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*Short communication*

# Polyphenols from *Aronia melanocarpa* in metabolic syndrome: effects on key pathophysiological mechanisms

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## Introduction

Metabolic syndrome affects approximately 20–25% of the adult global population and is characterized by central obesity, insulin resistance, arterial hypertension and dyslipidemia (International Diabetes Federation, 2023). Individuals with metabolic syndrome have increased mortality and a higher risk of cardiovascular disease and type 2 diabetes mellitus, making it an important predictor of cardiometabolic complications (International Diabetes Federation, 2023). Its pathogenesis is multifactorial and involves insulin resistance, adipose tissue dysfunction, chronic low-grade inflammation, oxidative stress and endothelial dysfunction (Roberts and Sindhu, 2009).

In this context, polyphenol-rich natural products have attracted scientific interest as nutritional support in cardiometabolic risk management. *Aronia melanocarpa* is one of the richest natural sources of polyphenols, particularly anthocyanins, proanthocyanidins, flavonols and phenolic acids (Kulling and Rawel, 2008).

## Pathophysiology of metabolic syndrome

Insulin resistance impairs glucose uptake in skeletal muscle, liver and adipose tissue, leading to compensatory hyperinsulinemia and disturbed glucose metabolism. Visceral adipose tissue further promotes metabolic dysfunction through free fatty acids and pro-inflammatory mediators, contributing to dyslipidemia and chronic low-grade inflammation (Chait and den Hartigh, 2020).

Oxidative stress contributes to metabolic syndrome by promoting lipid peroxidation, cellular damage, inflammatory activation and endothelial dysfunction. Reduced nitric oxide bioavailability impairs endothelium-dependent vasodilation, thereby supporting the development of hypertension, atherosclerosis and increased cardiovascular risk (Roberts and Sindhu, 2009).

## Mechanisms of action of *Aronia melanocarpa* polyphenols

Polyphenols from *Aronia melanocarpa* act on several targets relevant to metabolic syndrome, including oxidative stress, inflammation, glucose and lipid metabolism, and endothelial function. Their antioxidant activity is mainly related to the high content of anthocyanins and proanthocyanidins, which can neutralize reactive oxygen species and reduce lipid peroxidation (Kulling and Rawel, 2008). In experimental models, standardized *Aronia melanocarpa* extract improved redox balance, antioxidant defense and metabolic parameters related to cardiometabolic risk (Jakovljević et al., 2019).

The anti-inflammatory activity of Aronia polyphenols is also relevant, as these compounds reduce pro-inflammatory cytokine expression and inhibit the NF-κB signaling pathway, a central

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regulator of inflammatory gene transcription (Go et al., 2024). This mechanism supports their potential role in reducing chronic low-grade inflammation, which is one of the key pathophysiological mechanisms of metabolic syndrome.

Aronia polyphenols also influence glucose and lipid metabolism. In healthy adults, Aronia juice reduced postprandial blood glucose after a carbohydrate-rich meal, partly through inhibition of enzymes involved in carbohydrate digestion and incretin metabolism, including α-glucosidase and dipeptidyl peptidase IV (Yamane et al., 2017). In patients with metabolic syndrome, black chokeberry extract supplementation was associated with reduced blood pressure, glycemia and lipid profile parameters (Tasić et al., 2021).

A particularly important mechanism is the effect on endothelial function and vascular tone. Polyphenol-rich *Aronia melanocarpa* juice supports endothelial nitric oxide synthase activation through redox-sensitive signaling pathways, increasing nitric oxide production in endothelial cells (Kim et al., 2024). By increasing nitric oxide bioavailability and reducing oxidative stress, Aronia polyphenols support vascular relaxation and blood pressure regulation, which is also supported by experimental evidence in a hypertension model (Cebova et al., 2017).

## Conclusion

Metabolic syndrome involves central obesity, insulin resistance, hypertension and dyslipidemia, driven by impaired glucose and lipid metabolism, oxidative stress, chronic low-grade inflammation and endothelial dysfunction. Polyphenols from *Aronia melanocarpa* act on several of these mechanisms simultaneously by reducing oxidative stress, modulating inflammatory signaling, improving postprandial glycemic response, supporting lipid metabolism and increasing endothelial nitric oxide bioavailability. Therefore, *Aronia melanocarpa* represents scientifically justified nutritional support in individuals with metabolic syndrome and increased cardiometabolic risk, as part of a broader approach including lifestyle modification and risk factor control.

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