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ANTIDIABETIC ACTIVITY OF *COFFEA ARABICA L.*: A REVIEW OF IN-VITRO AND IN-VIVO EVIDENCE

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ABSTRACT

Diabetes mellitus is a chronic metabolic disorder characterized mainly by high blood glucose levels caused by problems with insulin secretion, insulin action, or both. Coffee, particularly *Coffea arabica L.*, contains several biologically active compounds such as chlorogenic acids, caffeine, trigonelline, caffeic acid, quinic acid, flavonoids and other phenolic compounds that may influence glucose metabolism. The antidiabetic potential of *Coffea arabica L.* has been investigated using coffee beans, green and roasted coffee, pulp and other coffee-processing by-products. In-vitro studies have reported inhibition of carbohydrate-digesting enzymes such as α-amylase and α-glucosidase, reduction of intestinal glucose transport, and changes in glucose transporter expression. Animal studies have also reported reductions in postprandial or diabetic blood glucose levels after treatment with selected coffee extracts or brewed Arabica coffee. However, the strength of the activity differs according to the plant material, extraction method, coffee origin, roasting condition, assay system and experimental model. The available evidence therefore supports the antidiabetic potential of *Coffea arabica L.* but further standardized in-vitro, animal and clinical studies are required before definite therapeutic conclusions can be made.

KEYWORDS: *Coffea arabica*, diabetes mellitus, α-amylase, α-glucosidase, chlorogenic acid, caffeine, glucose uptake, GLUT2, GLUT4, coffee pulp.

1. INTRODUCTION TO DIABETES MELLITUS

1.1 Diabetes mellitus

Diabetes mellitus is a metabolic disease characterized by persistent elevation of blood glucose, commonly called hyperglycemia.[1] Hyperglycemia can develop when insulin secretion is inadequate, when tissues become resistant to insulin, or when both abnormalities occur together.[1] Insulin is important for maintaining glucose homeostasis because it promotes glucose utilization and storage in tissues, while counter-regulatory hormones influence hepatic glucose production.[1]

Type 2 diabetes mellitus is the most common form of diabetes and is associated mainly with insulin resistance and impaired glucose regulation.[8] The available literature in the articles particularly focuses on type 2 diabetes because coffee-derived compounds may influence carbohydrate digestion, intestinal glucose absorption and peripheral glucose utilization.[4]

1.2 Causes and risk factors

Type 2 diabetes develops through a combination of metabolic and lifestyle-related factors, with insulin resistance, impaired glucose transport and abnormal glucose metabolism playing important roles.[1]

Increased intestinal glucose absorption may also contribute to the development and maintenance of

abnormal blood glucose levels, because dietary carbohydrates are converted into absorbable sugars by digestive enzymes.[4]

The studies included in this review mainly focus on the biochemical control of glucose rather than providing a complete discussion of every clinical risk factor for diabetes.[4] Therefore, coffee should be considered as a possible supportive dietary or nutraceutical approach rather than a replacement for established diabetes management.[5]

1.3 Types of Diabetes

Diabetes can occur in different forms, but the studies included in this review mainly investigate type 2 diabetes and experimental models of hyperglycemia.[8] Streptozotocin-induced diabetic rats have been used as an experimental model to investigate the effects of brewed Arabica coffee on glucose regulation, insulin, GLUT4, glucagon and cortisol.[9]

1.4 Treatment and Management of Diabetes

Management of type 2 diabetes generally aims to control blood glucose and improve insulin sensitivity, and metformin remains an important antidiabetic medicine discussed in the supplied literature.[10] Metformin reduces hepatic glucose production and can improve insulin sensitivity in peripheral tissues.[10]

The inhibition of carbohydrate-digesting enzymes is another approach for controlling postprandial blood glucose because inhibition of α-amylase and α-glucosidase can slow carbohydrate digestion and glucose release.[5] This mechanism provides an important basis for investigating *C. arabica* extracts as possible supportive agents for glucose management.[5]

2. *Coffea arabica*

2.1 Botanical Information

Coffea arabica L.. is one of the economically important species of coffee and is commonly known as Arabica coffee.[2] It is one of the two major commercially cultivated coffee species together with *Coffea canephora*.[2]

Coffee processing produces several plant-derived materials, including coffee beans, pulp, husk and silver skin, and many of these materials contain compounds of potential biological interest.[11] Coffee pulp alone represents an important fraction of coffee-processing waste and contains phenolic compounds and other bioactive constituents.[12]

2.2 Distribution

Coffea arabica L. belongs to the family Rubiaceae and is cultivated in several coffee-producing regions of the world, while the studies included here represent coffee materials from countries and regions including Ethiopia, Sumatra, Guatemala, Brazil, Mexico, Portugal and other coffee-producing areas.[5] Differences in geographical origin can influence the chemical composition and biological activity of coffee extracts.[6]

2.3 Important Plant Parts

The major materials relevant to the antidiabetic literature supplied for this review are the coffee bean, green coffee, roasted coffee, silver skin, pulp and other coffee-processing residues.[3] The coffee pulp is the fleshy material surrounding the coffee seed and is produced in large quantities during coffee processing.[13]

The supplied articles do not provide sufficient direct experimental evidence for *Coffea arabica L.*leaves or stem to allow their antidiabetic activity to be reviewed with the same confidence as the bean, pulp or silver skin.[14] Therefore, leaves and stem should be considered research gaps rather than established antidiabetic parts of *Coffea arabica L.* based on the present article set.[14]

2.4 Major Phytochemical Constituents

Coffee contains several groups of bioactive compounds, including caffeine, chlorogenic acids, caffeic acid, trigonelline, diterpenes, flavonoids and other phenolic compounds.[2] Chlorogenic acids are particularly important because coffee is a major dietary source of these phenolic compounds.[15]

Coffee pulp also contains chlorogenic acid, caffeic acid, ferulic acid, coumaric acid, flavonoids and condensed tannins such as procyanidins.[12] A recent study of *Coffea arabica L* coffee pulp reported total polyphenols of 90.33 mg GAE/g extract, total flavonoids of 60.48 mg CE/g extract and condensed tannins of 27.27 mg PC1eq/g extract.[16]

3. ANTIDIABETIC ACTIVITY OF DIFFERENT PARTS OF *COFFEA ARABICA*

3.1 Antidiabetic Activity of Coffee Beans

Coffee beans are among the most extensively studied parts of *Coffea arabica L.* for glucose-related effects.[2] In a Caco-2 cell model, *Coffea arabica L.* bean extract inhibited disaccharidase activity and reduced intestinal glucose absorption.[17]

The same study reported that the bean extract affected glucose transport through mechanisms involving SGLT1 and GLUT2 and altered AMPK-related signaling and hepatocyte nuclear factor 1α expression.[17] These findings suggest that coffee bean extract may reduce the amount of glucose entering intestinal cells rather than acting only through direct inhibition of digestive enzymes.[17]

The extract was prepared from dried *Coffea arabica L.* beans using hot-water extraction, demonstrating that aqueous extraction can recover compounds capable of producing measurable biological effects.[18]

3.2 Antidiabetic Activity of Green Coffee

Green coffee extracts have shown activity against several

mechanisms related to glucose regulation.[19] Green coffee extract contained relatively higher amounts of chlorogenic acids and produced strong inhibition of glucose and fructose uptake in Caco-2 intestinal cells.[19]

In one study, green coffee, roasted coffee and silver skin extracts all reduced glucose and fructose uptake, while green coffee produced the strongest overall inhibition.[19] At 1 mg/mL, green, roasted and silver skin extracts reduced GLUT2 gene expression by approximately 67%, 72% and 64%, respectively.[20] Green and roasted coffee also significantly reduced SGLT1 expression by approximately 36% and 38%, respectively.[20]

These findings indicate that the antidiabetic potential of green coffee may involve reduced intestinal sugar transport in addition to inhibition of carbohydrate-digesting enzymes.[20]



Fig. 1: Green Coffee Beans.

3.3 Antidiabetic Activity of Roasted Coffee

Roasting changes the chemical composition of coffee and can modify its biological activity.[19] A 2025 in-vitro study found that roasted coffee extract contained higher levels of flavonoids and tannins, whereas green coffee extract was richer in phenolic acids.[21]

Both green and roasted coffee extracts inhibited α-amylase and α-glucosidase, while roasted coffee showed better enzyme-inhibitory performance than the commercial treatments used in that study.[21] In a yeast glucose-uptake experiment, both extracts increased glucose transport at lower glucose concentrations, with approximately 90% uptake reported for green coffee and 77% for roasted coffee at 5 mm glucose.[22]

However, the glucose-uptake effect decreased at higher glucose concentrations, and green coffee maintained more of its activity than roasted coffee.[22]

3.4 Antidiabetic Activity of Silver Skin

Coffee silver skin is a major by-product generated during coffee roasting and contains caffeine and chloro genic acids.[11] Silver skin extract significantly inhibited glucose and fructose uptake in Caco-2 cells despite containing lower amounts of chlorogenic acids and caffeine than green and roasted coffee extracts.[23]

A laboratory-scale and pilot-scale study found that silver skin extracts significantly reduced glucose and fructose uptake and produced reductions in sugar-transporter expression.[11] Another study reported that silver skin exposure reduced GLUT2 expression to approximately 36% of the control level and showed an inhibitory effect on SGLT1 expression.[24]

The activity of silver skin is important because it shows that a coffee-processing by-product can retain biologically active compounds and may have value beyond being discarded as waste.[23]

3.5 Antidiabetic Activity of Coffee Pulp

Coffee pulp is one of the most promising non-bean parts of *Coffea arabica L.* in the supplied literature.[13] Coffee pulp contains considerable amounts of phenolic compounds, including chlorogenic acid, caffeic acid, ferulic acid, flavonoids and condensed tannins.[12]

A 2026 study found that *Coffea arabica L.* pulp extract inhibited α-amylase by 20.67 ± 2.28% and α-glucosidase by 34.69 ± 3.80% at 1000 µg/mL.[25] At the same concentration, acarbose produced 89.77 ± 0.94% α-amylase inhibition, whereas the pulp extract produced stronger inhibition against the yeast-derived α-glucosidase used in that particular assay.[25]

However, the authors correctly noted that the stronger apparent α-glucosidase inhibition should not be interpreted as proof that the pulp extract is superior to acarbose in humans because the enzyme source and experimental conditions can strongly influence the result.[25]

A separate 2025 study of Azorean *Coffea arabica L.* pulp found a reduction in glucose uptake by Caco-2 cells without a similar reduction in fructose uptake, suggesting possible selective effects on glucose transport.[26] The same pulp contained approximately 9.2 mg/g dry weight chlorogenic acid and about 0.98% caffeine.[26]

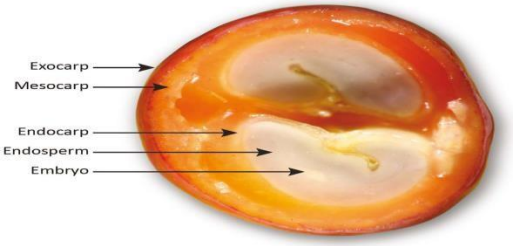


Fig. 2: Coffee Pulp.

3.6 Antidiabetic Activity of Coffee Husk

Coffee husk is another important coffee-processing by-product and has been investigated as a source of phenolic and other bioactive compounds.[27] The supplied literature identifies research on *Coffea arabica L.* coffee husk extracts and their carbohydrate-related biological activities, but the evidence is less extensive than that available for coffee beans, pulp and silver skin.[27]

Therefore, coffee husk can be considered a promising research material, but additional standardized studies are required to determine its relative α-amylase and α-glucosidase inhibitory strength and to establish whether these in-vitro effects translate into blood-glucose lowering effects in animals or humans.[27]

3.7 Antidiabetic activity of leaves

The articles does not provide adequate direct evidence for an antidiabetic study using *Coffea arabica* leaves.[14] Therefore, it would not be scientifically appropriate to state that *Coffea arabica L.* leaves have proven antidiabetic activity based on these articles alone.[14]

Some literature cited articles concerns coffee leaves from other *Coffea* species, but those findings should not automatically be transferred to *Coffea arabica L.*[28] Direct studies using authenticated *C. arabica* leaves should therefore be included in future work.[28]



Fig. 3: Coffee Plant Leaves.

4. ANTIDIABETIC ACTIVITY STUDIES AND ASSAYS

4.1 α-Amylase Inhibition Assay

α-Amylase is a digestive enzyme that begins the breakdown of starch into smaller carbohydrates, and its inhibition can slow the release of glucose from carbohydrate-containing foods.[25] Therefore, α-amylase inhibition is commonly used as an initial in-vitro screening method for potential antidiabetic plant extracts.[5]

Coffee extracts have demonstrated variable α-amylase inhibition depending on the plant material and extraction conditions.[21] In the 2026 coffee-pulp study, *C. arabica* pulp extract produced 20.67 ± 2.28% inhibition at 1000 µg/mL, compared with 89.77 ± 0.94% for acarbose.[25]

The 2025 green and roasted coffee study also demonstrated inhibition of α-amylase by both extracts, with roasted coffee producing stronger activity under the experimental conditions used.[21]

4.2 α-Glucosidase inhibition assay

α-Glucosidase catalyzes the final stages of carbohydrate

digestion and releases absorbable glucose from carbohydrate breakdown products.[25] Inhibition of this enzyme can therefore reduce or delay postprandial glucose release.[5]

C. arabica coffee extracts using rat intestinal α-glucosidase and porcine α-amylase assays.[5] The water extract of Sumatra coffee showed an α-glucosidase IC_{50} of 4.39 mg/mL, followed by Ethiopian coffee at 4.97 mg/mL and Guatemalan coffee at 5.19 mg/mL.[5]

These IC_{50} values show that the inhibitory activity varied between coffee origins even when the same general type of coffee material and extraction approach were used.[5] This variation may be related to differences in phytochemical composition, geographical origin, processing and extraction.[6]

4.3 Intestinal Glucose-Uptake Studies

In addition to digestive enzymes, coffee extracts can influence the movement of glucose from the intestinal lumen into intestinal cells.[17] *C. arabica* bean extract reduced glucose absorption in Caco-2 cells and inhibited disaccharidase activity.[17]

Green coffee, roasted coffee and silver skin extracts also reduced glucose and fructose uptake in Caco-2 cells.[3] The effect was associated mainly with reduced GLUT2 expression, while green and roasted coffee also significantly reduced SGLT1 expression.[20]

These results are important because they suggest that the antidiabetic effects of coffee may involve several stages of glucose handling rather than one single target.[20]

4.4 Glucose Uptake in Yeast Cells

The 2025 study by Calvo et al. used a yeast glucose-uptake assay as an additional in-vitro screening method.[22] At 5 mM glucose, green coffee produced approximately 90% glucose uptake and roasted coffee produced approximately 77% uptake, whereas the extraction solvent and acarbose produced much lower uptake.[22]

The effect decreased at higher glucose concentrations, but green coffee retained more activity than roasted coffee.[22] This experiment suggests that coffee extracts may influence cellular glucose utilization, although yeast assays cannot directly reproduce the complex physiology of human glucose metabolism.[22]

4.5 Chlorogenic acid and trigonelline

Chlorogenic acid and trigonelline are two important coffee compounds that have been directly investigated in relation to glucose tolerance.[15] In a randomized crossover trial involving 15 overweight men, ingestion of 1 g chlorogenic acid or 500 mg trigonelline significantly reduced early glucose and insulin responses during an oral glucose tolerance test.[15]

The study used 12 g decaffeinated coffee, 1 g chlorogenic acid, 500 mg trigonelline and placebo treatments, and the decaffeinated coffee supplied approximately 264 mg chlorogenic acid and 72 mg trigonelline.[15] However, neither treatment significantly changed the total glucose or insulin area under the curve during the two-hour OGTT.[15]

Therefore, these findings provide human evidence for an acute effect on early glucose and insulin responses, but they do not prove that chlorogenic acid or trigonelline alone can treat diabetes.[15]

4.6 Animal Studies Using Coffee Extracts

Animal studies provide stronger evidence than simple enzyme assays because they examine glucose responses in a whole organism.[5] In review article used Sprague–Dawley rats subjected to sucrose and starch loading and found that selected water extracts significantly reduced postprandial glucose levels.[5]

The Ethiopian water extract reduced the maximum glucose concentration by approximately 18% during sucrose loading and approximately 19% during starch loading.[5] These effects were associated with inhibition of intestinal sucrose and delayed carbohydrate absorption.[5]

A more recent study examined brewed *C. arabica* coffee in streptozotocin-induced diabetic male Wistar rats.[9] The animals received brewed Arabica coffee at 400 or 1200 mg/kg body weight for 28 days.[9]

Both doses reduced glucose levels, with the 1200 mg/kg dose producing the greater effect.[9] Coffee treatment also increased insulin and GLUT4 concentrations while reducing glucagon and cortisol compared with the diabetic control group.[9]

The reported correlations were negative between glucose and GLUT4 and between glucose and insulin, while glucose showed positive correlations with glucagon and cortisol.[9] These findings suggest that brewed Arabica coffee may influence both peripheral glucose uptake and hormonal regulation in diabetic animals.[9]

5. RESULTS AND DISCUSSION

The available studies show that *Coffea arabica L.* has antidiabetic potential through several possible pathways rather than through one single mechanism.[3] These pathways include inhibition of α-amylase and α-glucosidase, reduction of intestinal glucose absorption, modification of glucose transporter expression and improvement of glucose-regulating hormones.[4] Among the different plant materials, coffee beans and green coffee have strong evidence from cellular glucose-transport studies.[17] Green coffee showed particularly strong inhibition of glucose and fructose uptake in Caco-2 cells, while roasted coffee also showed considerable enzyme-inhibitory activity.[19]

Coffee silver skin is also promising because it produced glucose-uptake inhibition despite having lower concentrations of some major compounds than green or roasted coffee.[23] This suggests that the biological activity of a complex coffee extract cannot always be predicted simply from the concentration of one compound.[23]

Coffee pulp is another particularly interesting material because it combines enzyme inhibition, intestinal glucose-transport effects, antioxidant activity and evidence from animal studies.[25] Its α-amylase inhibition was relatively modest, whereas its α-glucosidase inhibition was higher under the conditions of the 2026 study.[25] However, direct comparison between studies should be made carefully because different studies used different extraction solvents, plant materials, coffee origins, enzyme sources, concentrations and assay systems.[6] For example, an extract that shows strong inhibition against yeast α-glucosidase cannot automatically be considered stronger than a drug tested against mammalian intestinal α-glucosidase.[25]

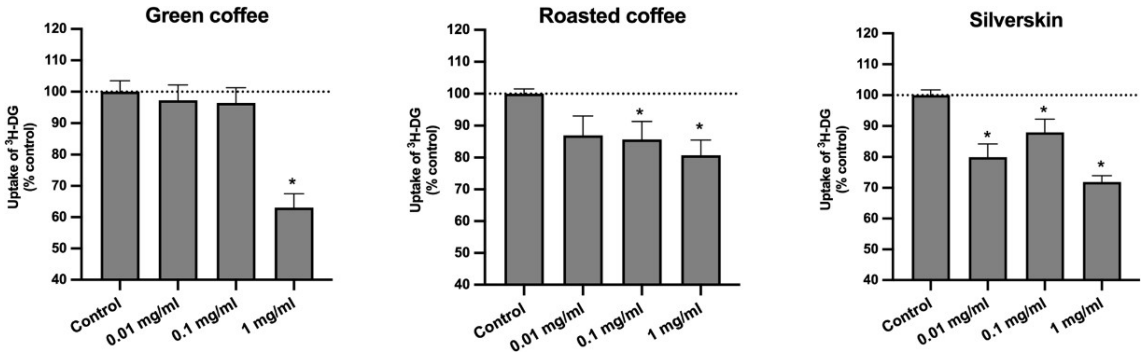


Fig. 4: Comparison of Antidiabetic Activity.

5.1 Influence of Extraction Method

Extraction is an important factor controlling the biological activity of coffee materials.[6] Water extraction produced measurable α-glucosidase inhibition in the Sumatra, Ethiopian and Guatemalan coffee samples, with IC_{50} values of 4.39, 4.97 and 5.19 mg/mL, respectively.[5]

Ultrasound-assisted aqueous extraction has also been used successfully for green coffee, roasted coffee and silver skin and produced extracts capable of modifying glucose uptake and transporter expression.[3] For coffee pulp, different extraction conditions have produced different levels of polyphenols, flavonoids and condensed tannins, demonstrating that extraction conditions can strongly influence the final extract.[29]

5.2 Possible Phytochemicals Responsible for the Activity

Chlorogenic acids are among the most important compounds proposed to contribute to the glucose-related effects of coffee.[15] Caffeic acid, quinic acid, protocatechuic acid, gallic acid and caffeine have also been identified in *C. Arabica* coffee extracts.[10]

A 2025 study using Brazilian *C. arabica* coffee beans identified chlorogenic acid, caffeine, quinic acid, caffeic acid, protocatechuic acid and gallic acid by LC-MS.[10] Molecular docking and molecular dynamics analyses in that study suggested particularly strong interactions between chlorogenic acid and α-glucosidase and α-amylase.[10]

The effect of coffee should therefore probably be understood as a combined effect of several compounds rather than the action of one isolated constituent.[23] In particular, a synergistic effect between caffeine and 5-caffeoylquinic acid was observed in glucose and fructose uptake experiments.[23]

6. CONCLUSION

The evidence reviewed from the supplied articles indicates that *Coffea arabica* has promising antidiabetic potential, particularly through inhibition of carbohydrate-digesting enzymes, reduction of intestinal glucose absorption and modulation of glucose-regulating pathways.[4] Coffee beans, green coffee, roasted coffee, silver skin and coffee pulp have all shown measurable biological effects related to glucose metabolism in different experimental systems.[3] Among these materials, green coffee and coffee beans have strong cellular evidence for reducing intestinal sugar uptake, while coffee pulp provides additional evidence from enzyme assays and animal studies.[17] Coffee pulp is especially interesting because it is rich in phenolic compounds, flavonoids and condensed tannins and has demonstrated both α-amylase and α-glucosidase inhibition.[16] Brewed Arabica coffee has also produced significant improvements in blood glucose, insulin and GLUT4 in streptozotocin-induced diabetic rats.[9]

Chlorogenic acids, caffeine, trigonelline, caffeic acid, quinic acid, flavonoids and other phenolic compounds are possible contributors to these effects, but the activity is likely to result from interactions among several constituents.[10] At the same time, the evidence for *C. arabica* leaves, stem and bark is insufficient in the supplied literature, and these plant parts require dedicated experimental investigation.[14]

Overall based on these study of *Coffea arabica L.* should currently be considered a promising source of antidiabetic and glucose-regulating bioactive compounds rather than a proven antidiabetic drug.[7] Further standardized in-vitro studies, well-designed animal experiments, pharmacokinetic and toxicity studies, and controlled human clinical trials are needed to confirm its therapeutic value and establish effective and safe doses.[5]

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