



Chemical Composition of Camel Colostrum and Milk: The Potential Consumption in Fresh and Frozen-thawed States on Blood Glucose Values and Hematological Profiles in Mice

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ABSTRACT

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

Methods: Forty male albino mice were distributed over five groups; control, camel milk (CM) and camel colostrum (CC) either fresh (F) or frozen-thawed (FT). Chemical composition of camel colostrum and milk were determined through milkoscan system. Body weights (BW), rectal temperature, pulse rate and peripheral oxygen saturation (SPO₂), were recorded. Blood glucose values were recorded per two days. Blood samples were collected for hematology analyses.

Result: The results showed that camel's colostrum had higher ($P<0.0001$) solid not fat (SNF), protein and lactose but lower fat values compared to camel's milk. Final body weights (g) were significantly increased in colostrum and milk groups if compared to control one. The highest blood glucose values were found in FTCC followed by FTMC groups whereas the lowest glucose values were found in FCC followed by FCM groups. Colostrum and milk groups had higher ($P<0.05$) red and white blood cells, hematocrite and hemoglobin if compared to control group. It could be concluded that FCC followed by FCM are potential in decreasing blood glucose levels versus frozen-thawed ones.

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

INTRODUCTION

People living in harsh environments face numerous challenges such as malnutrition and related metabolic disorders (Machan *et al.*, 2022). Malnutrition challenges in harsh environments include limited access to nutrient-rich foods, droughts and unpredictable weather patterns affecting food production and difficulties in storing and preserving perishable foods (Morgan and Fanzo, 2020). Additionally, the metabolic disorders include diabetes due to dietary limitations and stress, dehydration and mineral deficiencies (García-García *et al.*, 2020). Camels are considered the most important animal species to produce milk in the harsh environmental conditions (Djenane and Aider, 2024; Mohammed and Alshaibani, 2024). It has been reported that 2.12 million tons of camel milk were approximately produced from 5.25 million she-camels (Ramadan and Inoue-Murayama, 2017). Both camel colostrum and milk offer a unique nutritional profile and potential health benefits to both neonates and human as well (Mohammed and Alshaibani, 2024). In recent decades, numerous studies have investigated the changes in camel milk production and composition. Camel milk is a significant source of protein for people living in arid regions, particularly those who live nomadic lifestyles (Arain *et al.*, 2024). Camel milk and colostrum have been recognized for their potential health benefits particularly in arid and semi-arid regions where she-camels are prevalent (Mohammed and Alshaibani, 2024).

Several studies have explored the potential health benefits of camel milk, including its therapeutic effects on

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certain diseases in both experimental animals and humans (Liu *et al.*, 2023; Mohammed *et al.*, 2025a). It has been found that camel milk is rich in a variety of bioactive components, including immunoglobulins, lactoferrin, 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 milk, colostrum and camel milk products (Kanha, 2010; Almasri *et al.*, 2024). Evidences from several studies indicate that camel milk is effective in 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, physiological parameters, hematological profiles and plasma biochemistry values in mice consuming camel milk and colostrum (fresh and frozen-thawed) of low, medium and obese body weights.

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. Forty albino male mice were used for conducting the study (body weight g 33.80 ± 0.66) (Fig 1).

The study was designed to explore the changes of blood glucose levels, body weight gain, rectal temperature, pulse rate, SPO_2 , hematological profiles in mice receiving *ad libitum* camel milk and colostrum (fresh and frozen-thawed). Mice were kept in cage ($40.0 \times 24.0 \times 18.0$ 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 given fresh and frozen-thawed states. Animals had free access to diet. Mice were kept controlled under 12 h light and 12 h dark cycles starting at 8:0 a.m. The temperature ($^{\circ}C$) and relative humidity (%) values during the study were controlled to $24.50 \pm 1.5^{\circ}C$ and $41.0 \pm 6.0\%$, respectively. The duration of the experiment was sixteen days.

Monitoring body weight, rectal temperature, heart rate, peripheral oxygen saturation and blood glucose values

Body weights (g) of control and experimental groups were recorded using digital balance (Sartorius balance, Azulmart-KSA). The mice of all groups were sedated using 26.6 mg/kg BW xylazine for immediate recording of rectal temperature, pulse rate and SPO_2 . Rectal temperatures were recorded using clinical thermometer (Citizen) (Mohammed *et al.*, 2012). Peripheral oxygen saturation (SPO_2) and pulse rates were recorded using pulse oximeter apparatus (CMS60D-VET). Blood glucose values were recorded using blood glucose meter (iCare, Taiwan) without sedation. The tail vein of mice was punctured and 10 μ l tiny blood sample put on iCare glucose strips for recording blood glucose values.

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

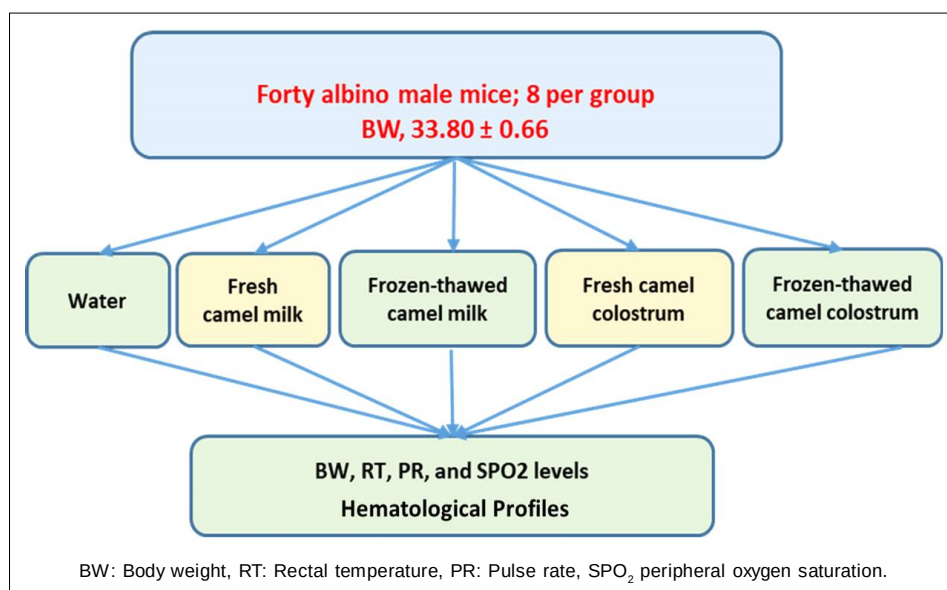


Fig 1: Effects of *ad libitum* consumption of fresh and frozen-thawed camel milk and colostrum on blood glucose values, physiological parameters, hematological profiles in mice.

(Hoff, 2000). The obtained blood samples were analyzed using automatic hematology analyzer (Mythic 5Vet PRO Hematology Analyzer). The resulting blood profiles include white and red blood cells, hemoglobin and hematocrit values (Mohammed and Al-Suwaiegh, 2023).

Statistical analysis

Body weight, blood glucose, rectal temperature, SPO_2 , pulse rate and hematological 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

Body weight, blood glucose, rectal temperature, SPO_2 and pulse rate, blood and plasma profile values of control and fresh and frozen-thawed camel milk and colostrum groups are presented in (Fig 2 and 3) (Table1 and 2).

Chemical composition of fresh camel colostrum and camel milk

Fresh colostrum and milk of Mejjham camel breed were collected from farm located in Al-Ahsaa region. In addition, fresh camel colostrum and milk were frozen and thawed. Chemical compositions of camel colostrum and camel milk were determined through milkoscan (Fig 2).

Body weight, rectal temperature, SPO_2 and pulse rate

Changes of final body weight (g), rectal temperature, pulse rate and SPO_2 are presented in Table 1. Value of final body weight was significantly increased in fresh and frozen-thawed camel milk and colostrum groups compared to that of control group and no differences was found between milk and colostrum groups either fresh or frozen-thawed groups in final body weight. Additionally,

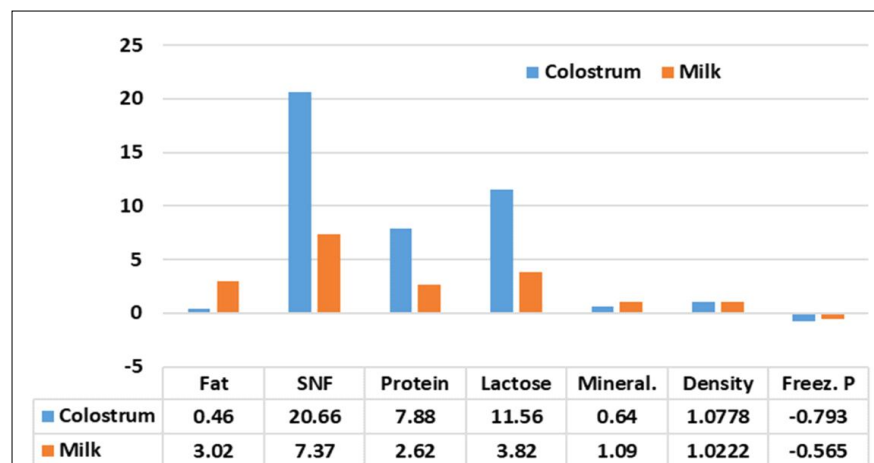


Fig 2: Chemical composition of fresh camel colostrum and camel milk. SNF, solid none fat; freez. P., freezing point.

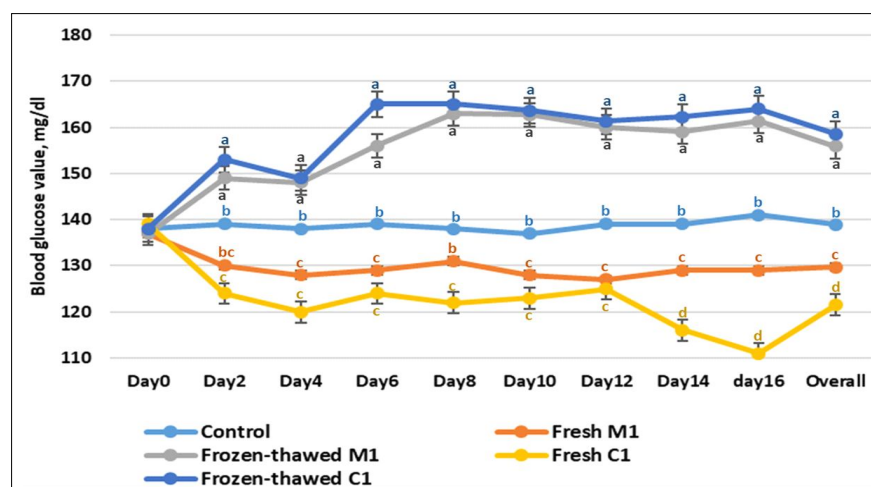


Fig 3: Changes in blood glucose values (mg/dl) upon consumption of camel fresh colostrum in mice of medium body weight.

rectal temperature ($^{\circ}\text{C}$), pulse rates and SPO_2 values were not differed among control, colostrum and milk groups.

Monitoring blood glucose levels

Blood glucose values per two days of medium body weight mice consuming fresh and frozen-thawed camel milk and colostrum are presented in Fig 3. There were no significant differences in blood glucose levels between any of the groups at the start of the experiment. All groups had similar starting glucose levels around 137-139 mg/dl. Over the sixteen days, the fresh colostrum group consistently showed the lowest blood glucose levels ($P < 0.001$), while the frozen-thawed colostrum group showed the highest ones. The fresh milk group showed a decrease in glucose levels, although it remained higher than the fresh colostrum group. The control group's glucose levels remained relatively stable over the sixteen days of experiment. Collectively, the highest ($P < 0.001$) blood glucose values were found in frozen-thawed colostrum followed by frozen-thawed milk groups whereas the lowest ($P < 0.001$) blood glucose values were found in fresh colostrum followed by fresh milk groups if compared to control group.

Hematological profiles

The effects of camel milk (fresh and frozen-thawed) and camel colostrum (fresh and frozen-thawed) compared to a control group on various hematological profiles are presented in Table 2. The control group had significantly lower (< 0.0001) RBCs counts ($7.45 \times 10^6/\mu\text{l}$) compared to all other groups ($\sim 8.4\text{--}8.5 \times 10^6/\mu\text{l}$). Similarly, the control group had a lower PCV (38.1%) compared to the other groups ($\sim 43.5\text{--}45.1\%$). In addition, the control group also had lower hemoglobin levels (13.50 g/dl) compared to the other groups ($\sim 14.5\text{--}14.6$ g/dl). The control group had the lowest ($P < 0.0001$) WBCs count ($5.60 \times 10^3/\mu\text{l}$). The fresh colostrum group had the highest ($P < 0.0001$) WBCs count ($6.90 \times 10^3/\mu\text{l}$), followed by the frozen-thawed colostrum group ($6.80 \times 10^3/\mu\text{l}$) and the fresh milk group ($6.50 \times 10^3/\mu\text{l}$). The same trends were obtained for types of WBCs and platelets.

Results of the presents experiments are presented in Fig 2-3 and Table 1-2 indicating the effects of camel milk and colostrum either fresh or frozen-thawed on body weight gain, blood glucose profiles, hematological profiles in

Table 1: Changes of body weight (g), rectal temperature ($^{\circ}\text{C}$), pulse rate and peripheral oxygen saturation (%) in mice receiving *ad libitum* fresh and frozen-thawed camel milk and colostrum groups in mice.

Parameters	Control	Fresh-M	Frozen-M	Fresh-C	Frozen-C	SEM	P value
Initial body weight, g	33.90	33.80	33.6	33.70	33.50	0.93	0.91
Final body weight, g	38.45 ^b	40.00 ^a	39.37 ^a	39.35 ^a	39.80 ^a	1.15	0.05
Rectal temperature, $^{\circ}\text{C}$	35.82	35.84	35.78	35.74	35.84	0.07	0.50
Pulse rate/min.	163.5	166.4	164.6	163.1	165.6	6.24	0.93
Peripheral oxygen saturation, %	83.2	87.3	86.3	87.6	87.3	2.87	0.07

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

Fresh-M fresh milk, Frozen-M frozen-thawed milk, Fresh-C fresh colostrum, Frozen-C frozen-thawed colostrum, SEM standard error of means.

Table 2: Changes of blood profiles of mice consuming fresh and frozen-thawed camel milk and colostrum.

Parameters	Control	Fresh milk	Frozen milk	Fresh colostrum	Frozen colostrum	SEM	P value
RBCs, $10^6/\mu\text{l}$	7.45 ^b	8.41 ^a	8.39 ^a	8.49 ^a	8.51 ^a	0.33	< 0.0001
PCV, %	38.1 ^b	43.6 ^a	43.5 ^a	45.1 ^a	44.1 ^a	2.12	< 0.0001
Hb, g/dl	13.50 ^b	14.6 ^a	14.5 ^a	14.5 ^a	14.6 ^a	0.35	< 0.0001
MCV, fl	51.0	52.0	51.8	53.0	51.8	0.57	< 0.10
MCH, pg	18.1 ^a	17.3 ^b	17.3 ^b	17.1 ^b	17.2 ^b	0.30	< 0.04
MCHC, g/dl	35.4	33.5	33.3	32.1	33.1	0.99	< 0.08
WBCs, $10^3/\text{ml}$	5.60 ^c	6.50 ^{ab}	6.20 ^b	6.90 ^a	6.80 ^a	0.49	< 0.0001
Neutrophils, $10^3/\mu\text{l}$	2.6 ^c	3.05 ^{ab}	2.90 ^a	3.15 ^a	3.10 ^a	0.17	< 0.001
Lymphocyte, $10^3/\mu\text{l}$	2.13 ^c	2.45 ^b	2.35 ^b	2.66 ^a	2.63 ^a	0.16	< 0.001
Monocyte, $10^3/\mu\text{l}$	0.466 ^c	0.580 ^b	0.54 ^b	0.660 ^a	0.65 ^a	0.002	< 0.001
Eosinophils, $10^3/\mu\text{l}$	0.330 ^b	0.361 ^a	0.357 ^a	0.357 ^a	0.348 ^a	0.001	< 0.05
Basophils, $10^3/\mu\text{l}$	0.064 ^{ab}	0.059 ^b	0.053 ^b	0.073 ^a	0.072 ^a	0.0003	< 0.0001
PLT, $10^3/\mu\text{l}$	938 ^b	1098 ^a	1113 ^a	1142 ^a	1115 ^a	20.38	< 0.01

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

SEM: Standard error of means; RBCs: Red blood cells; PCV: Packed cell volume; Hb: Hemoglobin; MCV: Mean corpuscular volume; MCH: Mean corpuscular hemoglobin; MCHC: Mean corpuscular hemoglobin concentration; RDW: Red cell distribution width; WBCs: White blood cells, PLT: Platelet.

mice. Collectively, the obtained results indicated a potential effect of fresh camel colostrum followed by fresh milk in decreasing blood glucose levels versus frozen-thawed and control groups. In addition, body weight gain, hematological profiles were improved in fresh and frozen-thawed camel milk and colostrum groups compared to control one. These effects could be attributed to the ingredients in camel colostrum and milk (Fig 2). Both camel colostrum and milk contain various biological compounds, some of which can be potentially effect on blood glucose levels and body functions (Khaliq *et al.*, 2024; 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).

Body weight, rectal temperature, SPO₂ and pulse rate

Camel milk and colostrum have been explored for a variety of potential health benefits (García-García *et al.*, 2020; Djenane and Aider, 2024). These benefits may include changes in body weight gain where the control group exhibited a significantly lower final body weight (38.45g) compared to all milk and colostrum supplemented groups ($P < 0.05$) (39.35 g to 40.00 g). This suggests that milk supplementation, regardless of type (fresh or frozen-thawed milk or colostrum), promoted weight gain compared to the control. This could be attributed to the contents of camel milk and colostrum (Fig 3) (Khaliq *et al.*, 2024; Olfa *et al.*, 2023). The similar final body weights among the milk and colostrum supplemented groups suggest that freezing procedure and type (milk vs. colostrum) did not significantly influence body weight gain. Rectal temperatures and pulse rates remained relatively consistent across all groups. The small variations observed are not likely to be biologically significant and suggest that milk and colostrum consumption did not substantially affect these physiological parameters.

Rectal temperatures and pulse rates remained relatively consistent across all groups. The small variations observed are not likely to be biologically significant and suggest that camel milk and colostrum consumption did not substantially affect these physiological parameters. A notable difference was observed in SPO₂ levels. The control group exhibited a considerably lower SPO₂ (83.2%) compared to all camel milk and colostrum supplemented groups, which ranged from 86.3% to 87.6%. This suggests that camel milk and colostrum consumption may have a positive impact on oxygen saturation. The higher SPO₂ in

the camel milk and colostrum groups could indicate improved respiratory function or oxygen utilization due to higher RBCs and Hb values (Table 2) (Hafen and Sharma, 2022; Mohammed *et al.*, 2025b).

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-thawed 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-thawed 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-thawed colostrum and milk if compared to control group (Fig 2).

Hematological profiles

Camel colostrum and milk supplementation, regardless of whether it was fresh or frozen, appear to have a positive effect on red blood cell parameters (RBCs, PCV, Hb), white blood cell parameters (WBCs, neutrophils, lymphocytes and monocytes) and platelet counts compared to the control group (Table 2). Camel colostrum and milk supplementation seem to enhance the production or levels of red blood cells, hemoglobin and platelets. In addition, camel colostrum and milk supplementation also appear to stimulate the production of various types of white blood cells, suggesting a potential immune-modulatory effect. Furthermore, freezing the camel colostrum and milk did not seem to significantly alter its effects on these hematological parameters. The higher concentration of bioactive compounds such as lactoferrin and various immunoglobulins (IgM, IgA, IgG and IgD) are found in camel colostrum and milk, which has turned camel colostrum and milk into substances with extraordinary medicinal properties (Ho *et al.*, 2022). The presence of high levels of

these compounds along with various vitamins (C, B1, B2, E, A) (Swelum *et al.*, 2021), lysozymes, insulin-like molecules and lactoperoxidase cause the therapeutic potential of camel milk (Behrouz *et al.*, 2024).

CONCLUSION

Significant effects of fresh and frozen-thawed camel colostrum and milk on body weight gain, hamtological 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-thawed colostrum and milk, respectively. 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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Novelty statement

Fresh camel colostrum supplementation gave the strongest hypoglycemic effect compared to fresh camel milk.

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Disclaimers

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

Informed consent

The Ethical Committee of Deanship of Scientific Research, King Faisal University, Saudi Arabia, approved all animal experimental care (KFU253484).

Conflict of interest

The authors have declared no conflict of interest.

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