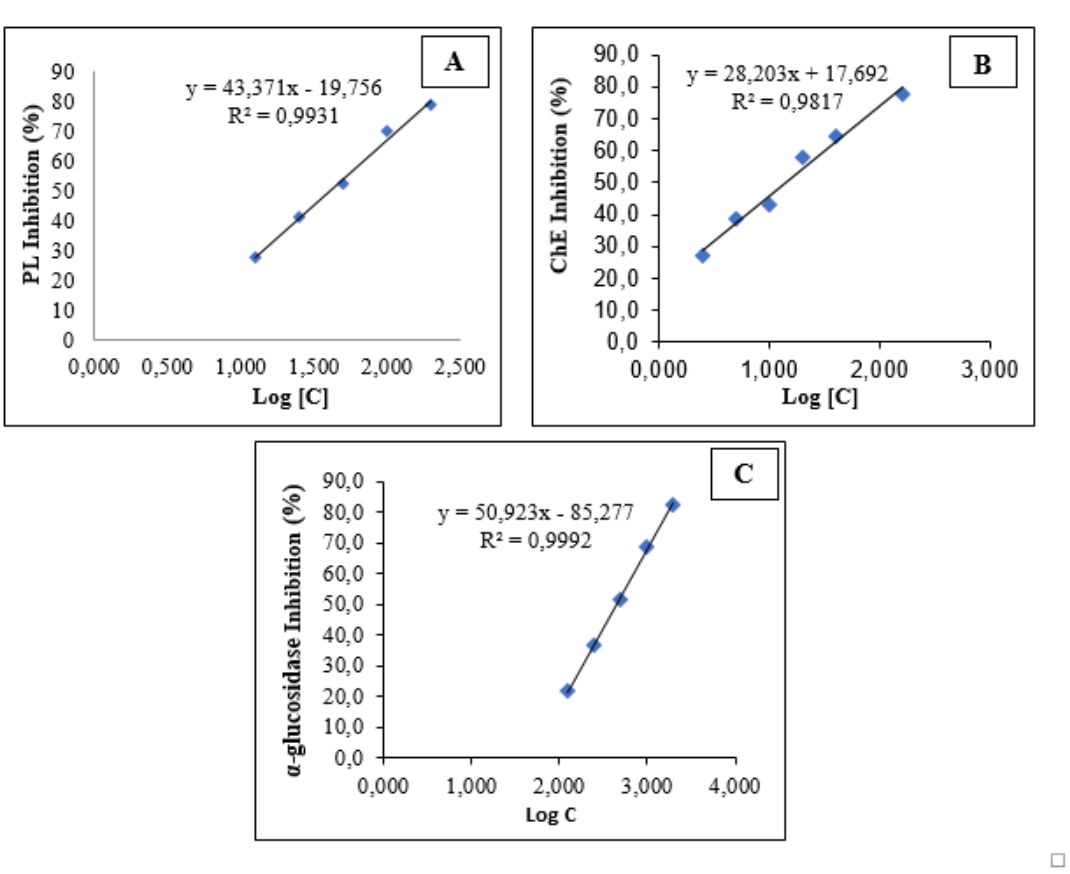


Figure 1. The calibration graphs of orlistat (A), simvastatin (B), and acarbose (C)

Regulating postprandial hyperglycemia and hyperlipidemia by inhibiting the enzymatic digestion of dietary fats and carbohydrates is reported to be an important and widely accepted therapeutic approach in the management of diabetes and obesity (Tucci et al., 2010; Magwaza et al., 2026). The literature contains various studies on the anti-obesity, antihyperglycemic, and antihyperlipidemic effects of extracts, compounds, and products obtained from natural sources (Bandara et al., 2023; Güverti et al., 2026). No previous studies were found on the pancreatic lipase, cholesterol esterase, and α-glucosidase inhibitory effects of *B. plantaginea* and *B. auriculata* var. *paludosa*. In this study, the antihyperlipidemic, antidiabetic, and anti-obesity effects of methanol extracts, ethyl acetate, chloroform, and the remaining aqueous subfraction obtained from the aerial parts of two *Barbarea* species naturally distributed in Türkiye, *B. auriculata* var. *paludosa* and *B. plantaginea*, were evaluated for the first time. Therefore, the findings obtained in the study may provide data for future studies on these species. *Barbarea* species have the potential to be used in studies aimed at developing health-beneficial products from natural resources. However, further *in vitro* and *in vivo* studies are needed to better understand the biological activities and mechanisms of action.

5. CONCLUSIONS

In conclusion, this study is the first to investigate the pancreatic lipase, cholesterol esterase, and α-glucosidase inhibitory potential of extracts obtained from the aerial parts of *B. auriculata* var. *paludosa* and *B. plantaginea*, which occur naturally in Türkiye. Among the samples tested, the ethyl acetate subfraction of *B. plantaginea* showed the highest pancreatic lipase and cholesterol esterase inhibitory activity, while the methanol extract of *B. auriculata* var. *paludosa* showed the most pronounced *α*-glucosidase inhibitory effect. These findings suggest that *Barbarea* species may be promising natural sources of bioactive compounds of potential importance for the management of obesity, hyperlipidemia, and postprandial hyperglycemia. However, further mechanism based enzyme inhibition studies and *in vivo* research are needed to identify the active compounds, elucidate their mechanisms of action, and evaluate their safety and therapeutic potential.

ACKNOWLEDGMENTS

The study was supported by the Office of Scientific Research Projects of Karadeniz Technical University (Project number: TLÖ-2023-10992).

AUTHOR CONTRIBUTION

MB: Conceptualization, Supervision, Formal analysis, Funding acquisition, Investigation, Methodology, Writing - original draft; ŞK: Formal analysis, Investigation, Methodology, Writing - review and editing; AK: Resources; AAÖ: Investigation, Formal analysis; HT: Investigation, Formal analysis.

DECLARATIONS

Ethics Approval and Consent to Participate

This study did not involve any human participants or animals. Therefore, ethics committee approval was not required.

Conflict of Interest

The authors declare that there is no conflict of interest.

REFERENCES

Agerbirk, N., & Olsen, C. E. (2015). Glucosinolate hydrolysis products in the crucifer Barbarea vulgaris include a thiazolidine-2-one from a specific phenolic isomer as well as oxazolidine-2-thiones. Phytochemistry, 115, 143-151.

Akkemik, Ü., & Yılmaz, H. (2016). A new species record for the flora of Turkey: Barbaraea bracteosa Guss. Journal of the Faculty of Forestry Istanbul University, 66(2), 636-640.

Aktar, N., Qureshi, N. K., & Ferdous, H. S. (2017). Obesity: A review of pathogenesis and management strategies in adult. Delta Medical College Journal, 5(1), 35-48.

Al-Shehbaz, I. A., Mutlu, B., & Dönmez, A. A. (2007). The Brassicaceae (Cruciferae) of Turkey, updated. Turkish Journal of Botany, 31(4), 327-336.

Andersson, A. A., Merker, A., Nilsson, P., Sørensen, H., & Åman, P. (1999). Chemical composition of the potential new oilseed crops Barbarea vulgaris, Barbarea verna and Lepidium campestre. Journal of the Science of Food and Agriculture, 79(2), 179-186.

Seyedan, A., Alshawsh, M. A., Alshagga, M. A., Koosha, S., & Mohamed, Z. (2015). Medicinal plants and their inhibitory activities against pancreatic lipase: A review. Evidence-Based Complementary and Alternative Medicine, 2015(1), 973143.

Badem, M., Sener, S. O., Kanbolat, S., Korkmaz, N., Yildirmiş, S., Ozgen, U., ... & Çalış, İ. (2021). Evaluation of biological activities of Barbarea integrifolia and isolation of a new glucosinolate derivated compound. Zeitschrift für Naturforschung C, 76(9-10), 375-382.

Badem, M., Sener, S. O., Korkmaz, N., Kanbolat, S., Yildirmiş, S., Ozgen, U., ... & Kandemir, A. (2020). Phenolic content and enzyme inhibition activities of Barbarea auriculata var. paludosa, B. integrifolia and B. plantaginea (Brassicaceae).

Badenes-Perez, F. R., Gershenzon, J., & Heckel, D. G. (2014). Insect attraction versus plant defense: Young leaves high in glucosinolates stimulate oviposition by a specialist herbivore despite poor larval survival due to high saponin content. PLoS ONE, 9(4), e95766.

Bağcı, Y. (2012). Barbarea. In A. Güner, S. Aslan, T. Ekim, M. Vural, & M. T. Babaç (Eds.), Türkiye bitkileri listesi (Damarlı bitkiler) (p. 1290). Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği Yayını.

Bandara, S., Devereaux, S., & Weerasooriya, A. (2023). Methods to evaluate the antiobesity effects of medicinal plants using enzyme assays. Obesities, 3(1), 13-35.

Baytop, T. (1984). *Türkiye'de bitkiler ile tedavi (Geçmişte ve bugün).* University of İstanbul, İstanbul, 417.

Bianco, G., Agerbirk, N., Losito, I., & Cataldi, T. R. (2014). Acylated glucosinolates with diverse acyl groups investigated by high resolution mass spectrometry and infrared multiphoton dissociation. Phytochemistry, 100, 92-102.

Bray, G. A., & Tartaglia, L. A. (2000). Medicinal strategies in the treatment of obesity. Nature, 404(6778), 672-677.

Bustanji, Y., Al-Masri, I. M., Mohammad, M., Hudaib, M., Tawaha, K., Tarazi, H., & AlKhatib, H. S. (2011). Pancreatic lipase inhibition activity of trilactone terpenes of Ginkgo biloba. Journal of Enzyme Inhibition and Medicinal Chemistry, 26(4), 453-459.

Cartea, M. E., & Velasco, P. (2008). Glucosinolates in Brassica foods: Bioavailability in food and significance for human health. Phytochemistry Reviews, 7(2), 213-229.

Dalby-Brown, L., Olsen, C. E., Nielsen, J. K., & Agerbirk, N. (2011). Polymorphism for novel tetraglycosylated flavonols in an eco-model crucifer, Barbarea vulgaris. Journal of Agricultural and Food Chemistry, 59(13), 6947-6956.

Ercan, P., & El, S. N. (2014). Obeziteyi önleyen gıda bileşenleri. Akademik Gıda, 12(1), 69-77.

Fraisse, D., Carnat, A., Viala, D., Pradel, P., Besle, J. M., Coulon, J. B., ... & Lamaison, J. L. (2007). Polyphenolic composition of a permanent pasture: Variations related to the period of harvesting. Journal of the Science of Food and Agriculture, 87(13), 2427-2435.

Güverti, Ö. F., Pekacar, S., Özüpek, B., & Orhan, D. D. (2026). In vitro evaluation of pancreatic lipase and cholesterol esterase inhibitory activities, antioxidant potential, and phytochemical content of Cistus laurifolius. Pharmaceutical Chemistry Journal, 1-7.

He, D., Huang, Y., Ni, X., & Bao, Z. (2026). Prospective associations of triglyceride-glucose related indices with cardiovascular disease and mortality in individuals with metabolic syndrome: Evidence from the UK Biobank. Cardiovascular Diabetology.

Hruby, A., & Hu, F. B. (2015). The epidemiology of obesity: A big picture. Pharmacoeconomics, 33(7), 673-689.

Hui, D. Y., & Howles, P. N. (2002). Carboxyl ester lipase: Structure-function relationship and physiological role in lipoprotein metabolism and atherosclerosis. Journal of Lipid Research, 43(12), 2017-2030.

Kahn, S. E., Hull, R. L., & Utzschneider, K. M. (2006). Mechanisms linking obesity to insulin resistance and type 2 diabetes. Nature, 444(7121), 840-846.

Kang, J. H., Lee, H. A., Kim, H. J., & Han, J. S. (2017). Gelidium amansii extract ameliorates obesity by down-regulating adipogenic transcription factors in diet-induced obese mice. Nutrition Research and Practice, 11(1), 17-24.

Khakimov, B., Tseng, L. H., Godejohann, M., Bak, S., & Engelsen, S. B. (2016). Screening for triterpenoid saponins in plants using hyphenated analytical platforms. Molecules, 21(12), 1614.

Kuzina, V., Nielsen, J. K., Augustin, J. M., Torp, A. M., Bak, S., & Andersen, S. B. (2011). Barbarea vulgaris linkage map and quantitative trait loci for saponins, glucosinolates, hairiness and resistance to the herbivore Phyllotreta nemorum. Phytochemistry, 72(2-3), 188-198.

Lowe, M. E. (2002). The triglyceride lipases of the pancreas. Journal of Lipid Research, 43(12), 2007-2016.

Magwaza, S. T. N., Olofinsan, K. A., & Islam, M. S. (2026). In vitro and computational investigation of the antidiabetogenic pharmacological bioactivities of Gigartina polycarpa (Kützing) Setchell & N. L. Gardner 1933 red seaweed. South African Journal of Botany, 190, 51-60.

O'Neill, S., & O'Driscoll, L. (2015). Metabolic syndrome: A closer look at the growing epidemic and its associated pathologies. Obesity Reviews, 16(1), 1-12.

Palanisamy, U. D., Ling, L. T., Manaharan, T., & Appleton, D. (2011). Rapid isolation of geraniin from Nephelium lappaceum rind waste and its anti-hyperglycemic activity. Food Chemistry, 127(1), 21-27.

Patra, S., Nithya, S., Srinithya, B., & Meenakshi, S. M. (2015). Review of medicinal plants for anti-obesity activity. Translational Biomedicine, 6(3).

Pedras, M. S. C., Alavi, M., & To, Q. H. (2015). Expanding the nasturlexin family: Nasturlexins C and D and their sulfoxides are phytoalexins of the crucifers Barbarea vulgaris and B. verna. Phytochemistry, 118, 131-138.

Rodríguez-Pérez, C., Segura-Carretero, A., & del Mar Contreras, M. (2019). Phenolic compounds as natural and multifunctional anti-obesity agents: A review. Critical Reviews in Food Science and Nutrition, 59(8), 1212-1229.

Sakunpak, A., Saingam, W., Jaisamut, S., Issuriya, A., & Ruangrungsi, N. (2021). Pyranocarbazole alkaloids, isolated from Clausena cambodiana leaves, as a pancreatic cholesterol esterase inhibitor, and their HPLC–DAD quantitative determination method. Chemical Papers, 75(6), 2451-2458.

Senatore, F., D'Agostino, M., & Dini, I. (2000). Flavonoid glycosides of Barbarea vulgaris L. (Brassicaceae). Journal of Agricultural and Food Chemistry, 48(7), 2659-2662.

Subaş, T., Çetinkaya, S., Şirin, S., Başer, T., & Süntar, I. (2026). Dietary polyphenols targeting NLRP3 inflammasome in obesity and metabolic disorders: A review on experimental and computational evidence. International Journal of Food Sciences and Nutrition, 1-17.

Tucci, S. A., Boyland, E. J., & Halford, J. C. (2010). The role of lipid and carbohydrate digestive enzyme inhibitors in the management of obesity: A review of current and emerging therapeutic agents. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 3, 125-143.

Vig, A. P., Rampal, G., Thind, T. S., & Arora, S. (2009). Bio-protective effects of glucosinolates: A review. LWT - Food Science and Technology, 42(10), 1561-1572.

Wei, Y., Peng, A. Y., Wang, B., Ma, L., Peng, G., Du, Y., & Tang, J. (2014). Synthesis and biological evaluation of phosphorylated flavonoids as potent and selective inhibitors of cholesterol esterase. European Journal of Medicinal Chemistry, 74, 751-758.

Zor, M., Pekacar, S., & Orhan, D. D. (2022). Nasturtium officinale'nin fitokimyasal içeriği, antioksidan ve enzim inhibitör etkileri. Journal of Faculty of Pharmacy of Ankara University, 46(1), 114-128.