REVIEW ARTICLE

THE EFFECT OF GARLIC ON CARBOHYDRATE METABOLISM AND GLYCAEMIC CONTROL: A REVIEW OF THE LITERATURE

Wpływ czosnku na metabolizm węglowodanów i kontrolę glikemii: przegląd literatury

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Abstract

Aim of the paper: To present a systematic review of the scientific literature on the hypoglycaemic effects of garlic (*Allium sativum* L.), with a focus on its mechanisms of action, clinical efficiency, and potential adverse effects. **Materials and methods:** Publications from 2015 to 2024 available in the PubMed, Scopus, and Web of Science databases were analysed. These included randomised clinical trials, meta-analyses, and systematic reviews. **Results:** The collected data suggest that garlic supplementation, particularly in its natural form, can significantly reduce fasting blood glucose levels, with more pronounced effects observed over longer intervention periods. Some studies also report positive effects on glycated haemoglobin, postprandial glucose, and fructosamine levels. The proposed mechanisms of action include increased insulin secretion, improved tissue sensitivity to insulin, and modulation of oxidative and inflammatory processes. **Conclusions:** The evidence indicates that garlic has considerable potential as a natural adjunct in the prevention and treatment of metabolic disorders. However, further large-scale clinical trials are required to conclusively confirm its efficacy and safety.

Streszczenie

Cel badania: Celem niniejszego badania jest przegląd systematyczny aktualnej literatury naukowej dotyczącej hipoglikemicznego działania czosnku (*Allium sativum* L.), ze szczególnym uwzględnieniem mechanizmów jego działania, skuteczności klinicznej i możliwych działań niepożądanych. **Materiały i metody:** Przeanalizowano publikacje z lat 2015–2024 dostępne w bazach danych PubMed, Scopus i Web of Science. Obejmowały one randomizowane badania kliniczne, przeglądy systematyczne i metaanalizy. **Wyniki:** Zebrane dane wskazują, że suplementacja czosnkiem, zwłaszcza w jego naturalnej postaci, znacznie obniża poziom glukozy we krwi na czczo, a efekt ten jest tym bardziej wyraźny, im dłuższy jest czas trwania interwencji. Niektóre badania wskazują również na pozytywny wpływ na poziom hemoglobiny glikowanej, glikemii poposiłkowej i fruktozaminy. Mechanizmy działania czosnku obejmują między innymi zwiększone wydzielanie insuliny, poprawę wrażliwości tkanek na insulinę oraz modulację procesów oksydacyjnych i zapalnych. **Wnioski:** Zebrane dowody wskazują na znaczny potencjał czosnku jako naturalnego środka wspomagającego profilaktykę i leczenie zaburzeń metabolicznych, jednak aby w pełni potwierdzić jego skuteczność i bezpieczeństwo, konieczne są dalsze szeroko zakrojone badania kliniczne.

Keywords: diabetes; hyperglycaemia; garlic; *Allium sativum*; fasting blood glucose

Słowa kluczowe: cukrzyca; hiperglikemia; czosnek; *Allium sativum*; glikemia na czczo

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Introduction

Diabetes is a condition that is becoming increasingly common in both older and younger populations, making it a challenge faced by physicians across multiple specialties, not only because of the disease itself, but also due to the complications it causes. According to the WHO, in the 1980s, there were nearly 108 million people worldwide living with this disease. In 2021, the number reached 537 million, and forecasts estimate that by 2030, the total number of diabetics will exceed 640 million. Diabetes is one of the world's leading causes of death, and its increasing prevalence shows how serious the problem already is, and what we will be facing in the future [1].

Therefore, effective measures to support diabetes treatment are continually being sought. One substance with documented hypoglycaemic properties is *Allium sativum* L., commonly known as garlic. This spice, which has been known for centuries, is valued in many countries and cultures not only for its flavour but also for its medicinal properties, for example in the traditional treatment of colds. The aim of this study was to analyse the available literature on the effects of garlic on glucose control, discuss the mechanisms by which its active substances regulate blood glucose levels, and highlight potential side effects.

Chemical composition of garlic

Garlic contains a wide range of bioactive components, many of which have significant health-promoting benefits, including hypoglycaemic, anti-inflammatory, and anticancer properties. Garlic is rich in phytochemicals, including sulphur-containing components formed by enzymatic changes when plant cells are damaged. The most important of these are:

- allicin,
- ajoene,
- alliin,
- S-allyl cysteine (SAC),
- diallyl trisulfide (DATS),
- diallyl disulfide (DADS).

These compounds affect glycaemic levels, improve tissue sensitivity to insulin, and protect pancreatic beta cells from oxidative stress [2, 3].

Garlic contains a variety of vitamins, especially B vitamins and vitamin C, as well as minerals such as selenium, phosphorus, and potassium. It also provides fructans, including inulin, which acts as a prebiotic. Garlic also contains polyphenols and flavonoids, such as quercetin and kaempferol, which have antioxidant properties and can regulate endothelial function and ongoing inflammatory processes [4].

The diversity of the content of these compounds depends on the form of garlic preparation (raw, cooked, aged extract, dried powder), growing conditions, and storage duration, as a result of which these preparations have different biological activities [5].

Mechanisms of action

The effect of garlic on blood glucose levels has been the subject of numerous scientific studies, as it can affect these levels through various mechanisms (Tab. 1). These mechanisms are well documented in preclinical research, but their direct confirmation in human studies still requires further analysis.

Side effects

Despite its numerous health-promoting properties, including the hypoglycaemic potential discussed in this paper, as well as its beneficial effects on other components of metabolic syndrome [20–22], garlic may cause adverse effects. The most commonly reported include unpleasant odour from the mouth and skin, which is more pronounced when raw garlic is consumed compared with its heat-treated forms [23], and gastrointestinal symptoms such as heartburn, reflux, nausea, bloating, and diarrhoea [24, 25]. Some patients may also experience allergic reactions, including urticaria, angioedema, and shortness of breath [26]. In addition, garlic may enhance the effects of certain medications, including anticoagulants, thereby increasing the risk of bleeding [27], as well as antidiabetic drugs such as metformin or glibenclamide, allowing therapeutic effects to be achieved with lower doses of medication [28, 29]. Therefore, garlic should be used with caution in both combination therapy and monotherapy, taking into account potential interactions and adverse effects.

Summary

An analysis of the available literature indicates that garlic has significant hypoglycaemic potential, associated with multiple molecular processes that are the subject of scientific research (Tab. 2). Its effectiveness depends on the form and method of processing. Studies suggest that

Table 1. Effects of garlic on the body and the molecular mechanisms underlying these effects

Effect of garlic on the body	Mechanism of action
Increased secretion of endogenous insulin	• Inhibition of pancreatic beta cell apoptosis [6, 7]
Increased tissue sensitivity to insulin	• Activation of the PI3K/AKT/Nrf2-Keap1 insulin pathway • Increased expression of the GLUT4 glucose transporter [6, 8]
Protection of pancreatic beta cells	• Reduction of oxidative stress [9, 10]
Inhibition of insulin resistance development	• Modulation of TNF-α and IL-6 • Reduction of reactive oxygen species [5]
Reduction of intestinal glucose absorption	• Inhibition of α-glucosidase and α-amylase activity [11, 12]
Support for the development of beneficial intestinal bacteria (including *Bifidobacterium*, *Lactobacillus*)	• Impact on the gut-pancreas axis [13]

Table 2. Review of meta-analyses (2015–2024)

Meta-analysis	Studies included	Scope of analysis	Conclusions	Comments
2015 (Hou LQ et al.) [14]	7 RCTs (513 participants)	Effect of garlic on FBG, PPG, and HbA_{1c} levels	• Garlic consumption statistically significantly reduces FBG levels	Insufficient data on the effect on PPG (a statistically significant reduction was reported in only one study) and HbA_{1c} (two studies with inconsistent results) [15, 16]
2017 (Emami S et al.) [17]	10 RCTs	Effect of garlic on FBG, PPG, and HbA_{1c}	• Garlic consumption statistically significantly reduces FBG levels, with a more pronounced effect in individuals with concomitant lipid disorders • Garlic consumption may reduce PPG, but does not significantly affect HbA_{1c} levels	Garlic in its natural form has been shown to be more effective than supplements
2017 (Wang J et al.) [18]	9 RCTs (768 participants)	Effect of garlic on FBG, HbA_{1c}, and fructosamine levels	• Garlic consumption statistically significantly reduces FBG levels • Garlic significantly reduces fructosamine and HbA_{1c} levels (data reported in two studies)	Five studies used garlic monotherapy compared to placebo, while the remainder used combination therapy with garlic and other hypoglycaemic drugs or insulin compared to a control group.
2023 (Fu Z et al.) [19]	19 RCTs (999 participants)	Effect of garlic on metabolic syndrome	• Garlic mildly lowers FBG, but without statistical significance	The effect of garlic on FBG was verified in only five studies, including 214 participants. Garlic significantly lowers TG, TC, LDL-C, DBP, BMI, and WC levels
2024 (Zhao X et al.) [2]	22 RCTs	Effect of garlic on FBG, HbA_{1c}, and lipid profile	• Garlic statistically significantly lowers FBG levels (results from 8 RCTs) and causes a decrease in HbA_{1c} (results from 3 RCTs)	Garlic significantly lowers TC and LDL-C levels, while increasing HDL-C levels. It does not significantly affect TG levels
RCT – randomised controlled trial; FBG – fasting blood glucose; PPG – postprandial glucose; glycated hemoglobin (HbA_{1c}) – haemoglobin A_{1c}; TG – triglycerides; TC – total cholesterol; LDL-C – low density lipoprotein cholesterol; HDL-C – high-density lipoprotein cholesterol; DBP – diastolic blood pressure; BMI – body mass index; WC – waist circumference				

fresh preparations have higher bioavailability and efficacy compared to supplements. It is also important to note that garlic, despite its natural origin, may cause side effects.

Available meta-analyses indicate that garlic can modulate carbohydrate metabolism, especially by lowering fasting blood glucose levels, and its hypoglycaemic effect is more pronounced when used in combination with antidiabetic drugs than as monotherapy.

The effect of garlic on glycated hemoglobin levels is less consistent, although more recent meta-analyses indicate a reduction following long-term use. Some studies also suggest a beneficial effect on postprandial glucose and fructosamine levels, highlighting the need for further research in this area.

In summary, current scientific data suggest a potentially beneficial effect of garlic on glycaemic control, but the lack of methodological consistency and variability in available study results highlights the need for standardised, high-quality, multicentre clinical trials to more accurately assess its efficacy and safety.

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