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Physical and Chemical Characteristics of Camel Milkfat and its Fractions

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ABSTRACT

The physical and chemical characteristics of camel milkfat (obtained by using the Rose–Gottlieb method) contained more long chain, unsaturated, and odd-number fatty acids and less short chain fatty acids than cow milkfat. The content of the C16:1 fatty acid in the camel milkfat (10·40%) was significantly higher than that in cow milkfat (3·60%). The saponification value, acid value and specific gravity of camel milkfat were lower than those of cow milkfat. The iodine value, melting point, solidification point and refractive index of camel milkfat were higher than those of cow milkfat.

Camel ghee samples were fractionated at 18·5°C from hexane into hard and soft fractions. The hard and soft fractions exhibited melting points (49·3°C and 37·9°C respectively) which were respectively higher and lower than that of the original milkfat (40·9°C). The averages of short chain fatty acids, unsaturated fatty acids, iodine value, saponification value, refractive indices and specific gravity for the hard fractions were lower than those for the soft fractions. The averages of long chain saturated fatty acids (61·98%) and odd-number fatty acids (7·98%) for the hard fractions were higher than those for the soft fractions (40·63 and 4·69% respectively).

INTRODUCTION

The camel population in the world has been estimated to be about 14·5 million head (Yagil, 1982). Most of them are found in African and Asian countries. The dromedaries (one humped camel) are found particularly in desert (arid) areas, while bactrians (two humped camel) are more prevalent in

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the cooler areas. In general, camels serve four purposes: (1) for meat, (2) for milk, (3) for transportation and (4) for sport racing.

Camel milk was traditionally consumed fresh, as raw milk, but nowadays it is consumed as a pasteurized milk in some cities. Research on camel milk has been limited, primarily to that done in African and Asian countries. Unfortunately, the research to date is inadequate to evaluate the camel either as a milk producer or a meat animal or both.

Recently, studies on Saudi (Najdi breed) and Libyan camel milk were carried out by Sawaya *et al.* (1984) and Gnan and Sheriha (1986) respectively. They determined the chemical composition of the milk as well as the fatty acids of the corresponding milkfat. In addition, Orlov and Servetnik-Chalaya (1981) and Dhingra (1934) measured some physical and chemical characteristics of Russian and Indian camel milkfat respectively. The primary aim of this study was to investigate physical and chemical properties and the fatty acid profile of Majaheem camel milkfat (Najdi sub-breed) as compared to cow milkfat. Hopefully, these studies will lead to additional research in the future to improve its commercial value.

There is a great deal of interest in the fractionation of milkfat using either solvents (Murthis *et al.*, 1984) or thermal–mechanical processes (Fjaervoll, 1970). Hard fractions of milkfat are increasingly used in Europe, especially in The Netherlands, in confectionery and chocolate. The soft fractions of milkfat are almost exclusively used in the production of ice cream (Muuse & Van der Kamp, 1984).

The studies reported in this paper were undertaken to evaluate the effect of the fractionation process (used on camel milkfat) on the physical and chemical properties of the fat fractions obtained. A further objective was to explore the possibility of using camel milkfat in the manufacture of various dairy foods.

MATERIALS AND METHODS

Camel milkfat

Preparation of milkfat

Ten female camels (Majaheem breed) were selected on a random basis from Prince Mohamed Bin Saud El-Kabeer Farm as a source of milk for this study. All camels were between 3 and 5 months into their lactation period. The animals were milked by hand and the milk was cooled immediately by the use of an ice water bath and transferred in an ice box to the laboratory. The Holstein cow milk was obtained from a farm bulk milk tank from the same farm.

Cream was obtained from the cow milk after allowing it to remain quiescent under refrigeration for several hours until a cream was formed, after which the cream was skimmed into a clean receptacle. However, camel milk required a much longer time in the refrigerator (5–6 days) before a cream layer was skimmable. This skimming process was repeated to obtain more cream from the milk.

Milkfat was extracted according to the Rose–Gottlieb method (AOAC, 1980). Three successive extractions were made. The extraction solvents were evaporated at 60–70°C until the milkfat was obtained. The milkfat was then stored in a refrigerator until analysis. All chemical solvents used in the extraction were of analytical grade.

Fractions of camel ghee

Preparation of camel ghee

Camel butter was melted at a temperature of not more than 110°C and clarified utilizing glass wool.

Fractionation of camel ghee

Camel ghee was fractionated according to the procedure of Muuse and Van der Kamp (1984). The temperature used in the crystallization process was 18·5°C instead of 12·5°C.

Chemical and physical analysis

The saponification value (SV), Hanus iodine value (IV), acid value (AV) and specific gravity (SG) were determined according to the methods outlined by Jacobs (1951). Refractive index (n^{40}) was also determined using an Abbé refractometer (Mehlenbacher, 1960). Melting and solidification points were also measured according to the Mehlenbacher procedure, (1960) using a Thomas–Hoover capillary melting point apparatus.

Fatty acids of milkfats

Methyl esters of fatty acids were prepared according to the method of AOAC (1980) and Metcalfe *et al.* (1966).

A Varian model 6500 gas chromatograph with a Varian 401 data handling system (Varian Associates, Palo Alto, CA) was used in this study. The gas chromatograph was equipped with a flame ionization detector. A stainless steel column of 4 m was used, GP 10% DEGS, SP-2330 on 100/120 chromosorb WAW (Supleco Inc., Bellefonte, PA). The column was conditioned overnight at 220°C before use. Injections were made at 120–206°C with a temperature increase of 6°C/min, with a 40 min hold. The gas chromatograph was supplied with carrier gas at a rate of 40 ml N_2, 300 ml air and 25 ml purified H_2 per min.

The fatty acids peaks were identified by comparing their retention times with those of known fatty acid standards. Peak areas of fatty acids were integrated by computing integrator (Varian CDS 401). Fatty acid profile was quantitated as outlined by the AOAC (1980).

RESULTS AND DISCUSSION

Physical and chemical characteristics of camel milk fat

The data presented in Table 1 show the fatty acid composition of camel and cow milkfat. Differences between the fatty acids of camel and cow milkfat were significant. Short chain fatty acids (C4–C12) were present in very small amounts in camel milkfat (0·99 ± 0·6%) compared with the cow milkfat (12·14 ± 1·20%). Since the Reichert–Meissl value (RV) is substantially a measure of the shortest chain, volatile, water-soluble fatty acids (primarily butyric (C4:0) and caproic (C6:0) acid) and the Polenske value (PV) is substantially a measure of the volatile, water-insoluble fatty acids (primarily caprylic (C8:0) and capric (C10:0) acids (DeMan & Finoro, 1980; Laruelle *et al.*, 1976)), the RV and PV number of camel milkfat were expected to be very low compared with those of cow milkfat (Table 1). These results did not agree with those of Dhingra (1934) who reported that camel milkfat had an RV and PV of 16·4 and 1·6 respectively. It was reported that the milkfat of ruminant animals was of high RV and PV (Kurtz, 1974), but that camel milkfat was of low RV and PV.

It was found that the contents of long chain fatty acids, of even-number (C14–C22) and odd-number (C15–C23), for camel milkfat (49·43 ± 0·85% and 3·82 ± 1·04% respectively), as presented in Table 1, were similar to the 50·10% and 3·20% respectively reported by Sawaya *et al.* (1984), but that they were higher than those for cow milkfat (44·1 ± 1·2% and 2·44 ± 0·2%, respectively). This increase may be attributed to the activity of microflora in the digestive tract (Kurtz, 1974). However, Russian camel milkfat contained fewer long chain and more short chain fatty acids than Saudi camel milkfat (Table 1).

The content of unsaturated (C14–C18) fatty acids, as presented in Table 1 (43·13 ± 1·75%), was relatively similar to those of the Najdi camel milkfat (45·3%) as reported by Sawaya *et al.* (1985). However, the content of unsaturated fatty acids in the Russian camel milkfat (52·5 ± 3·8%) was higher than that in Saudi camel milkfat. The content of unsaturated fatty acids in Majaheem camel milkfat was clearly higher than that in cow milkfat

TABLE 1
Fatty Acid Composition of Camel and Cow Milkfat

Fatty acids	*Camel milkfat*			*Cow milkfat*[a]
	Majaheem camel[a]	*Najdi camel*[b]	*Russian camel*[c]	
Saturated fatty acids				
Even number of carbon atoms				
Short chain (C4–C12)	0·99 ± 0·06	1·6	2·0 ± 0·7	12·14 ± 1·20
C4	—	0·1	—	3·5 ± 0·10
C6	—	0·2	—	2·1 ± 0·10
C8	0·10 ± 0·01	0·2	0·3 ± 0·1	1·4 ± 0·05
C10	0·12 ± 0·02	0·2	0·4 ± 0·4	2·05 ± 0·24
C12	0·77 ± 0·20	0·9	1·3 ± 0·4	3·09 ± 0·03
Long chain (C14–C22)	49·43 ± 0·85	50·1	44·2	44·10 ± 1·20
C14	10·14 ± 1·62	11·4	11·2 ± 0·4	10·40 ± 0·16
C16	26·60 ± 1·12	26·7	22·5 ± 2·1	25·60 ± 1·36
C18	12·20 ± 0·86	11·1	10·5 ± 1·5	7·86 ± 1·20
C20	0·57 ± 0·08	0·6	—	0·11 ± 0·01
C22	0·08 ± 0·02	0·2	—	0·23 ± 0·01
Odd number of carbon atoms	3·82 ± 1·04	3·2	—	2·44 ± 0·20
C15	1·62 ± 0·10	1·7	—	1·62 ± 0·23
C17	1·21 ± 0·14	1·2	—	0·80 ± 0·05
C19	0·57 ± 0·80	—	—	0·01
C21	0·38 ± 0·01	—	—	0·17 ± 0·02
C23	0·04 ± 0·01	0·1	—	0·01
Unsaturated fatty acids	43·13 ± 1·75	45·3	52·5 ± 3·8	38·80 ± 1·40
C14:1	1·86 ± 0·27	1·6	4·3 ± 0·7	1·70 ± 0·40
C16:1	10·40 ± 0·35	11	14·0 ± 0·7	3·60 ± 0·40
C18:1	26·25 ± 1·65	25·5	28·6 ± 4·4	29·00 ± 0·90
C18:2	2·94 ± 0·24	3·6	3·5 ± 2·2	3·20 ± 0·70
C18:3	1·37 ± 0·39	3·5	2·1 ± 1·2	1·10 ± 0·20
C22:1	0·57 ± 0·84	—	—	—
Unidentified fatty acids	2·76 ± 0·80	0·8	1·2 ± 0·6	2·60 ± 0·20

[a] Average of 7 replicates (%).
[b] Adapted from Sawaya *et al.* (1984).
[c] Adapted from Orlov and Servetnik-Chalaya (1981).

(43·13 ± 1·75% versus 38·80 ± 1·4%). The unsaturated fatty acids of camel milkfat were also characterized by an increase in the C16:1 fatty acid (10·40 ± 0·35%) as compared with cow milkfat (3·6 ± 1·4%). In addition, camel milkfat contained more of the essential fatty acids (C18:2 and C18:3) than cow milkfat, as shown in Table 1. Oleic acid (C18:1) was found in an abundant quantity in both camel and cow milkfat reaching 26·25 ± 1·65% and 29·0 ± 0·90%, respectively, of the total fatty acids.

The melting and solidification point of camel milkfat (41·9 ± 0·9°C and 30·5 ± 2·2°C respectively) were significantly higher than those of cow milkfat (32·6 ± 1·5°C and 22·8 ± 1·6°C respectively). It was reported that the melting point of milkfat depends largely on the degree of saturation, as measured by IV, and on the isomeric form of the fatty acids, as well as on the number of carbon atoms in the fatty acids (Fjaervoll, 1970; DeMan & Finoro, 1980; Kurtz, 1974). Therefore, the increased melting point of camel milkfat might be attributed to a lower content of short chain fatty acids (C4–C12) and to a higher content of long chain fatty acids (C15–C23) as well as to the isomeric form of oleic acid (Fjaervoll, 1970). The content of unsaturated fatty acids in camel milkfat (43·13 ± 1·75%) was significantly higher than that in cow milkfat (38·80 ± 1·40%), unexpectedly, however, it did not cause the depression of the melting point below that of cow milkfat.

The IV of camel milkfat (43·8 ± 1·2), as presented in Table 2, was substantially higher than that of cow milkfat (32·3 ± 2·0). However, it was obvious that the IV of Saudi camel milkfat was significantly lower than that of Russian camel milkfat (55·0). This may be attributed to the higher content of unsaturated fatty acids in the Russian camel milkfat (Table 1).

The SV of camel milkfat was substantially lower than that of cow milkfat (201·8 ± 0·9 versus 228·5 ± 2·4) as shown in Table 2. However, the SV of Saudi camel milkfat was not significantly different from that of Russian camel milkfat (200·0). The lower SV of camel milkfat reflects the higher content of long chain fatty acids (C14–C18) with an average of 94·8% and less short chain fatty acids (C4–C12) with an average of 1·2% compared with those of cow milkfat, with an average of 85·80 and 12·14% respectively. These values agreed with those for Russian camel milkfat, as reported by Orlov and Servetnik-Chalaya (1981). Moreover, these trends agreed with the observations reported by Rangappa and Achaya (1974).

Table 2 shows that the refractive index of camel milkfat was higher than that of cow milkfat (1·4567 ± 0·0004 versus 1·4539 ± 0·0005). It was reported that the increased refractive index of milkfat is due to increased content of both unsaturated fatty acids and longer chain fatty acids (Rangappa & Achaya, 1974).

The specific gravity of camel milkfat was significantly lower than that of cow milkfat. The reduced specific gravity is due to increased content of

TABLE 2
Physical and Chemical Characteristics of Camel and Cow Milkfat

Character	*Camel milkfat*		*Cow milkfat*[a]
	Majaheem camel[a]	*Russian camel*[b]	
Saponification value	201·8 ± 0·9	200·0	228·5 ± 2·4
Iodine value	43·8 ± 1·2	55·0	32·3 ± 2·0
Acid value	0·40 ± 0·05	0·30	1·5 ± 0·15
Melting point (°C)	41·9 ± 0·9	41·40	31·5 ± 1·5
Solidification point (°C)	30·5 ± 2·2	32·9	22·8 ± 1·6
Refractive index (40°C)	1·4567 ± 0·0004	—	1·4539
Specific gravity (40°C)	0·9108 ± 0·0010	—	0·9135 ± 0·0030
Colour (μg carotene/1 g fat)	0·45 ± 0·15	—	9·20 ± 0·50

[a] Average of 7 replicates.
[b] Adapted from Orlov and Servetnik-Chalaya (1981).

longer chain fatty acids and not unsaturated fatty acids which increase the specific gravity (Table 2).

The AV of the Majaheem camel milkfat was not significantly different from that of Najdi camel milkfat but was substantially lower than that of cow milkfat (0·40 ± 0·05 versus 1·5 ± 0·15 meq KOH/g fat respectively).

From the above data, it was obvious that the camel milkfat might be used as an indirect source of edible fat for humans. However, further studies are still needed to develop new uses for camel milkfat.

Carotene content of camel milkfat was lower than that of cow milkfat (0·45 ± 0·15 versus 9·20 ± 0·50 μg carotene/g). This may explain the fact that the camel milkfat is whiter than cow milkfat.

It could be concluded that the content of fatty acids of Majaheem and Najdi camel milkfat did not differ significantly but there was a significant difference between Majaheem and Russian camel milkfat in the fatty acids content. However, the content of fatty acids and physical properties of Majaheem camel milkfat were significantly different from those of cow milkfat.

Physical and chemical characteristics of fatty acids of fat fractions

Table 3 shows the fatty acids of the hard and soft fractions and the original camel milkfat. These data reveal that the short chain fatty acids (C10–C12) were increased and reduced in the soft and hard fraction respectively (1·83% and 1·45% respectively) during the fractionation process of the milkfat. The

TABLE 3
Fatty Acid Composition of Camel Milkfat Fractions[a]

Fatty acids	*Hard fraction*	*Soft fraction*	*Original milkfat*
Saturated fatty acids	71·41 ± 1·40	47·42 ± 1·30	53·92 ± 0·93
Even number of carbon atoms	63·43 ± 1·15	42·46 ± 0·95	48·12 ± 0·65
Short chain (C10–C12)	1·45 ± 0·25	1·83 ± 0·20	1·76 ± 0·18
C10	0·30 ± 0·10	0·42 ± 0·15	0·35 ± 0·10
C12	1·15 ± 0·15	1·41 ± 0·06	1·41 ± 0·10
Long chain (C14–C22)	61·98 ± 0·90	40·63 ± 0·85	44·53 ± 0·45
C14	10·59 ± 0·15	10·09 ± 0·20	10·30 ± 0·10
C16	29·11 ± 0·31	19·55 ± 0·39	21·24 ± 0·13
C18	20·80 ± 0·06	9·91 ± 0·17	11·80 ± 0·24
C20	1·10 ± 0·03	0·85 ± 0·06	0·906 ± 0·01
C22	0·38 ± 0·10	0·23 ± 0·05	0·28 ± 0·02
Odd number of carbon atoms	7·98 ± 0·35	4·96 ± 0·35	5·80 ± 0·30
C15	2·53 ± 0·06	1·87 ± 0·05	1·93 ± 0·01
C17	1·85 ± 0·06	1·20 ± 0·04	1·29 ± 0·02
C19	1·32 ± 0·01	1·01 ± 0·01	1·01 ± 0·02
C21	1·50 ± 0·10	0·33 ± 0·20	0·88 ± 0·03
C23	0·78 ± 0·11	0·33 ± 0·08	0·63 ± 0·25
Unsaturated fatty acids	24·69 ± 0·45	48·05 ± 3·65	42·94 ± 1·80
C14:1	2·00 ± 0·06	3·70 ± 0·08	3·11 ± 0·05
C16:1	5·67 ± 0·08	11·22 ± 0·74	10·40 ± 0·35
C17:1	0·85 ± 0·01	1·10 ± 0·02	1·00 ± 0·01
C18:1	11·90 ± 0·23	25·68 ± 1·20	22·15 ± 0·95
C18:2	1·85 ± 0·01	3·26 ± 0·01	3·10 ± 0·13
C18:3	1·92 ± 0·03	2·93 ± 0·07	2·83 ± 0·24
C22:1	0·50 ± 0·03	0·16 ± 0·01	0·37 ± 0·01

[a] Average of 5 replicates (%).

contents of long chain even-number (C14–C22) fatty acids of the hard and soft fractions and the original milkfat were 61·98, 40·13 and 44·53% respectively, indicating that these fatty acids increased in the hard fraction and were reduced in the soft fraction. It was found that the C14, C16 and C18 fatty acids were predominant in these fractions. However, the contents of C16 and C18 saturated fatty acids in the hard fraction were significantly higher than those in the soft fraction (29·11 ± 0·31 and 20·80 ± 0·06% versus 19·35 ± 0·39 and 9·91 ± 0·17% respectively). Moreover, the contents of C14, C20 and C22 fatty acids in the hard fraction were also higher than those in the soft fraction (Table 3).

It was observed that the odd-number (C15–C23) saturated fatty acids followed the same trend as the even-number (C14–C22) fatty acids during the fractionation of milk fat. The content of odd-number fatty acids in the hard fraction (7·98 ± 0·35%) was significantly higher than that in the soft fraction (4·96 ± 0·35%).

These findings reveal that the long chain fatty acids were easier to crystallize in the hard fraction than were the short chain fatty acids (Table 3). These trends were similar to those reported by Norris *et al.* (1971) in the studies on cow milkfat.

The percentage of unsaturated fatty acids in the original fat was 42·94 ± 1·80%. The predominant fatty acids were C16:1 and C18:1 acids, which formed 10·44 ± 0·35 and 22·15 ± 0·95% respectively. During fractionation of the fat, the content of unsaturated fatty acids decreased and reached 24·69 ± 0·45% in the hard fraction as a result of the decrease in C16:1 and C18:1 fatty acids in particular (5·67 ± 0·08 and 11·90 ± 0·23% respectively). Moreover, other unsaturated fatty acids found in small amounts in milkfat (C14:1, C17:1, C18:2, C18:3 and C22:1) were also decreased in the hard fraction (Table 3).

Table 4 shows the physical and chemical properties of the original fat and of its fractions. The iodine value of the hard fraction, averaging 19·4 ± 2.5, was substantially lower than that of the soft fraction, 45·1 ± 0·3, and of the original fat, 43·4 ± 0·10. These values were found to be correlated ($r = 0{\cdot}988$) with the percentage of unsaturated fatty acids which was 24·69 ± 0·45, 48·05 ± 3·65 and 42·94 ± 1·80% in hard, soft and original fat respectively. These results agree with those reported by Norris *et al.* (1971) and Rangappa and Achaya (1974).

TABLE 4
Physical and Chemical Characteristics of Camel Milkfat Fractions[a]

	Hard fraction	*Soft fraction*	*Original milkfat*
Percentage of portion	6·5 ± 1·7	93·5 ± 1·7	100
Saponification value	201·5 ± 1·8	205·2 ± 1·1	203·5 ± 0·8
Iodine value	19·4 ± 2·5	45·1 ± 0·3	43·4 ± 1·0
Acid value	0·20 ± 0·02	0·47 ± 0·03	0·34 ± 0·03
Melting point (°C)	49·3 ± 2·3	37·9 ± 2·0	40·9 ± 0·9
Solidification point (°C)	38·9 ± 3·4	25·6 ± 2·3	30·6 ± 3·1
Refractive index (40°C)	1·454 4 ± 0·001 1	1·456 8 ± 0·000 6	1·456 6 ± 0·000 4
Specific gravity (40°C)	0·904 2 ± 0·000 8	0·911 4 ± 0·001 1	0·910 3 ± 0·000 8
Colour (μg carotene/1 g fat)	0·20 ± 0·04	0·52 ± 0·08	0·45 ± 0·15

[a] Average of 5 replicates.

The melting and solidification points of camel milkfat (41·9 ± 0·9 and 30·5 ± 2·2°C respectively) were higher than those of cow milkfat (32·6 ± 1·5 and 22·8 ± 1·6°C respectively, unpublished data). The melting points of the hard, soft and original fat were 49·3 ± 2·3, 37·9 ± 2·0 and 40·9 ± 0·9°C respectively, whereas the solidification points were 38·9 ± 3·4, 25·6 ± 2·3 and 30·6 ± 3·1°C respectively. These trends in the melting points of the fat fractions were opposite to those of the corresponding iodine values. Variations in the melting and solidification points might be attributed to the percentage of the unsaturated fatty acids, as expressed by iodine value, and to the content of long chain fatty acids.

The changes observed in the SV of the milkfat fractions were small. The average value for the soft fraction (205·2 ± 1·10) was slightly higher than that of the hard fraction and the original fat (201·5 ± 1·8 and 202·7 ± 0·8 respectively), indicating that the soft fraction contained more short chain fatty acids than either the original or the hard fat.

The average refractive index of the hard fraction, 1·4544 ± 0·0011, was significantly lower than that of the soft fraction, 1·4568 ± 0·0006, and that of the original fat, 1·4466 ± 0·0004. These trends were similar to those reported by Muuse and Van der Kamp (1984). Rangappa and Achaya (1974) attributed the decrease in the refractive index of the fat to a decrease in the unsaturated fatty acid contents, particularly those of the C18:1 and C18:2 acids. However, there was a negligible difference between the refractive index of cow milkfat and its fractions (Norris *et al.*, 1970; DeMan & Finoro, 1980). The changes observed in the refractive index of camel milkfat fractions were negatively correlated with changes in the melting points of these fractions.

The acid value of the hard fraction (0·20 ± 0·02) was substantially lower than that of the fraction of the soft and of the original fat (0·47 ± 0·03 and 0·34 ± 0·03 respectively) indicating that the fractionation process increased the acid value in the soft fraction.

It was obvious that the specific gravity of the hard fraction (0·9042 ± 0·0008) was significantly lower than that of the soft fraction and of the original fat (0·9114 ± 0·0011 and 0·9103 ± 0·0008 respectively). These data were similar to those reported by Muuse and Van der Kamp (1984) who reported that the specific gravity of oil was increased by increasing unsaturated fatty acid content (Rangappa & Achaya, 1974). This agrees with the findings presented in Table 4. However, deMan and Finoro (1980) reported that there was no significant difference between the specific gravity of the original milkfat and the solid or liquid fractions obtained from the fractionation of cow milkfat.

The carotene content of milkfat tended to concentrate in the soft fraction during the fractionation process (Table 4). This accords with the data reported by Norris *et al.* (1971).

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