

"Kombucha as a potential support in insulin resistance: a multilevel analysis of the biological activity of kombucha from green and black tea – from chemical characterization and *in vitro* studies to intervention in individuals with insulin resistance"

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Type 2 diabetes and its precursor condition, insulin resistance, is one of the most serious health challenges of our time, affecting increasingly younger generations. With urbanization and the expansion of diets rich in highly processed foods, the prevalence of carbohydrate disorders is increasing, and it is estimated that diabetes will become the seventh most common cause of death worldwide by 2030. A key factor in this disease - impaired insulin signaling - is closely linked to chronic oxidative stress and inflammation, which can be modified by appropriate dietary components.

In the search for natural strategies to aid in the therapy and prevention of this disorder, increasing attention is being paid to functional foods - especially fermented products high in bioactive compounds. Kombucha, a fermented tea beverage prepared using symbiotic cultures of bacteria and yeast (SCOBY), contains a range of bioactive compounds, including polyphenols, organic acids, vitamins and minerals, among others, and studies *in vitro* and *in* animal models indicate its promising antioxidant, anti-inflammatory and anti-diabetic properties. However, despite the growing interest in fermented tea, its detailed composition and the effects of the different types of raw materials used (e.g., green or black tea) on its bioactive compounds and antiglycemic potential have not been fully understood.

Clinical data to date are very limited, with only two short-term studies in small groups of adults (11/12 subjects) showing a reduction in fasting glycemia and postprandial hyperglycemia. However, long-term analyses in patients with insulin resistance are lacking, as are comparisons of how the efficacy of kombucha is affected by both the type of tea used and the form of administration. Although kombucha is most often consumed as a beverage, a standardized, microencapsulated form in capsules could provide greater stability, convenience and acceptability - especially for people who do not like the sensory characteristics of kombucha (taste or aroma).

This project aims to fill the research gap through a comprehensive, multi-stage evaluation of kombucha's potential in the context of insulin resistance prevention and therapy. Initially, two variants of the beverage - based on green and black tea - will be examined for chemical composition including determination of total polyphenols, flavonoids, vitamin C, caffeine, organic acids, sugar, elements and microbial profile. The next step will be to simulate *in vitro* digestion and measure the bioavailability of key bioactive components and their ability to inhibit glycemic enzymes and neutralize free radicals, as well as sensory analysis to assess the consumer affordability of the tested products. The anti-diabetic properties of kombucha will then be analyzed, as well as its antioxidant and anti-inflammatory activity using both laboratory methods and human cell culture (THP-1). On this basis, a variant with better health-promoting potential in the context of insulin resistance will be selected.

The most important stage of the project will be a clinical trial involving people with insulin resistance, in which we will compare the effects of a selected kombucha variant administered traditionally as a beverage and in an innovative, microencapsulated form in capsules. This will allow us to see which form of intake provides better improvement in insulin sensitivity, blood glucose regulation and reduction in markers of inflammation and oxidative stress.

The project combines analytical methods, *in vitro* studies and clinical intervention, which guarantees the reliability and practical usefulness of the recommendations. The implementation of this project will make an important contribution to the development of clinical nutrition science, diabetology and food technology. The results can be used to create standardized fermented products with documented antiglycemic effects, tailored to the needs of different patient groups. In turn, a comparison of the effectiveness of the beverage and capsules will answer the real needs of consumers, for whom the taste and form of the preparation determine regular use. Ultimately, this project may lay the foundation for a new dietary and supplementation strategy in the prevention and treatment of lifestyle diseases, improving the quality of life for millions of patients.