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Research Article

Camel Milk Used as an Adjuvant Therapy to Treat Type 2 Diabetic Patients: Effects on Blood Glucose, HbA1c, Cholesterol, and TG Levels

Amel Sboui,[1,2] **Chiraz Atig**,[3] **Abdelmajid Khabir**,[4] **Mohamed Hammadi**,[1,2] **and Touhami Khorchani**[1,2]

[1]*Livestock and Wildlife Laboratory, Arid Land Institute, Medenine, Tunisia*
[2]*University of Gabes, Gabes, Tunisia*
[3]*Internal Medicine Department, Habib Bourguiba Hospital of Medenine, Medenine, Tunisia*
[4]*Histopathology Departmnt, Habib Bourguiba Hospital, Medenine, Tunisia*

Correspondence should be addressed to Amel Sboui; amelsb6@yahoo.fr

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The efficacy of camel milk to treat diabetes has been shown recently, especially in experimental animals and in patients with diabetes type 1 (T1DM), whereas studies on patients with type 2 diabetes mellitus (T2DM) are limited. In this clinical trial, 60 patients with T2DM who used oral antidiabetic drugs were assigned into two groups; group 1 received—in addition to the antidiabetic prescribed medicines—500 mL of raw camel milk divided equally two times/day (fasting in the morning and the night) for three months. Group 2 was treated during the same period only by the oral antidiabetic medicaments without consumption of camel milk. A significant decrease was shown in fasting blood glucose (FBG) (from 9.89 ± 0.98 to 6.13 ± 0.55 mmol/L) and postprandial glucose (PPG) (from 15.89 ± 4.34 to 7.44 ± 1.02 mmol/L) in the group 1. A significant decline ($P < 0.05$) in HbA1c levels was observed in the group treated with camel milk (from 9.44 ± 0.16 to 6.61 ± 0.14%, with a percentage decrease of 30%). Total cholesterol and TG significantly decreased in group 1. Urea and creatinine showed no statistical differences between the two groups during the trial. Based on this study's results, camel milk could be useful for glycemic control in T2DM patients using oral hypoglycemic agents.

1. Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by numerous abnormalities in carbohydrate, protein, and fat metabolism [1].

Diabetes affects people worldwide, and it has been shown that people with a family history of diabetes are at high risk of developing diabetes [2].

Diabetes mellitus (DM) is a disease characterized by a high level of blood sugar (i.e., glucose) that results from the failure of the body to produce sufficient insulin (type 1 diabetes) or from the inability to respond appropriately to insulin (type 2 diabetes) [3, 4]. DM and its complications have become the main focus of interest for researchers worldwide due to their close association with the risk of cerebrovascular and cardiovascular disorders.

Conventional management of this disease concentrates on keeping blood sugar levels as close to regular using strategies of diet, insulin, oral hypoglycemic drugs, and exercise [5]. However, the currently marketed antidiabetic drugs are associated with adverse effects on patients.

In this respect, natural foods with antihyperglycemic properties are being used increasingly by diabetic patients. Some studies have reported that camel milk has potential benefits and can be used as an alternative treatment for many diseases [6–8]. Nevertheless, the most important observations remain antihyperglycemic activity in type 1 diabetes using both human and animal models [8, 9]. For instance,

camel milk was proposed as an adjunct to insulin-based therapy, allowing the reduction of insulin doses required in patients with type 1 diabetes [10, 11]. In contrast, studies with consistent results regarding the effects of camel milk on T2DM are limited [12, 13].

Hence, the present study was designed to investigate the effects of camel milk consumption on the blood sugar, lipid profile, HbA1c, and insulin of patients with T2DM.

2. Material and Methods

2.1. Milk Samples. Camel milk was collected from healthy milking camels (*Camelus dromedarius*) of the Experimental Station of Chenchou, Arid Land Institute, Medenine, Tunisia. After discarding the first few squirts of milk, the milk was collected into clean containers. Camel milk was preserved at 4°C, transferred in an icebox, and distributed weekly to the patients.

2.2. Patients and Treatment Schedule. This clinical trial was conducted in the regional hospital of Medenine, southeast of Tunisia.

Patients included in this study were 40 to 65 years of age, with T2DM treated with oral hypoglycemic agents. All patients are diagnosed with type 2 diabetes mellitus for at least two years and were randomly followed by a specialist doctor in internal medicine.

All patients gave written consent before participation in the study and the study protocol was approved by the Tunisian Ethical Committee: 6/16-08/03/2016 (Habib Bourguiba Hospital, Sfax Tunisia).

Patients with the following conditions were excluded: pregnant or lactating women, requiring insulin injections, cardiovascular, liver, lung, or kidney diseases and thyroid dysfunctions.

Selected patients were divided into two groups:

Group 1: 30 patients treated with 500 ml of camel milk/day in two equally divided doses (fasting in the morning and night) during 3 months ($n = 30$, age = 52 ± 12 years, 12 mans/18 women) in addition to prescribed oral antidiabetics medicaments.

Group 2: 30 patients treated with prescribed oral antidiabetics medicaments without consumption of camel milk during 3 months ($n = 30$, age = 55 ± 10 years, 10 mans/20 women). This group was used as control.

Moreover, all participants were instructed to maintain their usual dietary habits and lifestyle to avoid consuming any milk other than camel milk provided to them by the researchers, and if possible, to prevent any changes in medication during the period of the trial.

2.3. Biochemical Analysis. Blood samples from the two groups were analyzed in the beginning and monthly induring trial for the following biochemical parameters: fasting blood glucose (FBG), postprandial blood glucose (PPG), cholesterol, triglycerides, urea, and creatinine using specific enzymatic methods. HbA1c was measured two times during this study before and at the end of the experiment (after 3 months) using high-performance liquid chromatography (HPLC) (variant Bio-Rad Company, USA, the Hospital laboratory).

2.4. Statistical Analysis. Statistical calculations were performed using SPSS (version 15.0) computer software. Values before and after treatment within each group and between the two groups were analyzed using the paired student's test. Data were prepared as mean ± SD, and the P value < 0.05 was considered statistically significant. Graphs were achieved using the GraphPad Prism package.

3. Results

Thirty participants in each group completed the three-month trial and were included in the statistical analysis. The acceptability of camel milk was good; only two patients in the camel milk-treated group were plained of flatulence and were dropped from the assay.

There were no significant differences in baseline characteristics between the study groups; all included patients in this study are with T2DM for at least 2 years and treated with oral hypoglycemic drugs.

3.1. Body Mass Index Variations. As shown in Figure 1, 70% of patients from group 2 showed an increase in BMI, this increase remains statistically nonsignificant (from 25.8 ± 1.36 to $28.26 \pm 1.33\ kg/m^2$).

3.2. Gross Composition of Camel Milk. The raw camel milk's pH and acidity provided to the diabetic patients were, respectively, 6.41 ± 0.18 and 16.87 ± 1.035°Dornic.

The gross composition of camel milk used in this research is illustrated in Table 1.

3.3. Effect of Camel Milk Treatment on Glycemic Parameters

3.3.1. Blood Glucose Variations. The variations of fast blood glucose and postprandial blood glucose during the present study are illustrated in Figure 2.

Group1 (supplemented with camel milk) showed a significant decrease in FBG (from 9.89 ± 0.98 to 6.13 ± 0.55 mmol/L) compared to group 2 (from 9.72 ± 0.25 to 8.37 ± 0.79 mmol/L).

As illustrated in Figure 2, when comparing FBG variations during the essay for each group, the camel milk-treated group showed a significant decrease of FBG after one month of the experiment (from 9.89 ± 0.98 to 6.86 ± 1.2 mmol/L, Figure 2(a)). The reduction in FBG in this group was accompanied by a significant decline in PPG since the first month of treatment (from 15.89 ± 4.4 to 11.16 ± 2.66 mmol/L, Figure 2(b)).

Whereas for group 2, the FBG and PPG levels did not show any significant difference during the experiment (Figure 2).

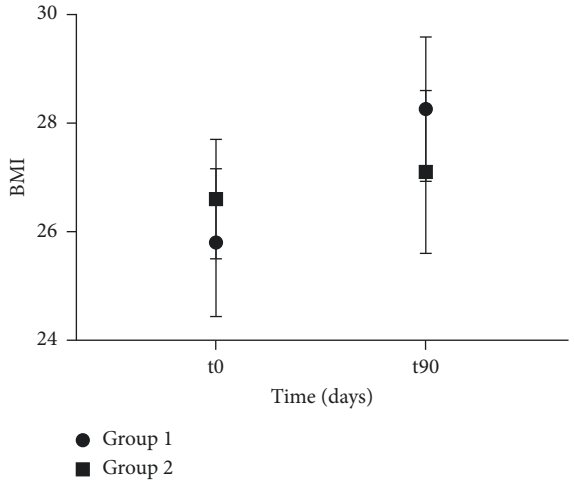

Figure 1: Body mass index variations during the experiment.

Table 1: Gross composition of camel milk used in this experiment.

chemical composition	Value (g/L)
Fat	37.5 ± 5
Dry matter	119.438 ± 15.34
Ash	7.5 ± 1.75
Proteins	34.15 ± 3.11
Lactose	42.78 ± 2.36

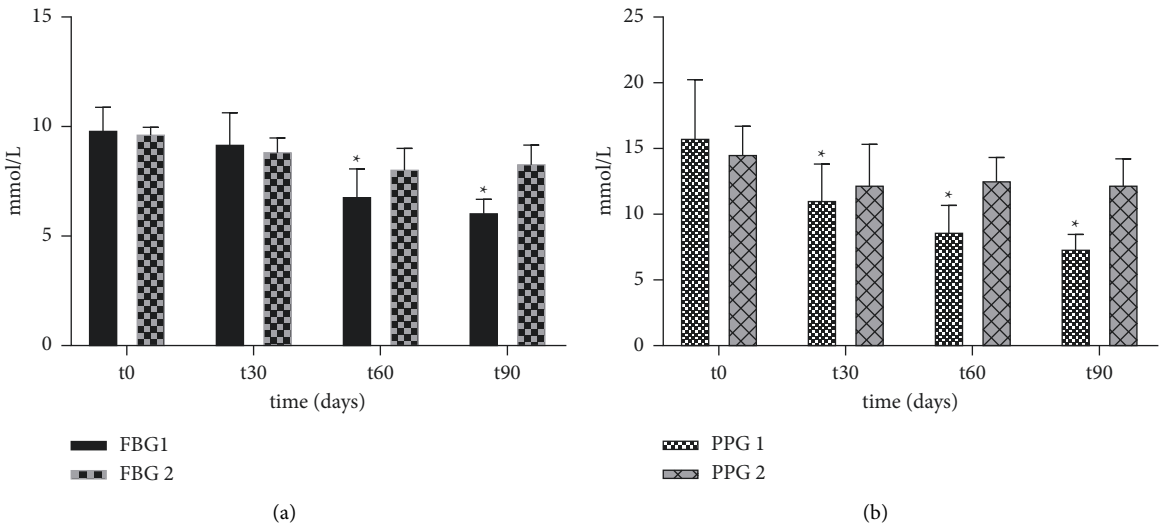

Figure 2: Blood glucose variations during camel milk treatment. (a) Fast blood glucose variations; (b) Postprandial glucose variations. FBG1: fasting blood glucose in group 1; FBG2: fasting blood glucose in group 2. PPG: postprandial glucose (1: diabetic + camel milk, 2: diabetic patients). *Significant difference compared to T0.

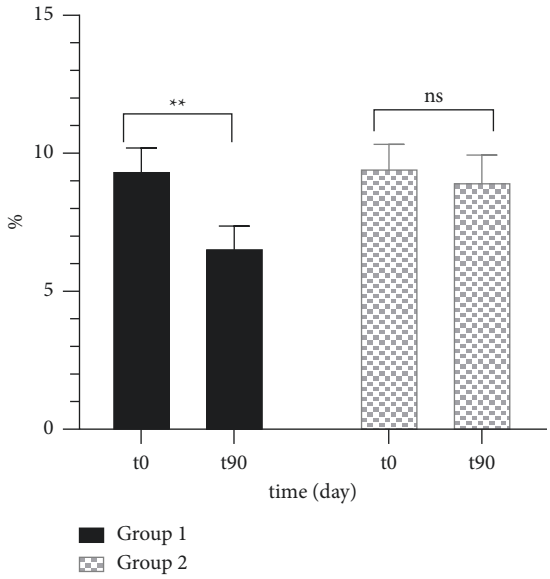

Figure 3: HbA1c variations during camel milk treatment.

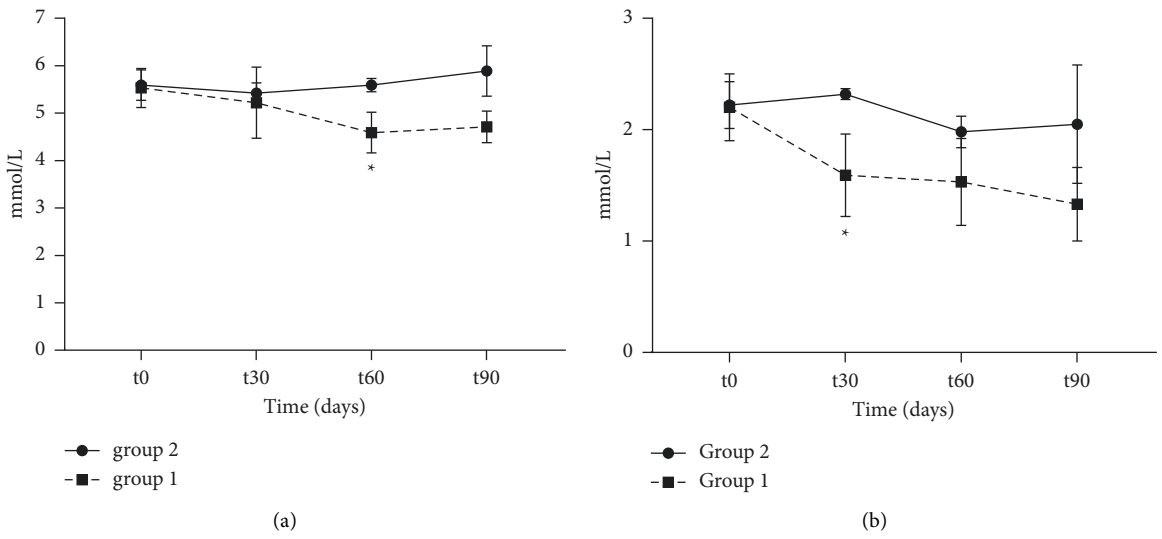

Figure 4: Effect of camel milk on cholesterol (a) and TG (b) levels. *Significant difference compared to T0.

3.3.2. HbA1c Variations. As shown in Figure 3, the camel milk-treated group demonstrated a significant decrease in the HbA1c level (from 9.44 ± 0.97% to 6.61 ± 0.75%).

3.4. Effect of Camel Milk Consumption on Cholesterol and TG Levels. The variations of cholesterol and TG levels are illustrated in Figure 4.

A significant decline in the monthly variations of the lipid profile was shown since the first month on TG levels (from 2.2 ± 0.3 mmol/L to 159 ± 0.37 mmol/L, Figure 4(b)) which remained in the normal range (Matthew, 2016) until the end of the experiment.

Despite being in the normal range, the cholesterol concentrations showed a significant decrease after two months of treatment with camel milk (from 5.53 ± 0.41 mmol/L to 4.59 ± 0.43 mmol/L, Figure 4(a)).

3.5. Effect of Camel Milk Consumption on Urea and Creatinine Levels. Creatinine and urea blood levels reflected the glomerular filtration rate (GFR) and defined kidney function for the clinician.

The urea and creatinine concentrations for all included patients in this study are presented by means ± SD in Table 2.

Urea and creatinine levels varied in the normal range [14] (2.5–7.8 mmol/L, and 50-120 μmol/l, respectively) for all patients included in this essay.

The variations of these parameters did not show any significant differences within and between the two groups.

Table 2: Urea and creatinine variations during camel milk treatment.

Time (days)	Urea (mmol/l)		Creatinine (μmol/l)	
	Group 1	Group 2	Group 1	Group 2
T0	5.66 ± 0.88	5.52 ± 0.75	82.33 ± 10.66	83.54 ± 14.83
T30	6.03 ± 0.79	5.73 ± 0.67	83 ± 10.88	80.39 ± 8.85
T 60	5.44 ± 1.02	5.07 ± 0.88	79.66 ± 11.45	79.96 ± 11.32
T 90	6.88 ± 0.66	5.00 ± 0.97	82.33 ± 9.46	82.21 ± 8.03
P value*	0.061	0.396	0.223	0.201

*P value; difference between T0 and T90 for each group and each parameter.

4. Discussion

Natural foods with antihyperglycemic properties are being used increasingly by patients with T2DM. Some studies have reported that camel milk might improve the glycemic control of patients with T2DM [13, 15] but remains very limited compared to those on T1DM.

Thus, this research was designed to investigate the effects of three-month camel milk consumption on the fasting blood glucose, PPG, lipid profile, kidney parameters, HbA1c, and insulinemia of patients with T2DM.

Significant improvements were observed in most parameters after 3 months of treatment with camel milk. These improvements were clear and meaningful, particularly in the regulation of fasting blood glucose, postprandial glucose (PPG), TG, cholesterol levels, and HbA1c.

These results were in concordance with those published by some previous research [16, 17] except that a higher number of patients and a more extended experiment period are used in the present study in this trial.

Similar results were reported by some researchers using experimental diabetic animals [8, 18, 19].

Moreover, recent research showed that camel milk is safe and efficient in improving long-term glycemic control, with a significant reduction in insulin doses in type 1 diabetic patients [20, 21].

At the end of this study, it was prescribed for 40% of patients treated with camel milk to reduce the oral hypoglycemic agent dose. Nevertheless, it was suggested that camel milk has an advantage that it contains "insulin-like" small molecules that mimic insulin interaction with its receptor. It can be suitable for treating patients who have insulin resistance (T2DM) [15]. This efficacy of camel milk on glycemic parameters was also explained in some research by its immunomodulatory functions on the β cells of the pancreas, anti-inflammatory effect, and high concentration of antioxidants [22].

T2DM is usually associated with hyperlipoproteinemia, in particular hypercholesterolemia. Therefore, elevated levels of cholesterol in the blood are regarded as a significant risk factor for heart disease. In the current study, the effect of camel milk treatment on lipid profile in type 2 diabetic subjects was illustrated by a substantial decrease in cholesterol and TG levels which was similar to the results of some previous studies but with different percentages of reduction; Wang et al. (2009) [23] showed that camel milk decreased TG and total cholesterol in patients with T2DM.

Moreover, it was demonstrated that the administration of raw or fermented camel milk has a hypocholesterolemic effect in diabetic experimental animals [8, 24].

The hypocholesterol mechanism of camel milk is still unclear. Still, different hypotheses were discussed, including the interaction between bioactive peptides from camel milk and cholesterol levels are derived, which leads to cholesterol-lowering [12]. Diabetes has a strong relationship with renal and liver diseases [25]; nevertheless, in this study, there was no significant effect of camel milk treatment on the monitored renal parameters (urea and creatinine).

In this way, it was reported that camel milk limits diabetic complications such as elevated cholesterol levels, liver and kidney diseases, decreased oxidative stress, and delayed wound healing [21, 25].

5. Conclusion

Based on these results, it can be concluded that consumption of camel milk has a powerful effect in reducing blood glucose, PPG, and HbA1c levels in patients with T2DM. Furthermore, camel milk treatment may reduce the dose of used oral antidiabetic drugs and limited diabetic complications such as elevated cholesterol and TG levels. In addition, further studies are needed to isolate the bioactive component responsible for reducing blood glucose and improving the clinical state of diabetic patients.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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