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Abstract

Xinjiang province is the main camel feeding area in China with a large square, and camel milk from different areas have different qualities. By now, there are few reports about the quality of camel milk from different areas of Xinjiang province in China. In this study, seven batches of camel milk and one batch of cow milk were collected, and the contents of fat, protein, lactose, total solid, and nonfat milk solid of these milk samples were determined, as well as the contents of lysozyme and vitamin C. All samples were scored and compared by principal component analysis score and comprehensive weighted multi-index score. As the results, camel milk from different areas showed different contents of fat (4.62-7.02%), protein (3.34-3.95%), lactose (3.85-4.79%), total solid (13.59-17.00%), nonfat milk solid (8.55-9.73%), vitamin C (12.10-41.25 μg/mL), and lysozyme (8.70-22.80 μg/mL), as well as different qualities. This variation would help people to know more about quanlity of camel milk in Xinjiang province. Camel milk from Jeminay showed the best quality, and then followed by camel milk from Fukang, Changji, and Fuhai, while cow milk showed the lowest score. Therefore, Jeminay is the most suitable place for grazing camels. Our findings show the different qualities of camel milk in different distribution areas of Xinjiang province, and provide an insight for the evaluation of camel milk. In the present study, only seven components in camel milk were determined, many other factors, such as cfu, mineral, and other vitamins, have not been considered.

Keywords:

Camel milk, Comprehensive quality, Nutritional components, Lysozyme, Jeminay

Introduction

Milk of the Bactrian camel has been referred to as a traditional Chinese medicine in Compendium of Materia Medica with functions of tonifying middle-Jiao and Qi and strengthening bone and musculature. Also, camel milk has been considered as a medicinal food to treat with cough by Uyghur and Kazakh people living in Xinjiang of China due to its rich nutritional and functional ingredients. According to Kazakh Medical Record, camel milk has the functions of nourishing, calming, nourishing yin, and detoxifying, which can restore the weak body after various diseases. Also, according to Common Medicinal Herbs in Uyghur Medicine, camel milk has the affects of tonifying and remedying symptom-complex of excessive eating. Furthermore, many papers have reported camel milk with many bioactivities, such as the treatments for diabetes (Arshida *et al.*, 2021; Kilari *et al.*, 2020), platelet activity (Sultan, 2022), inflammatory, low immunity, and gut microbiota disorders (He *et al.*, 2022; Wang *et al.*, 2018).

By now, more and more people have realized the benefits of camel milk, and consumption of camel milk raised rapidly. Meanwhile, the population of Bactrian camels increased, especially in China. Xinjiang province is one of the main breeding areas of Bactrian camels in China, and feeding areas of Bactrian camel are mainly distributed in Urumqi city, Changji city, Hami city, Altay city, Hotan city, Kashgar city, and so on, while all camel are grazed in the desert and can freely consume plants that growing on deserts feeding. Camel milk contains many varieties of nutritional components, including fat, protein, and lactose. Fat is an important active component of camel milk to supply energy for people, and is composed of triglycerides and phospholipids (Ali *et al.*, 2019). And for people with traditional diets high in carbohydrates, camel milk also can provide plenty of essential fatty acids to meet their daily nutritional needs, as well as vitamins (Fayed *et al.*, 2017). Moreover, a large number of conjugated linoleic acids in camel milk can help to reduce inflammation, lower blood sugar, and reduce the incidence of lipid-related cardiovascular disease (O'Shea *et al.*, 2004). High content of protein is one of the main characteristics of camel milk, and it can be hydrolyzed into bioactive peptides with many beneficial effects on humans by enzymes (Redha *et al.*, 2022). Apart from casein, camel milk contains many protective proteins for human, such as lactoferrin, lactoperoxidase, lysozyme, and immunoglobulin (Anahita *et al.*, 2019). Lysozyme is a natural enzyme present in animal tissues with bactericidal properties by lysing the cell wall of bacteria (Chandrima *et al.*, 2015). As one of the key whey proteins in camel milk, it can inhibit the growth of gram-positive growth (Fratini *et al.*, 2015), and can kill or inhibit a large spectrum of pathogens (Zhang *et al.*, 2008). Also, along with other factors including immunoglobulins, lactoferrin, and lactoperoxidase, lysozyme can limit the migration of neutrophils into a damaged tissue as an anti-inflammatory agent (Nidia *et al.*, 2006). In addition, as one of the main carbohydrate components, camel milk contents about 4.37% lactose, which is lower than that in cow milk (Ismaili *et al.*, 2017) and can avoid the untoward reactions of patients with lactose intolerance (Cardoso *et al.*, 2010).

Usually, the contents of nutritional components were used to evaluate the quality of medicine and food. The quality of camel milk could be affected by variety, lactation stage, nutritional level, feeding management, and sampling techniques (Swelum *et al.*, 2020). Therefore, the contents of nutritional components in camel milk from different areas varied, and now the quality of camel milk from different areas in Xinjiang province has been poorly reported and compared.

In the present study, the contents of fat, protein, lactose, and vitamin C in camel milk from different feeding areas were determined and compared, as well as the content of lysozyme protein. Principal Component Analysis (PCA) score and Comprehensive Weighted Multi-index (CWM) score were used to grade samples at a comprehensive level based on the chemical components. By doing this, people can easily understand the quality condition of camel milk from different production areas in Xinjiang province of China.

Materials and Methods

Materials and Chemical reagents

Seven batches of fresh camel milk were collected from seven different regions of Xinjiang, details were showed as **Table 1**, including Midong District and Dabancheng District of Urumqi city, Changji city and Fukang city of Changji region, Yiwu county of Hami region, Fuhai county and Jeminay county of Altay region. One batch of cow milk was collected from Haozi Ranch in Urumqi city. These batches of raw milk were collected from the peak lactation period of camel in July and August of 2021, and then kept in a 4℃ car-refrigerator on their return journey.

Pure lysozyme was purchased from Sigma-Aldrich Co., LLC., and freeze-dried powder of *Micrococcus Lysodeikticus* was gained from China Food and Drug Control Research Institute (Beijing, China), while disodium hydrogen phosphate, sodium dihydrogen phosphate, 2,6-Dichlorophenol Indophenol, and oxalic acid with analytical grade both were obtained from Tianjin Fuyu Fine Chemical Co., Ltd. (Tianjin, China).

Determination of Nutritional Components

Milk was poured into a clean capped centrifuge tube with a volume of 50 mL, and put into a 40℃ water bath for 20 minutes. After that, the centrifuge was shaken well up and down, and filter the milk with fine gauze to make the milk well-mixed. And then, the contents of fat, protein, lactose, total solid, and nonfat solid of the milk were determined using a milk composition analyzer (Lacto Scope FTIR), which has been fully preheated and zeroed.

Determination of Vitamin C

The content of vitamin C was determined using the method of 2,6-Dichlorophenol Indophenol reported by Dabrowski & Hinterleitner (1989).

Determination of Lysozyme

The content of lysozyme was determined using the method described by Wang *et al.* (2021). Briefly, *Micrococcus lysodeikticus* was dissolved in 0.2 mol/L phosphate buffer (pH=6.2) to make the substrate solution with 1 mg/mL *Micrococcus lysodeikticus*. Lysozyme was added into 0.2 mol/L phosphate buffer (pH=6.2) to prepare a strong solution of lysozyme, which can be diluted into different concentrations of 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, and 10.0 μg/mL. After that, 10 μL lysozyme diluent with each concentration was added into wells in a 96-well plate carefully together with 50 μL substrate solution. The 96-well plate was incubated at 40℃ for 30 minutes before being detected at 540 nm in a full wavelength microplate reader (MULTISKAN Sky). A standard curve was formed with concentration as the horizontal axis and absorbance as the vertical axis. The content of lysozyme in milk was determined in the same method and calculated according to the standard curve, and data were expressed as mg.

Comprehensive Evaluation of milk by PCA Score and CWM Score

PCA score and CWM score were used to grade samples at a comprehensive level based on the chemical components. PCA was conducted according to the method described by Zhang (2005), and CWM was calculated as **Table S3** in the Supplementary material.

Statistical Analysis

All data were carried out by three replicates (n=3) and expressed as mean ±

standard deviation (SD). The SPSS version 17.0 statistical software package was used for all statistical analyses. The significant differences were detected by one-way ANOVA followed by Tukey's test. Statistically significant was considered at $p<0.05$ level.

Results

Contents of Nutritional Components in Camel Milk and Cow Milk

Contents of five nutritional components are shown in **Table 2**, and ranges of the contents of fat, protein, lactose, total solid, and solid nonfat in camel milk are 4.62%-7.02%, 3.34%-3.95%, 3.85%-4.79%, 13.78%-17.00%, and 8.55%-9.73%, respectively. When compared with cow milk, camel milk always contain high levels of fat, protein, lactose, total solid, and solid nonfat.

Contents of Vitamin C in Camel Milk and Cow Milk

Contents of vitamin C in camel milk and cow milk are shown in **Table 2**, and ranges of vitamin C in camel milk is 12.10-41.25 μg/mL, while content of vitamin C in cow milk is 6.60 μg/mL.

Contents of Lysozyme in Camel Milk and Cow Milk

There was a negative linear correlation between lysozyme contents and absorbance of liquids, and the equation is $y= -0.0460X + 0.8267$ with a regression coefficient of $r^2=0.998$. As shown in **Fig.1**, the contents of lysozyme in different camel milk samples were calculated according the equation, and ranged from 8.7 μg/mL to 22.8 μg/mL, while content of lysozyme in cow milk is 10.2 μg/mL.

Comprehensive Quality Evaluation of Camel Milk and Cow Milk

In this part, two methods were involved to grade samples at a comprehensive level based on their chemical components. PCA scores were calculated according to the method described by Zhang (2005), while CWM scores were computed with subjectively assigned coefficients. All calculations were added as supplementary material, and higher score means better quality.

In the PCA method, based on the reduction of variables seven variances were simplified to two variables, as shown in **Table S1 &S2**, and they explained 79.084% of the total variance. The first principal component explained 51.143% of the total variance, and contained protein, lactose, total solid, vitamin C, and lysozyme, while the second principal component explained 27.941% of the total variance, and contained fat and solid nonfat. All samples were scored, and higher score means higher quality in a comprehensive level. According to **Fig. 2(A)**, the highest four samples are camel milk from Jeminay, Fukang, and Changji, while camel milk from Midong, Hami, and Dabancheng, and cow milk get negative scores. As showed **Fig. 2(B)**, CWM scores varied, and the highest four samples are camel milk from Jeminay, Fukang, Fuhai, and Changji in turn, while camel milk from Dabancheng and Midong get lower scores, and cow milk gets the lowest score.

Discussion

Contents of fat, protein, lactose, total solid, and solid nonfat in camel milk determined in this study are similar to the previous report about camel milk in Xinjiang province of China by Yi *et al.* (2018). According to the report, camel milk from Inner Mongolia contains 3.88% fat, 4.73% protein, 5.96% lactose, 14.82% total solid, and 10.89% solid nonfat during 90 days postpartum (Xiao *et al.*, 2022), and it contains less fat and more fat, protein, lactose, and solid nonfat than camel milk from Xinjiang. It is clear that the quality of camel milk from different areas varied significantly, and these differences can be ascribed to the differences of variety, age, calving quantity, nutrition, management, lactation stage, and living environment of the mother camel (Ereifej *et al.*, 2011).

When compared with cow milk, camel milk always contain more fat, protein, lactose, total solid, and solid nonfat than cow milk, and this result also is consistent with the former study (Yi *et al.*, 2018), and supports that camel milk contains more nutritional ingredients (Liu *et al.*, 2023). Specifically, the fat content in camel milk is 2 folds that in cow milk, and the protein content in camel milk is 1.29 times that in cow milk. These conditions are close to the results of Faye *et al.* (2008) and Zhu *et al.* (2008), respectively. Furthermore, supplementing protein and energy during the peak lactation of camel can help to increase milk yield, as well as the contents of protein and fat in camel milk (Dereje and Peter, 2005). In the present study, camel milk contains 4.48% lactose, while the content of lactose is 4.37% in camel milk from Morocco (Ismaili *et al.*, 2017). This discrimination may be mainly attributed to the different cultivated varieties, because the Dromedary camel is raised in Morocco.

Camel milk contains more unsaturated fatty acid than cow milk, and proportions of oleic acid, linoleic acid, α- linolenic acid and eicosapentaenoic acid in camel milk are higher than that in cow milk, which also make camel milk to be more healthy for people than cow milk (Paul *et al.*, 2021). Fat in camel milk plays an important role in human medicine and nutrition, and more than 92 and 107 different triglycerides have been identified from milk of *Camelus dromedarius* and *Camelus bactrianus*, respectively. Milk fat of *Camelus bactrianus* contains higher proportion of saturated fatty acids than milk fat of *Camelus dromedarius*, as well as higher melting and crystallization degrees of milk fats (Bakry *et al.*, 2020).

Protein is another main active component in camel milk, and proteins in camel milk are mainly divided into casein, whey protein, and milk fat globular membrane (MFGM) protein. Especially, camel milk has more whey protein and less casein than cow milk (Baig *et al.*, 2022), and camel milk contains a large amount of functional whey protein, such as lactoferrin, peptidoglycan recognition protein 1, osteopontin and lactoperoxidase in summer (Zou *et al.*, 2022a). In the past ten years, many camel milk-derived peptides from fermented camel milk and camel milk protein hydrolysate have been reported to be responsible for the antioxidant, anti-diabetic, anti-hypertensive, antibacterial, and anticancerous activities (Redha *et al.*, 2022). Furthermore, many bioactive peptides with free radical scavenging activity (Ibrahim *et al.*, 2018) and inhibit activity on starch digestion (Rami *et al.*, 2023) have been identified come from whey protein and casein.

Lactose is the main carbohydrate in milk, and some children and adults would develop lactose intolerance as a result of the high content of lactose in cow milk, which could cause diarrhea and abdominal distension. People have a good tolerance to camel milk, and this phenomenon always is ascribed to the low content of lactose in camel milk (Cardoso *et al.*, 2010; Faraz *et al.*, 2020). In general, lactose content in cow milk is about 4.8%, and camel milk contains a little bite less lactose than cow milk (Ismaili *et al.*, 2017). Hence, it is possible that some components in camel milk would be beneficial to the good tolerance to camel milk by regulating gut microbiota and protecting the intestine (He *et al.*, 2022; Wang *et al.*, 2018)

By now, camel milk has been considered a promising alternative protein base for human infant formula powder production due to the lack of β-lactoglobulin, high β-/α_s-casein ratio, and protective proteins (Zou *et al.*, 2022b), as well as the good tolerance to camel milk.

Higher content of vitamin C in camel milk can provide enough vitamin C to baby camel and camel milk consumer, especially to people living in deserts and lack vegetables and fruits. Camel milk contains more vitamin C than cow milk, and the content in camel milk is 3.82 times of that in cow milk, which is similar to the result of

Xu *et al*. (2014). According to the study of Jirimutu *et al*. (2005), colostrum always contain less vitamin C than mature milk for mother camel, and content of vitamin C in mature milk of Alxa Bactrian camel is 29.60 μg/mL, which is lower than that in mature milk of Xinjiang Bactrian camel.

However, the contents of lysozyme in camel milk and cow milk have been reported as 0.15 μg/mL and 0.07 μg/mL (Elagamy *et al.*, 1996), separately, which are lower than our results. This variation may be attributed to many factors, such as analytical methods, geographical area, nutrition conditions, breed, lactation stage, age, and number of calvings. Also, camel milk contains more lysozyme than cow milk, and this result is in agreement with the reports (Felfoul *et al.*, 2017; Khalesi *et al.*, 2017).

Lysozyme is one kind of the key protective proteins in milk, and it can kill gram-negative and gram-positive organisms, aerobic, and anaerobic bacteria by lysing the cell wall of bacteria (Barbour *et al.*, 1984). Previous studies showed that lysozyme can inhibit bacteria in the gut together with other functional proteins (Beermann and Hartung, 2017). Therefore, camel milk is a natural antibacterial food, and lysozyme is an important component and the main antibacterial component of camel milk. However, the activity of lysozyme can be affected by temperature, and low-temperature long-time pasteurization of milk does not reduce the activity of lysozyme (Martini *et al.*, 2019), while the activity decreases significantly when the temperature reached 80℃ (Felfoul *et al.*, 2017). Particularly, fermented cow milk can be produced without boiling due to its rich lysozyme, and camel milk can be further studied as a source of lysozyme additive.

When evaluated by the PCA score and CWM score, we can know that camel milk from different areas of Xinjiang province varied greatly, and camel milk from Jeminay has the highest quality with the most nutritional compositions and lysozyme. Cow milk gets the lowest scores when evaluated with methods of PCA and CWM, which mean that cow milk is lower than camel milk from seven different areas of Xinjiang province. All these results also support that camel milk is more nutritious than cow milk. Moreover, Jeminay is the key camel breeding area in Xinjiang province of China, and camel milk from Jeminay possesses the highest quality. Results in the present study also illustrate that camel milk is better than cow milk. However, camel milk is becoming an increasingly interesting product in the world, not only for its good nutritive property, but also for its interesting and medical health protection products.

Xinjiang province is the main camel feeding area in China with a large square, and camel milk from different areas have different qualities. By now, there are few reports about the quality of camel milk from different areas of Xinjiang province. In the present study, the contents of nutritional compositions and lysozyme were determined, and two comprehensive quality evaluation methods were used to distinguish these samples. As a result, camel milk from Jeminay shows the best quality, and then followed by camel milk from Fukang, Changji, and Fuhai. Our findings would show the quality distribution of camel milk in different areas of Xinjiang province, and provide an insight for the evaluation of camel milk.

Camel milk samples in this study were mainly collected from local families of nomads produced by mother camels with different ages, the number of lactations during their lifetime, and the number of calving, and they can better represent camel milk quality of regions referred in this study in some extent. Furthermore, camels living in deserts can eat plants freely, and different deserts have different plant species, climate environments, and water. Therefore, the different qualities of seven batches of camel milk can be mainly ascribed to their eating habits and living conditions.

However, only contents of fat, protein, lactose, total solid, solid nonfat, vitamin C, and lysozyme were used for evaluating the quality of camel milk in this study, and more indexes involved for the evaluation of camel milk, such as determinations of cfu, mineral, other vitamins, and many other active components, would make this kind of work more meaningful. Now, more and more evaluation methods have been used to quality of food, and they also can be available for the evaluation of camel milk, while PCA and CWM methods were referred in the present study.

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Tables and Figures

Table 1 Details of seven batches of Camel Milk

Group	Purchasing Agency	Milking mode	latitude and longitude
Dabancheng	Milk mixture of 9 camels of a local family of nomads	Hand milking	E87.84, N44.07
Midong	Milk mixture of 35 camels of a local family of nomads	Hand milking	E87.80, N43.42
Fuhai	Milk mixture of 21 camels of a local family of nomads	Hand milking	E87.46, N46.84
Jeminay	Milk mixture of 54 camels of a local family of nomads in Wantuo Garden	Machine milking	E86.22, N47.68
Changji	Milk mixture of 6 camels of a local family of nomads	Hand milking	E86.75, N44.29
Fukang	Milk mixture of 103 camels of Fukang Adelibek Camel Breeding Professional Cooperative	Machine milking	E87.92, N44.19
Hami	Milk mixture of 52 camels of a local family of nomads	Machine milking	E94.30, N43.36

Table 2 Contents of Nutritional Components in Camel Milk and Cow Milk

Groups		Fat (%)	Protein (%)	Lactose (%)	Total Solid (%)	Solid Nonfat (%)	Vitamin C (μg/mL)
Camel milk	Dabancheng	6.93±0.01^{c}	3.37±0.01^{b}	3.85±0.01^{a}	17.00±0.01^{c}	8.55±0.01^{a}	28.60±1.10^{c}
	Midong	5.77±0.74^{bc}	3.34±0.42^{b}	4.39±0.26^{bc}	13.78±1.36^{a}	8.64±0.85^{a}	16.50±2.20^{d}
	Fuhai	6.32±0.95^{c}	3.37±0.15^{b}	4.72±0.26^{cd}	14.69±0.76^{ab}	9.06±0.30^{ab}	12.10±1.10^{d}
	Jeminay	7.02±0.11^{c}	3.89±0.04^{bc}	4.63±0.02^{cd}	15.72±0.10^{bc}	9.62±0.05^{b}	30.25±2.20^{c}
	Changji	4.62±0.07^{b}	3.58±0.06^{bc}	4.79±0.01^{d}	13.59±0.13^{a}	9.41±0.07^{ab}	41.25±2.20^{a}
	Fukang	5.83±0.06^{bc}	3.95±0.04^{c}	4.66±0.01^{cd}	14.34±0.09^{ab}	9.73±0.04^{b}	35.75±4.40^{b}
	Hami	6.65±0.68^{c}	3.40±0.38^{b}	4.30±0.05^{b}	14.65±1.04^{ab}	8.61±0.42^{a}	12.10±1.10^{d}
Mean of camel milk		6.16	3.56	4.48	14.88	9.09	25.22
Cow milk		3.03±0.09^{a}	2.76±0.03^{a}	4.21±0.05^{b}	10.31±0.11^{d}	9.41±0.06^{ab}	6.60±0.11^{e}

Note: Different letters indicate that there are significant differences between the data at $P < 0.05$ level.

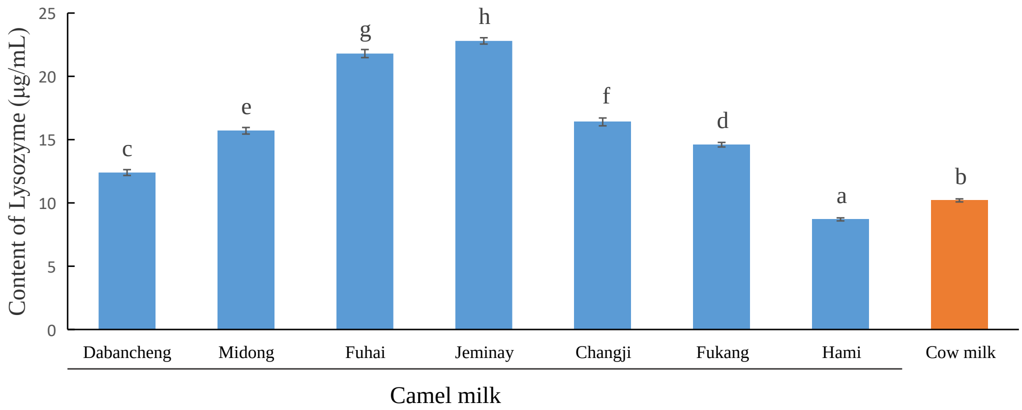

Fig. 1 Contents of lysozyme in camel milk from seven different regions by colorimetric method

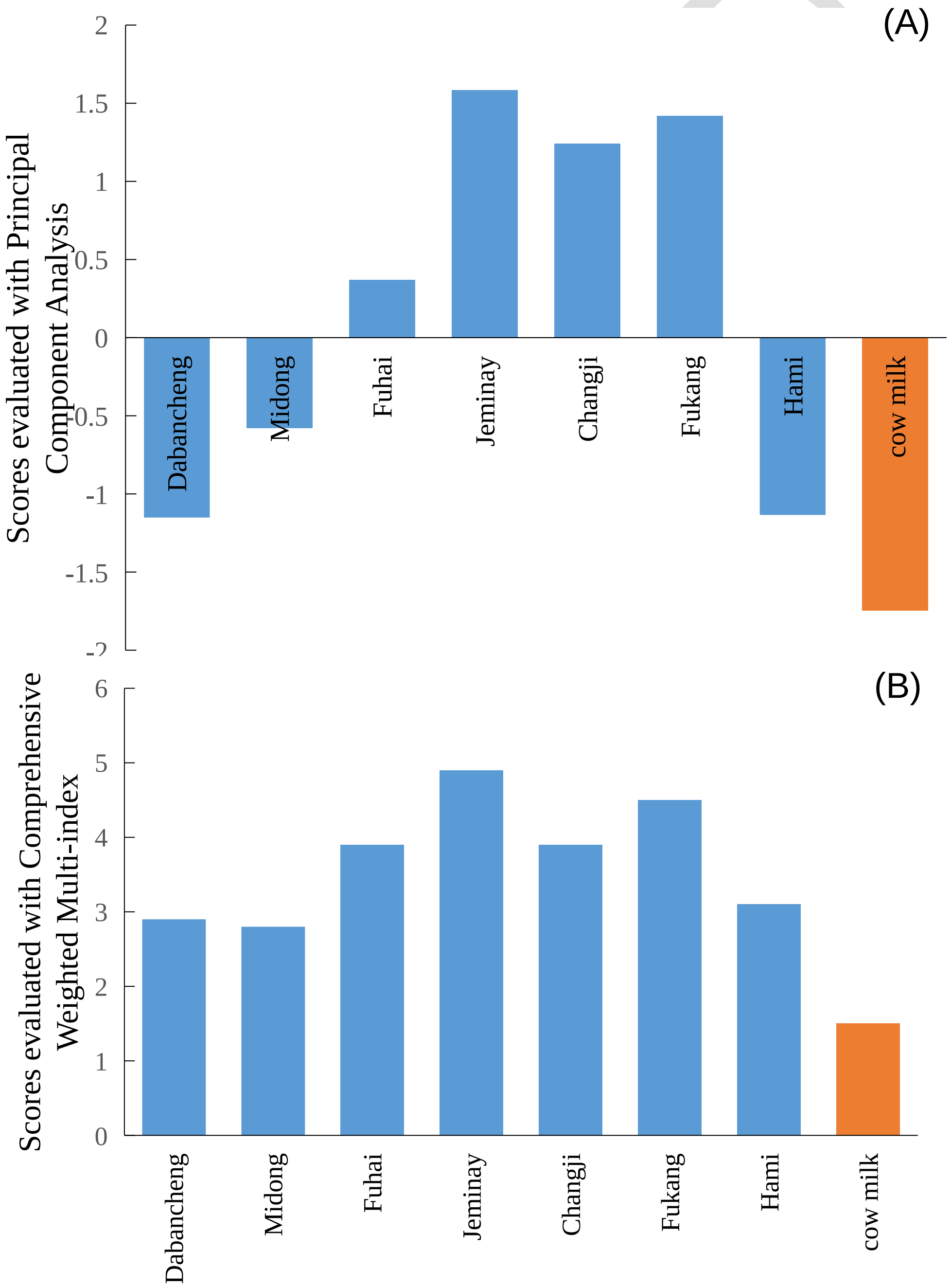

Fig.2 Scores of seven batches of camel milk evaluated with methods of Principal Component Analysis and Comprehensive Weighted Multi-index. (A) for Scores evaluated with Principal Component Analysis (PCA), (B) for Scores evaluated with Comprehensive Weighted Multi-index (CMW).

Supplementary material

Data of PCA score

Table S1 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	% of Variance	Cumulative %	Total
1	3.58	51.143	51.143	3.58	51.143	51.143
2	1.956	27.941	79.084	1.956	27.941	79.084
3	0.823	11.764	90.848			
4	0.361	5.16	96.008			
5	0.264	3.768	99.776			
6	0.014	0.195	99.971			
7	0.002	0.029	100			

Extraction Method: Principal Component Analysis.

Table S2 Component Matrix(a)

	1	2
Fat	0.584	-0.747
Protein	0.946	-0.043
Lactose	0.664	0.558
Total Solid	0.800	-0.536
Solid Nonfat	0.380	0.871
Vitamin C	0.734	0.149
Lysozyme	0.762	0.124

Extraction Method: Principal Component Analysis.
2 components extracted.

Data of CWM score

Table S3 CWM score of camel milk and cow milk

Proportion	Fat	Protein	Lactose	Total Solid	Solid Nonfat	Vitamin C	Lysozyme	Score
	0.2	0.2	0.2	0.1	0.1	0.1	0.1	
Dabancheng	5	3	1	5	1	4	2	3.0
Midong	4	3	3	3	1	2	3	2.9
Fuhai	5	3	5	4	3	1	5	3.9
Jeminay	5	5	5	5	5	4	5	4.9
Changji	3	4	5	3	4	5	3	3.9
Fukang	5	5	5	4	5	5	3	4.7
Hami	5	3	3	4	1	1	1	2.9
cow milk	1	1	2	1	4	1	1	1.5