



The Potential Influence of *Ad Libitum* Fresh and Frozen-thawed Camel Colostrum and Milk Consumption on Blood Glucose in Mice of Different Weights

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ABSTRACT

Background: Camel milk has been shown to improve blood glucose value, kidney and liver functions.

Methods: Eighty-eight male albino mice were distributed over two experiments. In experiment I, forty male albino mice were distributed over five groups; control, camel milk (CM) and camel colostrum (CC) either fresh (F) or frozen-thawed (FT) for investigating changes in plasma biochemistry upon consumption. In experiment II, forty-eight male mice of low, medium and high BW receiving FCC were distributed over three groups for investigating changes in blood glucose values of different body weights.

Result: The results showed that the highest blood glucose values were found in FTCC followed by FCM groups whereas the lowest glucose values were found in FCC followed by FCM groups. Control group had lower total protein levels compared to all other milk and colostrum groups. FCC and FTCC groups had lower AST and ALT levels compared to the control, FCM and FCM groups. FCC and FTCC groups had higher iron levels compared to control, FCM and FCM groups. The more pronounced result is the decrease in blood glucose values in low BW mice receiving FCC compared to medium and high BW mice. It could be concluded that FCC followed by FCM are potential in decreasing blood glucose levels versus frozen-thawed ones.

Key words: Biochemistry, Blood, Camel, Colostrum, Fresh, Frozen, Glucose, Milk, Plasma.

INTRODUCTION

Camel colostrum is the “first milk” produced by she-camels immediately after giving calves, within the first few days. Like colostrum from other mammalian species, it's a highly concentrated and nutrient-rich fluid that provides essential components for the newborn's health and development (El-Hatmi *et al.*, 2023). Camels are considered the most important animal species to produce milk in the harsh environmental conditions (Ashour and Abdel-Rahman, 2022). Both camel colostrum and milk offer a unique nutritional profile and potential health benefits to births (Swelum *et al.*, 2021). Camel milk is a significant source of protein for people living in arid regions, particularly those who live nomadic lifestyles (Alhassani, 2024). Camel colostrum and milk have been recognized for their potential health benefits particularly in arid and semi-arid regions where she-camels are prevalent (Khaliq *et al.*, 2024).

Several studies have explored the potential health benefits of camel milk, including its therapeutic effects on certain diseases in both experimental animals and humans (Swelum *et al.*, 2021; Liu *et al.*, 2023; Alhassani 2024; Musa *et al.*, 2025). It has been found that camel colostrum and milk is rich in a variety of bioactive components, including lactoferrin, immunoglobulins, vitamins and minerals, suggesting a wide range of therapeutic applications (Khaliq *et al.*, 2024). Researchers are beginning to unravel the mechanisms underlying these purported benefits of camel colostrum, milk, colostrum and camel milk products (Almasri *et al.*, 2024). Evidences from several studies indicate that camel milk is effective in

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treating many diseases such as diabetes, cancer, viral hepatitis and other infections (Oselu *et al.*, 2022; Shakeel *et al.*, 2022).

People who are overweight or obese are more likely to develop insulin resistance (Fryk *et al.*, 2021). Doctors often adjust insulin dosages based on a person's weight (Dailey *et al.*, 2010). Being overweight is a major risk factor for type 2 diabetes (Yashi and Daley, 2025). Due to the assumption of lowering blood glucose levels upon consuming camel milk particularly for individuals with diabetes, the aims of the current study were to explore the changes of blood glucose levels, plasma biochemistry profiles in mice consuming camel milk and colostrum (fresh and frozen-thawed) of low, medium and high body weights for the first time.

MATERIALS AND METHODS

The experimental procedures were approved by the ethical committee of King Faisal University [KFU-REC-2025-FEB-EA252]. The fresh and frozen-thawed camel colostrum and camel milk were obtained from camel farm located in Al-Ahsaa area of KSA. The experimental procedures were carried out in the experimental animal labs of Agriculture and Food Sciences College, King Faisal University of KSA.

Animal management and site of study

The present two experiments were carried out from October 2024 to January 2025 in the department of animal and fish production of King Faisal University. Eighty eight albino male mice were used for conducting two experiments; forty

males for experiment I (medium body weight g 33.80 ± 0.66) and forty-eight males for experiment II (low body weight 17.30 ± 0.66 , medium body weight g 33.65 ± 0.93 and high body weight 50.80 ± 1.39) (Fig 1 and 2).

The adult medium BW mice were chosen for experiment I due to their healthy weights for blood collection if compared to growing low BW mice in addition to their sufficient number of functional insulin receptors if compared to obese high BW mice. The normal body weight of male albino mice according to Jackson laboratory is ranged 25-40 grams. Therefore, the classification of mice in this study to low BW (growing), medium BW (adult) and high BW (obese) is corresponding to 4-6, 10-12, 16-20 weeks, respectively.

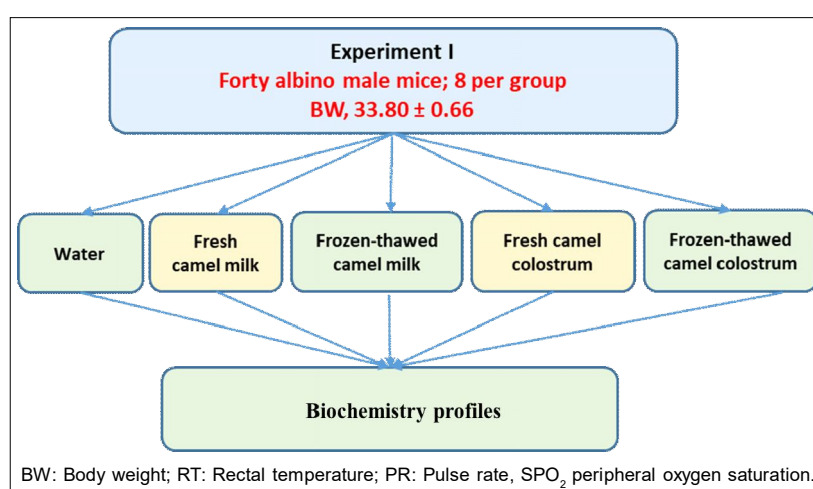


Fig 1: Effects of *ad libitum* consumption of fresh and frozen-thawed camel milk and colostrum on blood glucose values, physiological parameters, hematological and biochemistry profiles in mice of medium body weight.

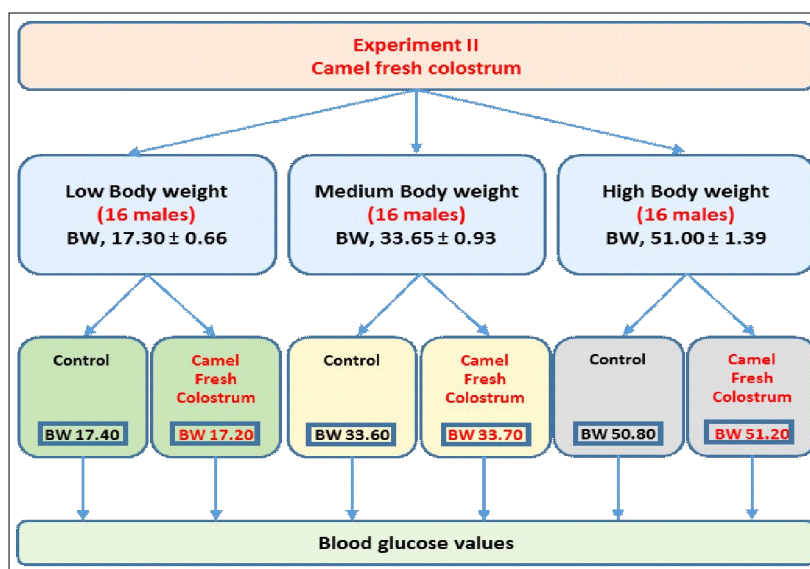


Fig 2: Effects of *ad libitum* consumption of fresh camel colostrum on blood glucose values in mice of low, medium and high body weights.

The first experiment were carried out to explore the changes of plasma biochemistry values in medium body weight mice receiving *ad libitum* camel milk and colostrum (fresh and frozen-thawed). Thereafter, the second experiment was carried out to explore the changes of blood glucose levels in mice receiving *ad libitum* fresh camel colostrum of low, medium and high body weights. Mice were kept in cage (40.0 × 24.0 × 18.0 cm) of control and the milk and colostrum groups. The mice were fed pellet diet composed of 22.0 protein, 3.20 fiber, 2.90 fat, 1.0 mixture of minerals and vitamins and energy of 3300 kcal/kg. The control group was provided *ad libitum* water whereas camel milk and colostrum groups were provided *ad libitum* camel milk and colostrum diluted with water (1:1 volume) through bottles with automated nipple. The mice consumed daily ~5.0 and ~4.0 ml of diluted milk and colostrum, respectively. This *ad libitum* method was chosen to allow the animals to regulate their intake according to their voluntary needs and reduces stress. The camel milk and colostrum were either fresh or frozen-thawed. Animals had free access to diet. Mice were kept controlled under 12 h light and 12h dark cycles starting at 8:0 a.m. The temperature (°C) and relative humidity (%) values during the study were controlled to 24.50±1.5°C and 41.0±6.0%, respectively. The duration of the two experiments were six weeks.

Blood sample collection and analyses

Blood samples were collected from the orbital sinus of control mice group, fresh and frozen-thawed camel colostrum and milk mice groups at the end of experiment (Hoff, 2000). The obtained blood samples were analyzed using biochemistry analyzer (Skyla VB1). The resulting biochemistry profiles include total protein, urea, creatinine, liver and kidney enzymes and mineral values (Mohammed and Al-Suwaiegh 2023; Mohammed *et al.*, 2024; 2025b).

Statistical analysis

Plasma profile values and blood glucose values of control and fresh and frozen-thawed camel colostrum and milk groups were statistically analyzed using General Linear

Model procedure of one way ANOVA (SAS 2008) according to the following model:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where,

μ = Mean.

T_i = Effects of fresh and frozen-thawed camel colostrum and milk consumption.

e_{ij} = Standard error.

Duncan's multiple range test (1955) was used to compare between means of control and fresh and frozen-thawed camel colostrum and milk groups.

RESULTS AND DISCUSSION

Plasma profiles and blood glucose values of control and fresh and frozen-thawed camel colostrum and milk groups are presented in Table (1) and Fig (3), respectively.

Plasma profiles

The effects of camel colostrum (fresh and frozen) and camel milk (fresh and frozen) compared to a control group on various biochemical profiles are presented in Table (1). The control group had significantly ($P<0.01$) lower total protein levels (4.1 g/dl) compared to all other milk and colostrum groups (~4.4-4.6 g/dl). The control, milk and colostrum groups showed varied urea levels. The fresh colostrum and frozen colostrum groups had significantly ($P<0.01$) lower urea levels (~26 mg/dl) compared to the control, fresh milk and frozen milk groups (~29-31 mg/dl).

The control group had significantly ($P<0.01$) lower creatinine levels (0.50 mg/dl) compared to all other groups (~0.6-0.7 mg/dl). Glucose levels varied significantly across groups ($P<0.001$). The frozen milk and colostrum had the highest glucose levels (around 156-159 mg/dl), while the fresh colostrum group had the lowest value (121.5 mg/dl). The control and fresh milk groups had intermediate levels. The fresh and frozen colostrum groups had significantly ($P<0.001$) lower AST and ALT levels compared to the control, fresh and frozen milk groups. The fresh and frozen colostrum groups had significantly ($P<0.05$) lower lactate dehydrogenase levels (~542-550 U/l)

Table 1: Changes of plasma biochemistry of mice consuming fresh and frozen-thawed camel milk and colostrum in mice.

Parameters	Control	Fresh milk	Frozen milk	Fresh colostrum	Frozen colostrum	SEM	<i>P value</i>
Total protein, g/dl	4.1 ^b	4.4 ^a	4.5 ^a	4.6 ^a	4.5 ^a	0.13	0.01
Urea, mg/dl	29.0 ^a	31.0 ^a	30.0 ^a	26.0 ^b	26.5 ^b	1.01	0.01
Creatinine, mg/dl	0.50 ^b	0.6 ^a	0.6 ^a	0.7 ^a	0.6 ^a	0.04	0.01
Glucose, mg/dl	138.9 ^b	129.7 ^c	155.9 ^a	121.5 ^d	158.6 ^a	1.76	<0.001
AST, U/l	190.0 ^a	180 ^a	189.0 ^a	133.0 ^b	137.0 ^b	12.1	<0.001
ALT, U/l	215.0 ^a	202.0 ^a	205.0 ^a	164.0 ^b	166.0 ^b	14.1	<0.001
Lactate D, U/l	620.0 ^a	610.0 ^a	603.0 ^a	550.0 ^b	542.0 ^b	19.7	0.05
Iron, µmol/L	349.0 ^c	415.0 ^b	405.0 ^b	516.0 ^a	537.0 ^a	9.74	<0.001

^{a,b}. Values between groups with different superscripts in the same row significantly differ at $P<0.05$.

AST: Aspartate Aminotransferase; ALT: Alanine Aminotransferase; SEM: Standard error.

compared to the other groups (~603-620 U/l). The fresh and frozen colostrum groups had ($P<0.001$) significantly higher iron levels (~516-537 $\mu\text{mol/L}$) compared to the control group (349 $\mu\text{mol/L}$) and the fresh and frozen milk groups (~405-415 $\mu\text{mol/L}$).

Blood glucose levels

Blood glucose values of low, medium and high body weight of control and fresh camel colostrum groups, respectively, are showed in Fig (3). The results indicated that the low body weight control group had a glucose level of 118.25, while the colostrum group had a glucose level of 98.42 indicating a highly significant difference ($P<0.0001$). Additionally, the medium body weight control group had a glucose level of 138.90, while the colostrum group had a glucose level of 121.5 indicating a highly significant difference ($P<0.0001$). Finally, the high body weight control group had a glucose level of 138.20, while the colostrum group had a glucose level of 133.1 indicating none significant difference ($P<0.15$). The decrease in blood glucose values of low, medium and high body weight mice consuming fresh camel colostrum were 16.76, 12.52 and 3.69% compared to control groups.

Results of the presents experiments are presented in Fig (3) and Table (1) indicating the effects of camel milk and colostrum either fresh or frozen on plasma biochemistry profiles and blood glucose values in mice. Collectively, the obtained results indicated a potential effect of fresh camel colostrum followed by fresh milk in decreasing blood glucose levels versus frozen and control groups. In addition, plasma profiles were improved in fresh and frozen camel milk and colostrum groups compared to control one. These effects could be attributed to the ingredients in camel colostrum and milk (Mohammed and Alshaibani, 2025). Both camel colostrum and milk contain various biological compounds, some of which can be potentially effect on blood glucose levels and body functions (Seyiti *et al.*, 2024; Mohammed *et al.*, 2025a). Freezing

and thawing, a common method for preserving food and biological samples can have significant effects on protein structures of camel colostrum and milk. These freezing and thawing procedures of milk and colostrum can range from subtle changes in their immunoglobulins and other bioactive compounds conformation to irreversible denaturation and aggregation, ultimately influencing protein functions and stability (Wöll *et al.*, 2023). Freezing can lead to the formation of ice crystals, which can disrupt these delicate structures, potentially causing denaturation. Freezing can also affect the stability of milk and colostrum lipids, potentially leading to oxidation or other forms of degradation (Fasse *et al.*, 2021).

Plasma profiles

The effects of camel colostrum and milk, either fresh or frozen, compared to a control group on various biochemical parameters is presented in Table (1). The camel milk and colostrum seems to have a more significant impact on biochemical parameters (Khaliq *et al.*, 2024). The camel milk and colostrum increased total protein levels (4.4-4.6 g/dl) if compared to control group (4.1 g/dl) due to camel milk and colostrum protein contents (Fig 3). The fresh and frozen camel colostrum groups had significantly lower urea levels (26.0 and 26.5 mg/dl, respectively) compared to the control, fresh and frozen camel milk groups (29.0-31.0 mg/dl), which are generally indicative of better kidney function. The control group had significantly lower creatinine levels (0.50 mg/dl) compared to camel milk and colostrum supplemented groups (0.6-0.7 mg/dl). The increase could be related to increased protein intake in consumed colostrum and milk if compared to control one. The frozen milk and colostrum groups had the highest glucose levels (155.9 and 158.6 mg/dl, respectively), while the fresh colostrum group had the lowest (121.5 mg/dl). The control and fresh milk groups had intermediate levels. This suggests that fresh colostrum have the strongest hypoglycemic effect compared to other groups (Alshaibani and Mohammed, 2025). Iron

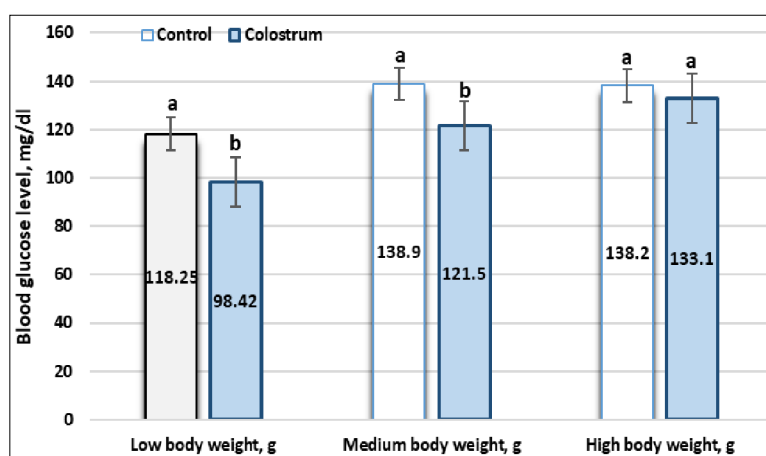


Fig 3: Changes of blood glucose levels (mg/dl) in low, medium and high body weight mice consuming fresh camel colostrum.

levels were significantly higher in the fresh and frozen colostrum colostrum compared to the control and milk groups might be attributed to higher iron contents in camel colostrum (El-Hatmi *et al.*, 2023). Both AST and ALT were significantly lower in the fresh colostrum and frozen groups compared to other groups. Fresh camel colostrum appears to have beneficial effects on glucose metabolism (lower glucose), liver function (lower AST and ALT) and potentially kidney function (lower urea) (Khaliq *et al.*, 2024). Camel colostrum is a complex mixture of proteins, immunoglobulins, growth factors and other bioactive compounds. Fully understanding the individual and synergistic effects of these components requires extensive research. The role of the specific active ingredients in camel colostrum can be studied in further studies.

Blood glucose levels

The control group exhibits a relatively stable blood glucose level throughout the experimental period, with a slight increase towards the end. This suggests that without any milk and colostrum supplementation, blood glucose remains consistent with minor fluctuations. The fresh camel colostrum supplementation indicates the strongest hypoglycemic effect followed by fresh camel milk versus the strongest hyperglycemic effect of frozen colostrum and milk, respectively, if compared to control one. The hypoglycemic effect of camel milk has been confirmed in several studies (García-García *et al.*, 2020; Mohammadabadi and Jain, 2024; Mbye *et al.*, 2025) whereas the hypoglycemic effect of camel colostrum has been not explored to the best of our knowledge earlier. Camel milk is suggested to be a suitable hypoglycemic factor in experimental animals and diabetic people (García-García *et al.*, 2020; AlKurd *et al.*, 2022; Mohammadabadi and Jain, 2024). Consuming camel milk lowers blood glucose value and reduces the amount of insulin required for treatment by 30-35% for patients with type I diabetes (Mirmiran *et al.*, 2017; García-García *et al.*, 2020; Mohammadabadi and Jain 2024). It has been assumed that camel milk contains insulin-like proteins that enhance health of diabetic patients (Anwar *et al.*, 2022). With frozen procedures, such insulin-like proteins in camel colostrum and milk might be denatured and aggregated. In addition, the SNF, fat, proteins and lactose contents of camel colostrum and milk could be attributed to hyperglycemic effect of frozen colostrum and milk if compared to control group.

A comparison of blood glucose levels (mg/dl) between control mice groups and treated mice groups of low, medium and high body weights receiving fresh colostrum is shown in Fig (3). The most striking observation is lowering blood glucose levels in groups receiving fresh colostrum if compared to control groups within each body weight category. The difference in blood glucose values between the control and colostrum receiving groups is

substantial in the low body weight category. This suggests that individuals with lower body weights might experience a more pronounced glucose lowering (16.91% $P < 0.001$) benefit from colostrum supplementation compared to medium (12.52% $P < 0.01$) and high (3.69% $P < 0.09$) body weight categories. The result provides compelling evidence that fresh camel colostrum supplementation suggests a possible interaction between body weight and the effectiveness of fresh camel colostrum on glucose regulation, with the effect potentially being more pronounced in individuals with lower body weights. Excess body weight is a major risk factor for insulin resistance (Buscemi *et al.*, 2024). In addition, fat cells, especially those in the abdomen, release hormones and other substances that can interfere with insulin's action (Dilworth *et al.*, 2021).

CONCLUSION

Significant effects of fresh and frozen camel milk and colostrum on plasma profiles. The most prominent findings of this study indicated that fresh camel colostrum supplementation gave the strongest hypoglycemic effect followed by fresh camel milk versus the strongest hyperglycemic effect of frozen colostrum and milk, respectively. The strongest hypoglycemic effect of fresh camel colostrum was more pronounced in low body weight mice, followed by medium and high body weight mice. Further studies are still required to explore the fresh camel milk and colostrum on diabetic experimental model animals with different body weights.

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Disclaimers

The views expressed in this article are solely those of the authors and do not necessarily represent the official stance of their affiliated institution.

Informed consent

Ethical Approval of Scientific Research Deanship Committee of King Faisal University.

Novelty statement

Fresh camel colostrum supplementation gave the strongest hypoglycemic effect in mice of low body weight compared to those of medium and high body weights.

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Conflict of interest

The authors have declared no conflict of interest.

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