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ORIGINAL ARTICLE

Amino acids content and electrophoretic profile of camel milk casein from different camel breeds in Saudi Arabia

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Abstract This study aimed to evaluate amino acids content and the electrophoretic profile of camel milk casein from different camel breeds. Milk from three different camel breeds (Majaheim, Wadah and Safrah) as well as cow milk were used in this study.

Results showed that ash and moisture contents were significantly higher in camel milk casein of all breeds compared to that of cow milk. On the other hand, casein protein of cow milk was significantly higher compared to that of all camel milk breeds. Molecular weights of casein patterns of camel milk breeds were higher compared to that of cow milk.

Essential (Phe, Lys and His) and non-essential amino acids content was significantly higher in cow milk casein compared to the casein of all camel milk breeds. However, there was no significant difference for the other essential amino acids between cow casein and the casein of Safrah breed and their quantities in cow and Safrah casein were significantly higher compared to the other two breeds. Non-essential amino acids except Arg and the essential amino acids (Met, Ile, Lue and Phe) were also significantly higher in cow milk α-casein compared to α-casein from all camel breeds. Moreover, essential amino acids (Val, Phe and His) and the non-essential amino acids (Gly and Ser) content was significantly higher in cow milk β-casein compared to the β-casein of all camel milk

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breeds and the opposite was true for Lys, Thr, Met and Ile. However, Met, Ile, Phe and His were significantly higher for β-casein of Majaheim compared to the other two milk breeds. The non-essential amino acids (Gly, Tyr, Ala and Asp) and the essential amino acids (Thr, Val and Ile) were significantly higher in cow milk κ-casein compared to that for all camel milk breeds. There was no significant difference among all camel milk breeds in their κ-casein content of most essential amino acids.

Relative migration of casein bands of camel milk casein was not identical. The relative migration of α_s-, β- and κ-casein of camel casein was slower than those of cow casein. The molecular weights of α_s-, β- and κ-casein of camel caseins were 27.6, 23.8 and 22.4 KDa, respectively. More studies are needed to elucidate the structure of camel milk.

1. Introduction

Camels in Saudi Arabia play a major role in supplying the desert dwellers with milk of good nutritional quality under extremely hostile conditions of temperature, drought and lack of pasture (Yagil and Etzion, 1980). Camel milk contains all the essential nutrients found in bovine milk (El-Agamy et al., 1998; Karue, 1998) and consumed in Saudi Arabia as fresh and soured milk (Abu-Taraboush et al., 1998). Camels in Saudi Arabia can be classified into different ecotypes as Majaheim, Wadah, Safrahh, Malha, Hamra and Omani among others (Bhattacharya, 1988; Elamin and Wilcox, 1992; Saoud et al., 1988). The average camel milk yields of Majaheim, Wadah and Safrah were 3896, 2336 and 2236 kg per lactation, respectively (Saoud et al., 1988).

Casein makes up about 80% of cow milk proteins (Hipp et al., 1952), while the casein content of camel milk is 52–87% as reported by Al haj and Al-kanhal (2010). The principal casein fractions for cow are αs_1-, αs_2-, β- and κ-casein in ratio 4:1:4:1 (Walstra et al., 1984) and the numbers of amino acid residues in these four casein fractions were 199, 207, 209, 169, respectively as compared to 207, 178, 217 and 162, respectively for camel casein as reported by Kappeler et al. (1998).

Dromedary milk and bovine milk had similar amino acid composition, however, Gly and Cys were significantly lower in dromedary milk casein compared to that in bovine milk (Farah and Rüegg, 1989). Sawaya et al. (1984) reported also that camel milk was rich in sulfur amino acids. Camel milk casein contained most of the essential amino acids in high ratios. Glu was the most abundant amino acid followed by Leuc, Lys and Asp (Abu-Tarboush and Ahmed, 2005). The amino acids of casein fractions were found to be similar between camel milk casein and cow milk casein Larsson-Raznikiewicz and Mohamed (1986). Breeds of camel could have affected in the amino acid composition of casein, therefore the aims of this study were to determine the amino acids content and the electrophoretic profile of camel breeds (Majaheim, Wadah and Safrah) milk casein and compare it with cow milk casein.

2. Materials and methods

2.1. Milk samples

Milk samples were taken from each female dromedary Majaheim, Wadah and Safrah camels in the afternoon milking. Samples were collected from Prince Abdulaziz bin Fahd Farm, Riyadh in the central region of Saudi Arabia. The feeding regime was approximately the same for all camels in the farm. The samples collected were immediately refrigerated and transferred to the laboratory. For comparison, bulk cow milk of Friesian breed, obtained from Al-Azizia Farm, Al-Kharj governorate, was used.

2.2. Acid casein preparation

Acid casein was prepared from raw skim milk of Majaheim, Wadah and Safrah camels and cow according to the modified method of Shammet et al. (1992). Briefly Skim milk was acidified to pH 4.6 with 1 M HCl. Casein precipitate was washed three times with water, then redissolved in NaOH 1 M at pH 7.0, reprecipitated at pH 4.6, and the precipitated casein washed further for two times with water. The caseins were freeze dried.

2.3. Proximate analysis

Samples of casein fractions were analyzed for ash, moisture and protein according to the procedures outlined in AOAC (1995).

2.4. Separation of casein fractions

Casein fractions α-, β- and κ-caseins were separated by the methods of Hipp et al. (1952), Aschaffenburg (1963), and Girdhar and Hansen (1978).

2.5. Amino acid analysis

Acid hydrolysis (6 N HCl) for the freeze-dried casein samples was performed according to AOAC (1995) method, then amino acid analysis was performed on reverse phase high pressure chromatography (Shimadzu LC-10 AD, Shimadzu Corporation, Kyoto, Japan). Samples were analyzed on Shimpack amino-Na type column (10 cm × 6.0 mm) obtained from Shimadzu Corporation. The amino acids of samples were derivatized with *O*-phthadialdehyde (OPA) detected by Fluorescent detector and data were integrated using an integrator model C-R7A (Shimadzu chromatopac data processor).

2.6. Polyacrylamide gel electrophoresis (SDS–PAGE)

Samples of caseins were separated using a polyacrylamide gel according to the procedures of Pharmacia instruction No. 80-1310 (1993) using a Pharmacia unit (Pharmacia, fine

Table 1 Proximate analysis of camel casein from different camel breeds.

Component (%)	Majaheim	Wadah	Safrah	Cow
Ash	3.30 ± 0.05[b,*]	4.1 ± 0.01[a]	2.95 ± 0.01[c]	2.47 ± 0.10[d]
Moisture	8.89 ± .021[b]	6.7 ± 0.05[c]	9.33 ± 0.17[a]	5.90 ± 0.08[c]
Protein	66.26 ± 0.51[c]	64.07 ± 0.65[d]	67.54 ± 0.09[b]	86.95 ± 0.66[a]

[*] Means ± S.D. (n = 3). Means with different letters in each row are significantly different ($P < 0.05$).

chemicals AB, Uppsala, Sweden) and using a polyacrylamide gel using following characteristics. Separation gel: 12.5% acrylamide; 0.3% bisacrylamide; 0.1% SDS; 0.37 M Tris–HCl buffer, pH 8.8; 0.1% N,N,N',N'-tetramethylenediamine (temed) and 0.03% ammonium persulfate. Stacking gel: 4.5% acrylamide; 0.12% bisacrylamide; 0.1% SDS; 0.1% N,N,N',N'-tetramethylenediamine (temed); 0.125 M Tris–HCl buffer, pH 6.8; and 0.09% ammonium persulfate. Running buffer: 0.196 M glycine, 0.125 M Tris and 0.1% SDS (wt/vol), pH 8.3. After the electrophoresis run (18 mA/1.5 mm thickness gel at 10 °C for approximately 6 h, then the gel was marked with Coomassie brilliant blue R-250 (0.2% in 45: 45:10 water: methanol:acetic acid). The standard proteins (broad range, Sigma) were bovine albumin (66-kDa), egg albumin (45-kDa), glyceraldehyde phosphate dehydrogenase (36-kDa), carbonic anhydrase (29-kDa), trypsinogen (24-kDa), trypsin inhibitor (20-kDa) and α-lactalbumin (14.2-kDa).

2.7. Statistical analysis

The statistical analyses of the data were performed with a SAS program (SAS, 1997). Three replicates were performed in a completely randomized design. Results were expressed as the mean ± standard deviation. To ascertain the significance among means of samples, Duncan's multiple range test was used (Steel and Torrie, 1980).

3. Results and discussion

3.1. Proximate analysis

Data in Table 1 show significant ($p \leqslant 0.05$) difference in ash content of the casein of cow and camel milk. Casein ash content in camel milk was higher than that in cow milk. Breeds of camel had also affected in casein ash content of camel milk and there were significant ($p \leqslant 0.05$) differences among breeds in ash content. Wadah breed casein had the highest ash (4.1%) content, whereas Safrah casein had the lowest ash (2.95%) content. Abu-Tarboush and Ahmed (2005) reported higher casein ash content in camel milk compared to this study. This difference could be due to the pooled camel milk which was used in their study. Other previous studies also indicated differences in ash content of camel milk due to breeds, feeding and analytical methods (Mehaia et al., 1995) as well as amount of water consumed by camel (Haddadin et al., 2008). Difference in the amount of minerals in camel milk due to breeds was also mentioned in other studies (Elamin and Wilcox, 1992; Mehaia et al., 1995; Sawaya et al., 1984).

Results in Table 1 also show significant ($p \leqslant 0.05$) difference in the casein moisture content among camel breeds. Casein moisture content of the Safrah breed was the highest (9.33%), whereas Wadah breed had the lowest casein moisture (6.07%) content. Generally, casein moisture content was higher in camel milk compared to cow milk. Abu-Tarboush and

Table 2 Amino acid profile of casein for camel (Majaheim, Wadah and Safrah) and cow milk (g amino acid/100 g protein).

Amino acids	Majaheim	Wadah	Safrah	Cow
Essential				
Lysine	7.50[b] ± 0.35[*]	7.27[b] ± 0.23	7.74[b] ± 0.30	9.78[a] ± 0.19
Threonine	4.05[a] ± 0.05	3.91[a] ± 0.11	3.89[a] ± 0.22	4.00[a] ± 0.04
Valine	5.63[b] ± 0.15	5.60[b] ± 0.10	6.02[a] ± 0.11	6.17[a] ± 0.17
Methionine	2.51[ab] ± 0.06	2.41[b] ± 0.15	2.54[ab] ± 0.05	2.66[a] ± 0.04
Isoleucine	4.43[b] ± 0.16	4.48[b] ± 0.10	4.77[a] ± 0.005	4.64[ab] ± 0.18
Leucine	7.58[b] ± 0.18	7.64[b] ± 0.14	8.11[a] ± 0.03	8.24[a] ± 0.20
Phenylalanine	3.76[c] ± 0.18	3.89[c] ± 0.01	4.24[b] ± 0.04	4.62[a] ± 0.30
Histidine	2.53[b] ± 0.11	2.50[b] ± 0.02	2.61[b] ± 0.04	2.97[a] ± 0.07
Non-essential				
Aspartic acid	5.62[bc] ± 0.01	5.4[c] ± 0.01	5.92[b] ± 0.19	7.3[a] ± 0.25
Glutamic acid	18.75[c] ± 0.28	18.61[c] ± 0.1	19.41[b] ± 0.33	21.38[a] ± 0.09
Glycine	0.98[c] ± 0.02	0.91[d] ± 0.02	1.08[b] ± 0.01	1.76[a] ± 0.01
Serine	4.65[c] ± 0.03	4.52[c] ± 0.01	4.86[b] ± 0.08	5.81[a] ± 0.11
Tyrosine	4.16[c] ± 0.21	3.91[c] ± 0.19	4.5[b] ± 0.01	4.97[a] ± 0.25
Arginine	3.48[bc] ± 0.06	3.39[c] ± 0.07	3.81[a] ± 0.01	3.53[b] ± 0.04
Alanine	1.90[c] ± 0.04	1.84[d] ± 0.04	2.03[b] ± 0.01	2.85[a] ± 0.01

[*] Each value is the mean ± SD. Means with different letters in each row are significantly different ($P < 0.05$).

Table 3 Amino acid profile of α-casein for camel (Majaheim, Wadah and Safrah) and cow milk (g amino acid/100 g protein).

Amino acids	Majaheim	Wadah	Safrah	Cow
Essential				
Lysine	$7.43^{c} \pm 0.23$*	$9.83^{a} \pm 0.36$	$8.44^{b} \pm 0.08$	$8.57^{b} \pm 0.19$
Threonine	$3.54^{c} \pm 0.02$	$3.95^{a} \pm 0.04$	$3.75^{b} \pm 0.18$	$2.42^{d} \pm 0.08$
Valine	$4.02^{b} \pm 0.14$	$4.29^{a} \pm 0.06$	$4.28^{a} \pm 0.03$	$4.29^{a} \pm 0.11$
Methionine	$1.48^{b} \pm 0.03$	$1.53^{b} \pm 0.05$	$1.53^{b} \pm 0.05$	$2.2^{a} \pm 0.03$
Isoleucine	$3.81^{c} \pm 0.08$	$4.02^{b} \pm 0.05$	$4.1^{b} \pm 0.01$	$4.29^{a} \pm 0.05$
Leucine	$5.24^{d} \pm 0.08$	$5.49^{c} \pm 0.02$	$5.65^{b} \pm 0.03$	$6.84^{a} \pm 0.10$
Phenylalanine	$3.79^{c} \pm 0.15$	$4.18^{b} \pm 0.09$	$4.03^{b} \pm 0.05$	$4.75^{a} \pm 0.03$
Histidine	$2.58^{c} \pm 0.05$	$2.71^{b} \pm 0.02$	$2.77^{a} \pm 0.01$	$2.69^{b} \pm 0.01$
Non-essential				
Aspartic acid	$6.66^{b} \pm 0.17$	$7.13^{a} \pm 0.14$	$7.08^{a} \pm 0.18$	$7.15^{a} \pm 0.33$
Glutamic acid	$16.12^{c} \pm 0.\ 39$	$16.99^{b} \pm 0.1$	$16.97^{b} \pm 0.36$	$18.47^{a} \pm 0.53$
Glycine	$1.29^{c} \pm 0.02$	$1.37^{b} \pm 0.03$	$1.42^{b} \pm 0.01$	$2.10^{a} \pm 0.05$
Serine	$4.22^{b} \pm 0.12$	$4.36^{b} \pm 0.08$	$4.36^{b} \pm 0.01$	$4.85^{a} \pm 0.06$
Tyrosine	$5.44^{c} \pm 0.05$	$5.52^{c} \pm 0.01$	$5.77^{b} \pm 0.05$	$5.99^{a} \pm 0.09$
Arginine	$4.27^{b} \pm 0.04$	$4.2^{b} \pm 0.37$	$4.65^{a} \pm 0.05$	$3.61^{c} \pm 0.03$
Alanine	$1.74^{c} \pm 0.02$	$1.87^{b} \pm 0.01$	$1.88^{b} \pm 0.02$	$2.71^{a} \pm 0.06$

* Each value is the mean ± SD. Means with different letters in each row are significantly different ($P < 0.05$).

Ahmed (2005) indicated that casein moisture content of pooled camel milk was 8.25% which was close to that of Majaheim breed in this study.

The high percentage of ash and moisture in camel milk casein accompanied by low protein content was significantly ($p \leqslant 0.05$) lower for all camel breeds compared to cow milk (86.95%). Moreover, there was significant ($p \leqslant 0.05$) difference in casein protein among the camel breeds and Safrah breed had the highest casein protein (67.54%), whereas Wadah breed had the lowest (64.07%) as shown in Table 1. Mehaia et al. (1995) indicated that the milk of Majaheim camel breed had higher protein compared to Wadah breed which agreed with the finding of this study. Moreover, data of this study agreed with the finding of Sawaya et al. (1984) which indicated difference in protein content of milk among some camel breeds.

3.2. Amino acids

Casein content of amino acids for camel and cow milk is shown in Table 2. Non-essential amino acids in cow milk casein were significantly ($p \leqslant 0.05$) higher compared to camel casein for all breeds except for Arg which was significantly ($p \leqslant 0.05$) higher in Safrah breed casein compared to the other two breeds as well as cow milk casein. However, no significant difference was found in Arg amount between the casein of cow milk and that of Majaheim breed casein.

Essential amino acids (Lys, Phe and His) were significantly ($p \leqslant 0.05$) higher in cow milk casein compared to their amounts in the casein of all camel breeds. However, there was no significant difference in the amount of Thr in the casein between cow and camel breeds. Generally, there were no sig-

Table 4 Amino acid profile of β-casein for camel (Majaheim, Wadah and Safrah) and cow milk (g amino acid/100 g protein).

Amino acids	Majaheim	Wadah	Safrah	Cow
Essential				
Lysine	$8.08^{a} \pm 0.02$*	$8.17^{a} \pm 0.13$	$8.16^{a} \pm 0.63$	$7.29^{b} \pm 0.32$
Threonine	$4.30^{b} \pm 0.04$	$3.93^{c} \pm 0.01$	$4.42^{a} \pm 0.05$	$3.67^{d} \pm 0.04$
Valine	$6.88^{b} \pm 0.01$	$6.78^{b} \pm 0.14$	$6.9^{b} \pm 0.11$	$7.82^{a} \pm 0.04$
Methionine	$3.75^{a} \pm 0.05$	$3.22^{b} \pm 0.02$	$3.09^{c} \pm 0.07$	$2.88^{d} \pm 0.05$
Isoleucine	$5.55^{a} \pm 0.12$	$5.03^{b} \pm 0.13$	$5.19^{b} \pm 0.03$	$4.12^{c} \pm 0.01$
Leucine	$10.32^{a} \pm 0.17$	$9.74^{b} \pm 0.21$	$9.9^{b} \pm 0.08$	$9.96^{b} \pm 0.12$
Phenylalanine	$5.32^{b} \pm 0.11$	$4.76^{c} \pm 0.09$	$4.65^{c} \pm 0.25$	$5.85^{a} \pm 0.13$
Histidine	$2.75^{b} \pm 0.04$	$2.42^{d} \pm 0.03$	$2.56^{c} \pm 0.02$	$3.53^{a} \pm 0.09$
Non-essential				
Aspartic acid	$4.84^{a} \pm 0.01$	$4.01^{c} \pm 0.06$	$4.55^{b} \pm 0.13$	$4.69^{ab} \pm 0.09$
Glutamic acid	$20.15^{c} \pm 0.17$	$20.54^{b} \pm 0.01$	$20.89^{a} \pm 0.21$	$20.27^{bc} \pm 0.13$
Glycine	$0.99^{b} \pm 0.01$	$0.56^{d} \pm 0.05$	$0.70^{c} \pm 0.03$	$1.42^{a} \pm 0.01$
Serine	$4.59^{b} \pm 0.11$	$4.71^{b} \pm 0.05$	$4.67^{b} \pm 0.20$	$5.36^{a} \pm 0.06$
Tyrosine	$4.77^{a} \pm 0.10$	$3.13^{c} \pm 0.07$	$3.42^{b} \pm 0.03$	$2.92^{d} \pm 0.01$
Arginine	$3.25^{a} \pm 0.07$	$2.46^{c} \pm 0.04$	$2.6^{b} \pm 0.05$	$2.66^{b} \pm 0.07$
Alanine	$2.10^{a} \pm 0.02$	$1.85^{c} \pm 0.02$	$2.0^{b} \pm 0.02$	$1.85^{c} \pm 0.00$

* Each value is the mean ± SD. Means with different letters in each row are significantly different ($P < 0.05$).

Table 5 Amino acid profile of κ-casein for camel (Majaheim, Wadah and Safrah) and cow milk (g amino acid/100 g protein).

Amino acids	Majaheim	Wadah	Safrah	Cow
Essential				
Lysine	$7.79^{ab} \pm 0.25^{*}$	$9.2^{a} \pm 1.44$	$7.46^{b} \pm 0.48$	$7.55^{b} \pm 0.30$
Threonine	$3.23^{b} \pm 0.20$	$2.88^{b} \pm 0.34$	$3.16^{b} \pm 0.07$	$4.64^{a} \pm 0.07$
Valine	$5.31^{b} \pm 0.15$	$5.27^{b} \pm 0.39$	$5.31^{b} \pm 0.16$	$5.83^{a} \pm 0.11$
Methionine	$2.43^{a} \pm 0.13$	$2.45^{a} \pm 0.09$	$2.3^{a} \pm 0.02$	$1.98^{b} \pm 0.05$
Isoleucine	$4.77^{b} \pm 0.14$	$4.67^{b} \pm 0.09$	$4.61^{b} \pm 0.01$	$5.09^{a} \pm 0.02$
Leucine	$8.33^{a} \pm 0.14$	$8.24^{a} \pm 0.48$	$7.88^{a} \pm 0.19$	$6.81^{b} \pm 0.05$
Phenylalanine	$5.37^{a} \pm 0.20$	$4.67^{b} \pm 0.41$	$5.20^{a} \pm 0.20$	$4.95^{ab} \pm 0.07$
Histidine	$3.13^{a} \pm 0.01$	$2.87^{a} \pm 0.26$	$3.05^{a} \pm 0.07$	$2.90^{a} \pm 0.03$
Non-essential				
Aspartic acid	$5.92^{b} \pm 0.09$	$5.29^{c} \pm 0.25$	$5.96^{b} \pm 0.07$	$6.34^{a} \pm 0.22$
Glutamic acid	$18.64^{a} \pm 0.25$	$18.45^{a} \pm 0.39$	$18.45^{a} \pm 0.01$	$18.01^{a} \pm 0.44$
Glycine	$1.22^{bc} \pm 0.05$	$1.14^{c} \pm 0.06$	$1.29^{b} \pm 0.01$	$1.40^{a} \pm 0.03$
Serine	$4.80^{b} \pm 0.01$	$4.9^{b} \pm 0.14$	$5.0^{ab} \pm 0.42$	$5.41^{a} \pm 0.17$
Tyrosine	$4.94^{b} \pm 0.01$	$4.44^{c} \pm 0.18$	$4.73^{b} \pm 0.08$	$5.16^{a} \pm 0.11$
Arginine	$3.84^{a} \pm 0.08$	$3.75^{a} \pm 0.07$	$3.85^{a} \pm 0.09$	$3.43^{b} \pm 0.08$
Alanine	$2.23^{b} \pm 0.23$	$2.06^{b} \pm 0.10$	$2.14^{b} \pm 0.05$	$3.70^{a} \pm 0.05$

* Each value is the mean ± SD. Means with different letters in each row are significantly different ($P < 0.05$).

nificant differences for the other essential amino acids between the casein of cow and that of the Safrah breed, however, their amounts were significantly ($p \leqslant 0.05$) higher in cow and Safrah breed caseins compared to that in the casein of the other two camel breeds (Table 2).

All amino acids in camel breed caseins were generally low in this study in the comparison with other studies (El-Agamy et al., 1998; Mehaia and Al-Kanhal, 1989; Renner, 1991; Sawaya et al., 1984; Zhao, 1994) and this could be due to breeds, feeding and environmental conditions.

Table 3 shows the amino acids content of α-casein for cow and camel breeds. The amounts of non-essential amino acids were significantly ($p \leqslant 0.05$) higher in cow milk α-casein compared to their amounts in all camel breeds α-casein except for Arg which was significantly ($p \leqslant 0.05$) higher in the α-casein of all camel breeds compared to cow α-casein. On the other hand, there was no significant difference in the amount of Asp between the α-casein of cow milk and that of camel breeds except for Majaheim breed α-casein.

Essential amino acids (Met, Ile, Leu and Phe) in the α-casein of cow milk were significantly ($p \leqslant 0.05$) higher compared to their amounts in the α-casein of all camel breeds. On the contrary, the amount of Thr was significantly ($p \leqslant 0.05$) higher in the α-casein of all camel breeds compared to that in the cow milk. Lys was significantly ($p \leqslant 0.05$) higher in the α-casein of Wadah breed, whereas His was significantly ($p \leqslant 0.05$) higher in the α-casein of Safrah breed compared to cow milk α-casein. However, no significant difference was found in the amount of Val in the α-casein between cow and camel breeds except for Majaheim breed. Table 3 shows also differences among camel breeds concerning the amounts of some essential and non-essential amino acids in the α-casein fraction.

The amount of amino acids in the α-casein fraction in this study was low when compared to the data reported by Larsson-Raznikiewicz and Mohamed (1986) except for Lys, His, Phe and Tyr and this could be due to the method of α-casein separation, feeding and environmental conditions. Moreover, Larsson-Raznikiewicz and Mohamed (1986) study was on α_{s1}-casein fraction rather than α-casein fraction.

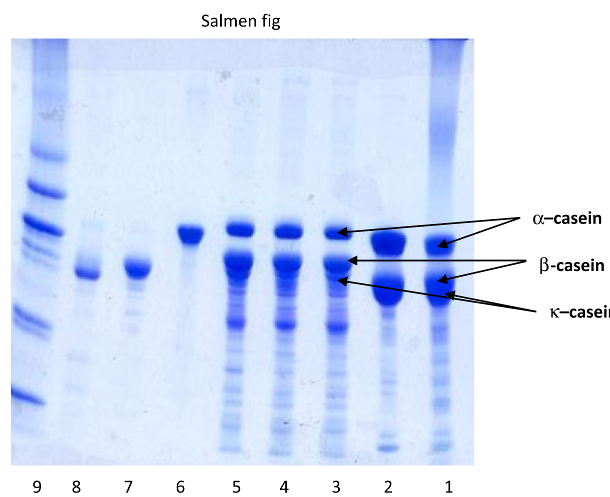

Figure 1 SDS–PAGE profiles of caseins of camel breeds and cow milk. 1: standard cow casein; 2: cow casein; 3: Majaheim casein; 4: Wadah casein; 5: Safrah casein; 6: α-casein; 7: β-casein; 8: κ-casein; 9: protein marker (66–14.2 KDa).

Essential amino acids (Val, Phe and His) were significantly ($p \leqslant 0.05$) higher in the β-casein of cow milk compared to their amounts in the β-casein of camel milk breeds (Table 4). On the contrary, Lys, Thr, Met and Ile were significantly ($p \leqslant 0.05$) higher in the β-casein of camel breeds compared to their amounts in the β-casein of cow milk. However, Leu was significantly ($p \leqslant 0.05$) higher in β-casein of Majaheim breed compared to that in the other two breeds as well as cow milk. Moreover, Met, Ile, Leu, Phe and His were significantly ($p \leqslant 0.05$) higher in the β-casein of the Majaheim breed compared to their amounts in the other two breeds, whereas Thr was significantly ($p \leqslant 0.05$) higher in the β-casein of Safrah breed compared to that in the other two breeds (Table 4).

In the case of non-essential amino acids, Table 4 shows that Gly and Ser were significantly ($p \leqslant 0.05$) higher in the β-casein of cow milk compared to that in camel breeds, whereas the

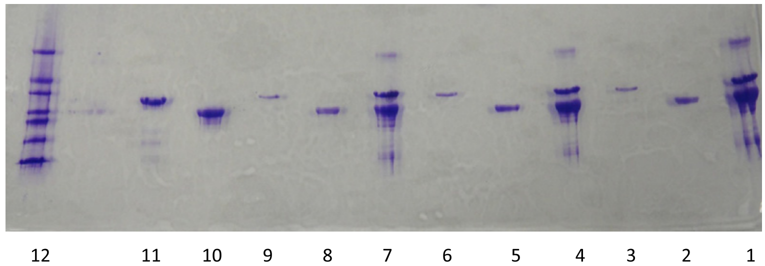

Figure 2 SDS–PAGE profiles of caseins of camel breeds milk and their fractions. 1: Majaheim casein; 2: β-casein of Majaheim; 3: α-casein of Majaheim; 4: Wadah casein; 5: β-casein of Wadah; 6: α-casein of Wadah; 7: Safrah casein; 8: β-casein of Safrah; 9: α-casein of Safrah; 10: β-casein (standard); 11: α-casein (standard); 12: protein marker (66–14.2 KDa).

opposite was true for Tyr. The amount of Arg was significantly ($p \leqslant 0.05$) higher in the β-casein of Majaheim breed compared to that in the other two camel breeds as well as cow β-casein. However, the amount of Asp was significantly ($p \leqslant 0.05$) higher in the β-casein of cow milk compared to its counterpart in Wadah breed. β-casein of Majaheim breed had higher amounts of Gly, Tyr, Arg, Ala and Asp compared to that in the other two breeds, whereas Glu was higher in Safrah breed compared to the other two breeds (Table 4).

This study shows that some amino acids (Lys, Phe, His, Tyro, Arg, Glu and Asp) content in β-casein of camel milk was higher, whereas other amino acids were lower compared to their amounts of data reported by Larsson-Raznikiewicz and Mohamed (1986).

The amount of amino acids in the κ-casein of cow and camel breed milk is shown in Table 5. The non-essential amino acids (Gly, Tyr, Ala and Asp) were significantly ($p \leqslant 0.05$) higher in the κ-casein of cow milk compared to that in camel milk breeds, whereas the amount of Arg was significantly ($p \leqslant 0.05$) higher in the κ-casein of camel milk breeds compared to that in cow milk. On the other hand, Ser was significantly ($p \leqslant 0.05$) higher in the κ-casein of cow milk compared to that in camel milk breeds except for Safrah breed which was not significantly different from the other two breeds.

Essential amino acids (Thr, Val, Ile) were significantly ($p \leqslant 0.05$) higher in the κ-casein of cow milk compared to that in camel breed milk, whereas Met and Leu flowed an opposite trend. The amount of Lys was significantly ($p \leqslant 0.05$) higher in the κ-casein of Wadah breed compared to that in Safrah breed as well as in the κ-casein of cow milk. On the other hand, there was no significant difference in the amounts of His and Phe between the κ-casein of cow milk and that of camel breeds. There was no significant difference among camel breeds in the amount of essential amino acids in the κ-casein except for Lys which was significantly ($p \leqslant 0.05$) higher in the κ-casein of Wadah breed compared to Safrah breed. Moreover, Phe was significantly ($p \leqslant 0.05$) higher in the κ-casein of Majaheim and Safrah breeds compared to Wadah breed. The amounts of Asp and Tyr were significantly ($p \leqslant 0.05$) higher in the κ-casein of Majaheim and Safrah breeds compared to Wadah breed, whereas Gly was significantly ($p \leqslant 0.05$) higher in the κ-casein of Safrah breed compared to Wadah breed (Table 5).

However, the amounts of amino acids (Lys, Met, Phe, Glu, Tyr and Arg) in this study were higher, whereas the other amino acids were lower compared to the results reported by Larsson-Raznikiewicz and Mohamed (1986) and as indicated previously it could be due to breeds, feeding and environmental conditions.

3.3. Polyacrylamide gel electrophoresis (SDS–PAGE)

Fig. 1 shows the electrophoretic patterns of whole acid caseins of camel breeds (Majaheim, Wadah and Safrah) and cow milk. Results showed that the relative migration of casein bands were not identical. In camel caseins, the relative migration of α_s-, β- and κ-casein was slower than those of cow casein. The same trend was observed by Metwalli and Al-Saleh (2010) and El-Agamy et al. (2009). This indicates the differences in molecular weight of camel and cow caseins. The molecular weights of α_s-, β- and κ-casein of camel caseins were estimated to be 27.6, 23.8 and 22.4 KDa, respectively in comparison with 25.3, 22 and 20.5 for cow casein in the same order. These results are in good agreements with those obtained by El-Agamy et al. (2009) and Kappeler (1998), who reported 28 and 22.9 KDa for α_{s}- and κ-casein, respectively in comparison with 27.6 and 22.4 in these studies. However, the molecular weight of camel β-casein was lower than that reported by El-Agamy et al. (2009) who found 26 KDa molecular weight for β-casein of camel milk. Fig. 2 illustrates the α_s- and β-caseins prepared from Mjaheem, Wadah and Safrah camel milk breeds, respectively in comparison with cow milk casein.

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