Effect of pretreatment on freeze-drying time of camel milk

Journal of Food Science and TechnologyArticle2026DOI: 10.1007/s13197-026-06544-8

Dikhanbayeva, Fatima [a, b] ; Rakhmatulina, Ayaulym [a, c] ; Tlevlessova, Dinara [a, b] ; Aralbayev, Nurbek [a] ; Yessenova, Aidana [b]

[a] U. Joldasbekov Institute of Mechanics and Engineering, Shevchenko Str., 28, Almaty, Kazakhstan

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Abstract

Freeze-drying of camel milk is time-consuming due to its high density, protein, and fat content, which limits industrial application and increases energy demand. In this study, ultrasonic treatment (UT) and homogenization were applied as pretreatments prior to freeze-drying. A full factorial design (2^4) was used to evaluate process factors. Experimental trials were combined with mathematical modeling based on heat and mass transfer equations (Fourier's law, Fick's law, and dimensionless criteria Re, Pr, Nu). Pretreatment significantly improved drying efficiency: the drying time of camel milk was reduced from 28 h (control) to 22 h (treated samples), corresponding to a 21% decrease. Protein content and solubility were enhanced, while residual moisture decreased to 3–4%. The developed equations accurately predicted sublimation rates and drying kinetics, with $R^2 = 0.95$ confirming high model reliability. The integration of ultrasonic treatment and homogenization into freeze-drying provides a viable strategy for reducing drying time and improving product quality of camel milk. The established criterion equations and models support process optimization and industrial application. © Association of Food Scientists & Technologists (India) 2026.

Author keywords

Camel milk; Drying optimization; Freeze-drying; Homogenization; Process modeling; Ultrasonic treatment

Indexed keywords

Engineering controlled terms

Mass transfer; Optimization; Quality control

Engineering uncontrolled terms

Camel milks; Drying optimization; Drying time; Freeze drying; Homogenization; Optimisations; Pre-treatments; Process-models; Protein contents; Ultrasonic treatments

Engineering main heading

Homogenization method; Low temperature drying

Funding details

Details about financial support for research, including funding sources and grant numbers as provided in academic publications.

Funding sponsor	Funding number	Acronym
Ministry of Education and Science of the Republic of Kazakhstan See opportunities	BR21881957	
Ministry of Education and Science of the Republic of Kazakhstan See opportunities		

Funding text

This research was funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR21881957).

Corresponding authors

Corresponding author	D. Tlevlessova
Affiliation	U. Joldasbekov Institute of Mechanics and Engineering, Shevchenko Str., 28, Almaty, Kazakhstan
Email address	tlevlessova@gmail.com