REVIEW ARTICLE

Therapeutic Potential of Camel Milk in Type 2 Diabetes Mellitus: A Review

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Abstract

Camel milk is known as a superfood due to its high nutritional content; it is high in vitamins and minerals including calcium, iron, magnesium, copper, zinc and potassium. It has various therapeutic properties such as antibacterial, antiviral, and anti-inflammatory, anti-cancer and anti-diabetic properties. Due to its smaller fat globules size, it is easy for digestion. Camel milk has 3 times more Vitamin C than cow's milk and 10 times higher iron content. Camel milk is considered as hypoglycemic agent due to its blood glucose lowering effect in experimental group with diabetes. Treatment of diabetes by effective alternate therapies is a topic of great concern worldwide. In diabetes the cells may not respond to insulin or defects in insulin secretion by pancreas can cause increase in the blood sugar levels. Camel milk contains insulin-like proteins, that could be beneficial for antidiabetic effect. This milk is considered as hypoglycemic agent as it improves long term glycemic control in diabetic patients. It can also help improve diabetes related risk factors such as liver and kidney damage and cardiovascular complications. As per the evidence more scientific studies are required to validate the effectiveness of camel milk on type 2 diabetes mellitus (T2DM). This review represents scientific studies on favorable effects of camel milk on T2DM.

Key words: Camel milk, diabetes, hypoglycemic agent

INTRODUCTION

Diabetes is a metabolic disorder that includes insulin dysfunction and causes long term damage to the body. Complications include lower limb amputation, heart disorders, kidney diseases and eye damage.[1] Type 2 diabetes mellitus (T2DM) is causing global burden in healthcare worldwide. It is the ninth leading cause of mortality responsible for over 1 million deaths per year. Prevalence of diabetes worldwide is predicted to increase to 7,079 individuals/100,00 by 2030, leading to constant rise globally.[2] In emergent nations like India, the incidence of diabetes is high due to increase in number of overweight/obesity cases and unhealthy lifestyles.[3] It is expected that number of people with diabetes in India could rise to 79.4 million by 2030.[4,5] Predominantly, camel milk is consumed in different parts of the world for treating various diseases.[6]

Camel milk has antibacterial and antioxidant properties because it contains Vitamin C, Iron in abundance in comparison to cow milk. Intake of camel milk daily keeps the blood glucose levels in control.[7]

Through a radioimmunoassay of camel milk, high insulin concentration (52 U/L) was found.[8]

Camel milk contains insulin like protein that does not coagulate in the stomach's acidic environment making it more acceptable.[9] In India, it is seen that Camel milk breeders who drink camel milk regularly have lower risk of developing diabetes as compared with different communities who do not consume camel milk.[10]

Camel milk is rich in vitamin C and contains high levels of minerals, including sodium, potassium, copper, zinc, and magnesium, and has hypocholesterolemia, hypoglycemic effect making it unique as compared with other ruminant milk. Its health benefits are numerous because of camel milk composition. Camel milk helps in treatment of various diseases such as hypertension, diabetes, cancer, etc.[11]

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The potential anti-diabetic properties of camel milk are still under investigation. This systematic review aims to compile existing evidence on the beneficial effects of camel milk in managing T2DM, encompassing both experimental studies and clinical trials.

CAMEL MILK AND DIABETES

Animal studies

The effects of camel milk on serum glucose, lipid profile, and body weight were studied in alloxan-induced diabetic rats. Rats were divided into three groups: Non-diabetic control, diabetic control (no milk), and diabetic rats treated with camel milk. The treatment group received 1 mL of camel milk daily for 2 weeks, increasing to 2 mL for the following 2 weeks. The results showed that camel milk supplementation significantly reduced blood glucose, total cholesterol (TC), triglycerides (TG), Low density lipoprotein (LDL), and very LDL, while increasing high density lipoprotein (HDL) levels compared to the control group ($P < 0.05$).[12]

The anti-diabetic effects of camel milk supplementation were assessed in diabetic rats. Seventy-five rats were divided into five groups: Negative control, camel milk only, diabetic control, diabetic + metformin, and diabetic + camel milk. Camel milk was supplemented for 2 months. The results showed that camel milk improved serum biochemical markers and restored insulin and GLUT-4 expression in the pancreas, suggesting its potential as a therapeutic aid in managing diabetes.[13]

A study investigated the antidiabetic potential of camel milk in comparison to insulin using a streptozotocin (STZ)-induced diabetic albino Wistar rat model. The study involved 36 rats divided into six groups ($n = 6$/group): Normal control, control receiving camel milk, diabetic control, diabetic treated with insulin, diabetic treated with camel milk, and diabetic treated with both insulin and camel milk. The diabetic groups received daily treatments for 30 days—camel milk at a dose of 50 mL/rat, insulin at 6 units/kg of body weight, or a combination of both. As a result glycemic levels and weight gain were ameliorated in the camel milk group, insulin, and combined treatment groups as compared to the diabetic control group.[14]

The antidiabetic, hepatoprotective, and lipid-modulating effects of camel milk were assessed in a STZ -induced diabetic mouse model. Sixty mice were divided into five groups ($n = 12$): untreated control, camel milk only, diabetic control, diabetic + camel milk, and diabetic + glibenclamide. Diabetes was induced in groups 3–5, and groups 2 and 4 received fresh camel milk (83 mL/kg/day) for 7 weeks. Group 5 received glibenclamide for comparison. Camel milk supplementation significantly reduced blood glucose, glycated hemoglobin (HbA1c) ($P < 0.001$), aspartate transaminase, alanine transaminase, TGs, and cholesterol levels ($P < 0.01$) compared to the diabetic control group.[15]

In a study the effects of camel milk in STZ–induced diabetic rats were analyzed. There were five groups of eight rats each as follow: GI: Normal control rats (vehicle treated), GII: Normal rats fed with camel milk for 30 days, GIII: Diabetic control group injected with STZ (60 mg/kg b.wt.). GIV: Diabetic rats fed with camel milk. GV: Diabetic rats with insulin.i.p. injection (16 unit kg b. wt./day). In conclusion, supplementation of camel milk to diabetic rats has anti-hypoglycemic effects and prevent liver and renal damage associated with STZ –induced diabetic rats.[16]

A study examined the effects of camel milk on hypertension and insulin resistance in a rat model. Four groups were studied: normal control, salt-induced hypertensive (untreated), hypertensive treated with camel milk, and hypertensive treated with metformin (100 mg/kg) + nifedipine (10 mg/kg). Groups II–IV received an 8% salt diet for 10 weeks. Compared to the control, all hypertensive groups showed significant increases in blood pressure ($P < 0.05$), serum glucose, insulin levels, and Homeostasis model assessment-estimated insulin resistance.[17]

In other study the glucose-lowering and antioxidant effects of camel milk were evaluated in STZ -induced diabetic rats. Sixty male Swiss albino rats were divided into six groups ($n = 10$): normal control, diabetic control, and four diabetic groups treated with various camel milk fractions. The study demonstrated that camel milk possesses significant antihyperglycemic and antioxidant properties, suggesting its potential as a complementary therapy for diabetes.[18]

The hypoglycemic and antithrombotic effects of camel and bovine milk were compared in STZ -induced diabetic rats. Following induction of diabetes, rats were treated with either camel or bovine milk for 8 weeks. Both treatments improved weight, blood glucose levels, and glucose tolerance, with camel milk showing a more potent antidiabetic effect than bovine milk.[19]

The impact of camel whey protein (CWP) supplementation was studied in STZ -induced diabetic pregnant mice on the immune health of their offspring. Female mice were divided into three groups: Non-diabetic control, diabetic control, and diabetic mice treated with CWP (100 mg/kg/day) during pregnancy and lactation. The findings suggest that CWP may help reduce diabetes-related complications in the offspring of diabetic mothers by supporting immune function.[20]

Another study evaluated the effects of camel milk protein hydrolysate (CMPH) at doses of 100, 500, and 1,000 mg/kg body weight over 8 weeks in STZ -induced diabetic rats. Forty-eight rats were divided into six groups, including normal and diabetic controls, and diabetic groups treated with camel milk protein or varying CMPH doses. The mid-dose CMPH (500 mg/kg) showed the most significant hypoglycemic effect, reducing fasting blood glucose and improving glucose tolerance.[21]

The effects of camel milk-derived composite probiotics (CPCM) were investigated on glucose and lipid metabolism,

organ function, and gut microbiota in db/db mice. Probiotics were prepared using *Lactobacillus* and saccharomyces's from traditional fermented cheese whey. Forty db/db mice were divided into four groups (metformin, low-dose CPCM, high-dose CPCM, and diabetic control) and treated for 6 weeks, with 10 C57BL/Ks mice as normal controls. The high-dose CPCM group showed significant reductions in fasting blood glucose, oral glucose tolerance test, and HbA1c compared to the diabetic control group.[22]

The effects of camel milk on hyperglycemia, beta-cell function, oxidative stress, and inflammation were examined in diabetic pigs. Twenty-five pigs were divided into five groups: non-diabetic control, diabetic control, two camel milk-treated groups (250 mL/day and 500 mL/day), and a metformin group (500 mg/day). Camel milk significantly reduced fasting blood glucose, indicating its potential in managing hyperglycemia in diabetic pigs.[23]

Fortification of camel milk

Camel milk has gained significant attention for its potential therapeutic properties, particularly in managing diabetes. Several studies have explored its effects on hyperglycemia, lipid metabolism, oxidative stress, and overall metabolic health, providing promising insights into its role in diabetes management.

The effects of fortifying fermented camel milk (FCM) with sage or mint powder were investigated in alloxan-induced diabetic rats. They found that both sage and mint powders (at 1% and 1.5% concentrations) significantly improved glucose levels and lipid profiles, with the 1.5% concentration showing the most pronounced anti-diabetic effects. The study suggests that adding herbal powders to FCM could enhance its therapeutic potential, making it a promising functional food for managing diabetes.[24]

Supporting this, another study explored the combined effects of FCM and *Salvia officinalis* L. leaves hydroalcoholic extract (SOHE) in diabetic rats. Their results indicated a synergistic effect of FCM and SOHE in reducing blood glucose levels and improving weight recovery. This combination not only controlled blood glucose but also prevented oxidative stress, highlighting the dual benefits of camel milk and herbal supplementation in diabetes treatment.[25]

Also, the potential of camel milk was studied by combining it with *Lactobacillus brevis* strains to manage hyperglycemia and hyperlipidemia in diabetic mice. The study demonstrated that both camel milk and the *Lactobacillus* strains significantly reduced postprandial blood glucose levels. This suggests that camel milk, when combined with probiotics, may offer a holistic approach to diabetes management by not only controlling blood glucose but also improving gut health and overall metabolism.[26]

In a similar vein, Atwaa *et al*. investigated the effects of Sidr fruit pulp (SFP) supplementation on FCM in diabetic rats. The addition of 15% SFP significantly improved blood glucose control, lipid profiles, and liver and kidney function. This study underscores the importance of combining camel milk with functional ingredients to enhance its nutritional and therapeutic benefits, particularly for those managing diabetes and related complications.[27]

Finally, Hameed *et al*. evaluated the anti-diabetic effects of functional camel milk yogurt enriched with *Cinnamomum verum* and *Stevia rebaudiana* in STZ-induced diabetic rats. The functional yogurt significantly reduced blood glucose levels, with the highest reduction observed in the group receiving the yogurt. This suggests that camel milk, when combined with natural ingredients like cinnamon and stevia, can serve as an effective dietary intervention for managing diabetes.[28]

Human studies

A growing body of clinical and experimental research highlights camel milk's ability to improve glycemic control, reduce insulin resistance, and positively influence lipid profiles in diabetic patients.

Zheng *et al*. conducted a clinical trial to examine the hypoglycemic effect of camel milk powder on T2DM patients. In this study, participants were given 10 g of camel milk powder twice a day for 4 weeks. The results revealed a significant reduction in fasting blood glucose, 2-h postprandial blood glucose, and serum levels of TC, resistin, and lipocalin-2 in the camel milk group, compared to a placebo group receiving cow milk powder. This suggests that camel milk can help improve glycemic control and lipid metabolism in individuals with T2DM.[29]

Further supporting this, Fang *et al*. investigated the effects of camel milk powder supplemented with BBA6 on type 2 diabetic patients. Participants were administered 10 g of camel milk powder twice daily for 4 weeks. Following the intervention, the study observed a marked reduction in fasting blood glucose, serum TC, and cardiovascular risk index (TC/HDL- cholesterol), along with decreases in pro-inflammatory cytokines (interleukin-6, monocyte chemoattractant protein-1) and adipokines (adiponectin, resistin, lipocalin-2, adipsin). These findings underscore camel milk's potential not only for glycemic control but also for reducing inflammation and improving cardiovascular health in diabetic patients.[30] Table 1 shown Overview of studies on the effects of camel milk supplementation in different experimental studies in animals and Table 2 shown Overview of studies on the effects of camel milk supplementation on type 2 diabetes mellitus in different clinical trials.

Table 1: Overview of studies on the effects of camel milk supplementation in different experimental studies in animals

Study (year)	Target species	Intervention group	Control group	Duration of intervention	Outcomes
Hameed *et al.* (2023)	N–63, STZ-induced albino Wistar rats	Group 1: N–9, fresh camel milk (T1), Group 2: N–9, pure cinnamon extract (T2), Group 3: N–9, standardized camel milk yogurt (T3), Group 4: N–9, functional camel milk yogurt (T4) Group 5: N–9, pure stevia extract fed rats group (T5)	Group 6: untreated controls (T0), Group 7: insulin treated diabetic (T0+)	3 weeks	Decrease in mean blood glucose level Decline in blood glucose level (46%) was higher in functional camel milk yogurt (T4) group
Raj *et al.* (2023)	N–36 Streptozotocin induced diabetic albino Wistar rats	Control+camel milk (group II), N–6 insulin (group IV), N–6 camel milk (group V), N–6 combined camel milk+insulin (group VI) N–6	N–6, Group I (control group) Diabetic control (group III),	30 days	↓blood glucose and↓HbA1c levels (group V), net gain of 70% average body weight
Shahein *et al.* (2023)	N–42, adult normal male albino rats	1. Diabetic+85 mL FCM/kg B.W/day; N–6 2. Diabetic+85 mL $FCMS_1$/kg B.W/day ($FCMS_1$ group); N–6 3. Diabetic+85 mL $FMCS_2$/kg B.W/day ($FCMS_2$ group); N–6 4. Diabetic+85 mL $FCMM_1$/kg B.W/day ($FCMM_1$ group); N–6 5. Diabetic+85 mL $FCMM_2$/kg B.W/day ($FCMM_2$); N–6	1. N–06 (healthy control C group) 2. N–06 (diabetic control DC group)	8 weeks	↓ Blood glucose level↓Lipid profile↑Insulin level
Abdelazez *et al.* (2022)	N–56, 16–25 g/mice	Group 1 and Group 2: (N–8) L. brevis strains ($LACS_1$ and $LACS_2$) 250 μL 105 CFU/mL/day, Group 3: (N–8) (INS_{STZ}) insulin (0.5 unit/kg body weight) Group 4: (N–8) gavage orally 100 μL/day of camel milk (CaSTZ)	Group 5: (N–8) control group, 250 μL sterile PBS/day, Group 6: (N–8) the camel milk control (Ca Cont), 100 μL of raw camel milk Group 7: (N–8) Streptozotocin control (STZ) 180 μL streptozotocin only	4 weeks	CaCont and CaSTZ group- ↓ GLU concentrations, ↑ body weight, ↑ insulin concentrations

(Contd...)

Table 1: *(Continued)*

Study (year)	Target species	Intervention group	Control group	Duration of intervention	Outcomes
Alharbi *et al.* (2022)	N–56 Wistar rats (adult males) weighing 150 and 175 g	Group 2, N–8 diabetic rats (DR) (50 mg kg^{-1}) of streptozotocin Group 3, N–8, (Diabetic Rat [DR]+[FCM]), 5 mL FCM kg^{-1} daily, Group 4, N–8 (DR+SOHE [*Salvia officinalis* L. leaves hydroalcoholic extract]) 50 mg GAE SOHE kg–1 daily, Group 5, N–8 (DR+FCM-SOHE1) 5 mL FCM contains 25 mg GAE (Gallic acid equivalent) SOHE kg^{-1} daily Group 6, N–8 (DR+FCM-$SOHE_2$) 5 mL FCM contains 50 mg GAE SOHE kg^{-1} daily, Group 7, N–8 (DR+Metformin) rats orally administered 50 mg standard drug metformin kg^{-1} daily	Group 1, N–8 (normal rats, NR) received an intraperitoneal injection of saline solution and 5 mL distilled water orally per day.	4 weeks	Combining FCM with SOHE at 25 or 50 mg kg^{-1} lowered↓random↓blood glucose (RBG), ↓ fasting blood glucose (FBG), and improved weight gain recovery %
Ashraf *et al.* (2022)	N–60, male Swiss albino rats weighing 30–40 g aged 2–3 months	N–40 (10 in each group) Groups C, D, E and F-diabetic groups treated with various fractions of camel milk	Group A: N–10, Normal control, Group B: N–10, Streptozotocin induced Diabetic group	-	Percentage decrease of about 25%, 12.98%, 11.57% and 10.17% in blood sugar in groups C, D, E and F respectively
Atwaa *et al.* (2022)	32 male adult albino rats (weighing 150–185 g)	Group 2 (N–8), diabetic rats given STZ (60 mg/kg body weight; positive control Group 3 (N–8), diabetic rats fed a basal diet with fermented camel milk (10 g/day) Group 4 (N–8), diabetic rats fed a basal diet with fermented camel milk supplemented with 15% SFP (10 g/day)	Group 1 (N–8), nontreated nondiabetic rats (negative control);	- - -	↓ blood glucose, ↓ cholesterol, ↓ TG, ↓ LDL-C, ↓ AST, ↓ ALT, ↓ creatinine, and↓urea levels, ↑ HDL-C, ↑ total protein, and↑albumin
Rilwan *et al.* (2022)	N–25, pigs	Group 3: N–05, camel milk at 250 mL/day Group 4: N–05, camel milk at 500 mL/day Group 5: N–05, metformin at 500 mg/day	Group 1: N–05, Standard Control Group 2: N–05, Diabetic Control	10 weeks	↓ Hyperglycemia, ↓ interleukin (IL-1β) and↓tumour necrosis factor-alpha (TNF-α)

(Contd...)

Table 1: *(Continued)*

Study (year)	Target species	Intervention group	Control group	Duration of intervention	Outcomes
Kilari *et al.* (2021)	N–48, streptozotocin-induced diabetic rats (10–12 weeks old) weighing 200–220 g	Group 3: N–08, Diabetic rats+camel milk protein (CMP) 500 mg/kg of BW Group 4: N–08 Diabetic rats CMPH at a low dose of 100 mg/kg of BW (CMPH-L) Group 5, N–08 medium dose of 500 mg kg of BW (CMPH-M) Group 6, N–08 a high dose of 1,000 mg/kg of BW (CMPH-H)	Group 1: N – 08 Nondiabetic rats designated as normal control (NC). Group 2: N–08 STZ-induced diabetic control (DC).	8 weeks	CMPH at 500 mg/kg of BW exhibited potent hypoglycemic activity, ↓fasting blood glucose and↓OGTT levels , hypolipidemic effect
Manaer *et al.* (2021)	N–50 (6 week old db/db mice [n=40, female: male=1:1] and C57BL/Ks mice [n=10 female: male=1:1])	1. Metformin group– (N–10) metformin of 0.3 g/1 kg body weight 2. Low dose group- (N–10) low CPCM (composite probiotics from camel milk) 3. High dose group- (N–10) high dose CPCM	4. Normal group (N–10) C57BL/Ks mice - disinfected- skimmed camel milk 5. Model group (N–10)- disinfected-skimmed camel milk	6 weeks	high dose CPCM significantly decreased↓FBG, OGTT, HbAlc, plasma TC, TG, LDL-C, 24 h malb, urine ketone and urine sugar, increased↑CP, HDL-C levels
Hussain *et al.*, 2021	60 male and female mice	Group 2: Camel milk Group 4: Diabetic mice+raw camel milk Group 5: Diabetic mice+glibenclamide	Group 1: No treatment Group 3: Diabetic mice	7 weeks	Reduced blood glucose, Hba1c, aspartate transaminase, alanine transaminase, triglyeride, and cholesterol.
Korish *et al.*, (2020)	N–60	N–10, the control bovine-milk-treated group (CBM); the diabetic camel-milk-treated group (DCM); N -10 diabetic bovine-milk-treated (DBM) treated with bovine milk, N–10 (CCM) , N–10, healthy rats receiving camel milk	N–10, control group (C) healthy rats receiving no treatment; N–10, the untreated diabetic group N–10, (D) STZ-induced diabetic rats receiving no treatment; N–10, the control camel-milk-treated group	8 weeks	weight gain, ↓ blood glucose levels, and improved glucose tolerance
Mansour *et al.* (2017)	(N–75), adult male albino rats, 8 weeks old, 200 g body weight	N–15, non-diabetic rats supplemented with camel milk N–15, Diabetic rats administered metformin (D+MET) N–15, diabetic rats supplemented with CM (D+CM)	N–15, non-diabetic control group N–15, diabetic control group	2 months	Diabetic rats supplemented with camel milk showed a decrease in glucose levels and increase in insulin secretion

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Table 1: *(Continued)*

Study (year)	Target species	Intervention group	Control group	Duration of intervention	Outcomes
Mahmoud *et al.* (2016)	N–30 streptozotocin-induced female diabetic (BALB/c) mice weighing 25–30 g	Group 3: N–10, (diabetic mice), non-denatured Camel Whey Protein (100 mg/kg body weight dissolved in 250 μL/day	Group 1: non-diabetic control dams administered distilled water (250 μL/mouse/day Group 2: diabetic mice administered distilled water (250 μL/mouse/day)	1 month	Restored levels of blood glucose and insulin
Mainasara *et al.* (2016)	N–32 Wistar albino rats weighing between 170–220 g	Group III: N–8, salt-loaded treated with Camel milk (5 mL/kg/day) Group IV: N–8, salt-loaded, orally dosed with 100 mg/kg Metformin+10 mg/kg Nifedipine.	Group I: N–8, normal (control group) Group II: N–8 salt-loaded, untreated	6 weeks	↓ serum glucose, ↓ insulin, ↓ HOMA-IR
Baragob (2015)	N–40 streptozotocin–induced male albino Wister rats (200–250 g)	GII: N–8, Normal rats fed with camel milk for 30 days. GIV: N–8, Diabetic rats fed with camel milk. GV: N8, Diabetic rats treated with insulin by .i.p. injection (16 unit kg b. wt./day)	GI: N–8, Normal control rats (vehicle treated) GIII: N–8, Diabetic control group injected with STZ (60 mg/kg b.wt.)	30 days	↓ blood glucose↓cholesterol, ↓ low density lipoprotein and↓high density lipoprotein-cholesterol and↓triglycerides↓urea, ↓ uric acid and↓creatinine levels
Isa *et al.* (2013)	N–15, wistar albino rats weighing between 160 and 200 g	Group 3 (diabetic- induced) N–15, 1 mL of camel milk daily using 1 mL for 2 weeks. The dose was then increased to 2 mL for additional 2 weeks.	Group 1, N–15 ,(non-diabetic -non supplemented) Group 2, N–15, (diabetic-non supplemented)	4 weeks	Group 3- ↓ blood glucose, ↓ TC, ↓ LDL-C, ↓ VLDL-C, and↑HDL-C

HbA1c: Glycated hemoglobin, FCM: Fermented camel milk, B.W: Body weight, FCMS1: Fermented camel milk fortified with 1.0% sage leaves powder, FCMS2: fermented camel milk fortified with 1.5% sage leaves powder, FCMM1: Fermented camel milk fortified with 1.0% mint leaves powder, FCMM2: Fermented camel milk fortified with 1.5% mint leaves powder, *L. brevis:* *Lactobacillus brevis*, LACS1: *Lactobacillus* brevis $KLDS_{1.0727}$ with streptozotocin, LACS2: *Lactobacillus* brevis $KLDS_{1.0373}$ with streptozotocin, INS_{STZ}: Insulin withstreptozotocin, CaCont: Camel milk control, CaSTZ: Camel milk withstreptozotocin, STZ: Streptozotocin, SFP: Sidr fruit pulp, TG: Triglyceride, LDL-C: Low density lipoprotein cholesterol, AST: Aspartate transaminase, ALT: Alanine transaminase, HDL-C: High density lipoprotein cholesterol, OGTT: Oral glucose tolerance test, CMPH: Camel milk protein hydrolysate, CMPH-L: Low-level dosage, CMPH-M: Mid-level dosage, CMPH-H: High-level dosage, FBG: Fasting blood glucose, CP: C-peptide, HOMA-IR: Homeostasis model assessment-estimated insulin resistance

Table 2: Overview of studies on the effects of camel milk supplementation on type 2 diabetes mellitus in different clinical trials

Study (year)	Target population	Intervention group	Control group	Duration of intervention	Outcomes
Margdarinejad *et al.* (2021)	*n*=50	N–25 Camel milk 500ml/day	N – 25 Cow milk 500 mL/day	8 weeks	↓ HbA1c, ↓ TG concentration
Zheng *et al.* (2021)	*n*=27, 35–68 years	N–14 Camel milk powder (10 g twice a day)	N–13 Cow milk powder	4 weeks	↓ Fasting blood glucose, ↓ 2-h postprandial blood glucose, ↓ Serum content of total cholesterol↓Serum content of resistin and↓lipocalin-2, ↓ adi- pokines ↑amylin and↑GLP-1
Fang *et al.* (2020)	*n*=28, 35–68 years	N–14, camel milk powder containing BBA6 at a dose of 2×1010 viable cells	N–14, Camel milk powder	4 weeks	↓Fasting blood glucose, ↓Serum content of TC, ↓ Cardiovascular risk (TC/HDL-C), ↓ Inflammatory cytokines (IL-6, MCP-1) and adipokines (adiponectin, resistin, lipocalin-2, adipsin)
Ejtahed *et al.* (2015)	*n*=20, 20–70 years	N–11, 500 mL Camel milk	N–09, 500 mL Cow milk	2 months	↑Serum insulin, No significant changes in FBS, Lipid profile and blood pressure

HbA1c: Glycated hemoglobin, TG: Triglyceride, GLP-1: Glucagon like peptide1, TC: Total cholesterol, HDL-C: High density lipoprotein cholesterol, MCP-1: Monocyte chemoattractant protein-1, FBS: Fasting blood sugar

Ejtahed *et al*. conducted a single-blinded controlled clinical trial with 20 T2DM patients, randomly assigned to either a camel milk or a cow milk group. The camel milk group consumed 500 mL daily for 2 months, while the control group consumed the same quantity of cow milk. At the end of the study, insulin concentration significantly increased in the camel milk group, indicating improved insulin sensitivity. However, no significant differences were observed in fasting blood sugar, lipid profile, or blood pressure between the two groups. While camel milk did not show a substantial impact on these parameters, it did lead to a favorable change in insulin levels, suggesting its role in improving insulin function in T2DM patients.[31]

Margdarinejad *et al*. performed a case-control clinical trial involving 50 T2DM patients, divided into intervention and control groups. The intervention group consumed 500 mL of camel milk daily for 8 weeks, while the control group received cow milk. At the study's conclusion, the camel milk group demonstrated a significant decrease in HbA1c and TG levels, which are key markers of long-term glycemic control and lipid metabolism. These results further support the beneficial effects of camel milk on glycemic control and lipid profile in T2DM patients.[32]

CONCLUSION

In conclusion, the body of evidence suggests that camel milk can play a positive role in managing type 2 diabetes by improving glycemic control, enhancing insulin sensitivity, and optimizing lipid metabolism. The findings from these studies provide promising insights into camel milk as an adjunctive treatment for diabetes. However, more empirical and wide-ranging studies are needed to confirm these results and further explore the mechanisms underlying camel milk's therapeutic effects. With its potential to improve both metabolic and inflammatory markers, camel milk may serve as an important dietary intervention for individuals with T2DM.

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