Author Queries

AQ1 Table 30.1: Please confirm that permissions in footnote are correct. If not, please amend as necessary.

AQ2 'The milk yield of reindeer is significantly affected by week of lactation and individual performance,…' Amended sentence OK?

AQ3 Figure 30.5: '…(b) *trans*-monounsaturated fatty acid (MUFA) other than 11-*trans* 18:1 (gray) and 11-*trans* 18:1 (black)…' Is this part of the caption correct?

AQ4 'They also reported that the respective mean (±SD) values for hexose and sialic acid of the seven samples were 1.21 ± 1.13 and 0.32 ± 0.09.' Units for hexose and sialic acid values?

AQ5 Aikio et al 2002: please provide a web address where this report can be accessed.

AQ6 Holand et al 2002: updated ref. details correct? In different chapters in the book this reference appears as 2002 and 2003. Please confirm which should be used, or can this be updated to 2011 edn?

AQ7 Johansson 2007: web address for this article?

AQ8 Ling et al 1961: page numbers.

AQ9 Malinen et al 2002: web address for this article?

30
Milk From Other Minor Species (Reindeer, Caribou, Musk Ox, Llama, Alpaca, Moose, Elk and Others)

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30.1 INTRODUCTION

Generally, there is a paucity of scientific information on the milk of minor species such as reindeer, caribou, musk ox, llama, alpaca and others besides minor domesticated species such as sheep, goats, buffaloes, camel, yak, mithun, horse, and donkey. Since the milk of some of these mammals is produced for human consumption only in certain parts of the world and only limited studies on their milk have been conducted, the availability of research data has been scarce. However, their milk is important for the nutritional and economic well-being of people in certain regions of the world, where production of cow milk is limited or impossible for climatic reasons.

The composition of the milk of wild and domesticated minor species may vary widely due to lack of sample numbers, difficulties in defining the stage of lactation, bias introduced during sampling, and different analytical procedures (Oftedal, 1984; Park, 2011). Milk products from these species are small in numbers, but they are unique to the needs of people in special regions of the world, where they significantly contribute to the nutritional and economic well-being of these people. This chapter discusses the milk of reindeer, caribou, musk ox, llama, alpaca, moose, elk and other minor species in comparison to human milk.

On the other hand, a distinction is necessary: some domesticated minor species, such as goat, sheep, camel, buffalo, mithun, yak, horse, donkey, reindeer, and moose, are managed also for milk production, but except for a few goat and sheep breeds are not "dairy" species; furthermore, there are no wild dairy species, nor are the "other minor" species discussed in this book, such as sows, caribou, musk ox, elk, pinnipeds, polar bear, and elephant, managed for milk production except under experimental research conditions.

30.2 GENERAL ASPECTS OF MILK OF MINOR SPECIES

The specific chemical composition of milk of different domesticated or wild species is designed by natural selection to provide the nutritional needs of the neonate of the specific species (Park, 2006). There are considerable differences in the basic composition of milk among different domesticated and wild mammals (Table 30.1).

Differences in milk composition between minor species can be erroneous or misleading due to the unknown stage of lactation and time of sampling from the gland, resulting in confounding effects on the composition of the milk (Oftedal, 1984). Even under standard conditions of milk sampling, there are substantial short-term (diurnal and day-to-day)

Milk and Dairy Products in Human Nutrition: Production, Composition and Health, First Edition. Edited by Young W. Park and George F. W. Haenlein.

Table 30.1. Average composition (g/dL) of milk of minor mammalian species. AQ1

Mammals	Days of lactation	No. samples	Total solids	Protein	Lactose	Fat	Ash
Ass	60–120	9	9.1	1.6	6.2	1.0	0.4
Bison	?	2	13.7	4.2	4.7	1.7	1.0
Caribou	?	3	23.6	7.6	3.7	11.0	1.3
Dromedary	?	15	13.6	3.6	5.0	4.5	0.7
Elk	14–77	28	19.0	5.7	4.2	6.7	1.3
Llama	2–120	54	13.1	3.4	6.5	2.7	0.5
Moose	>2	15	23.6	11.0	3.3	8.5	1.5
Musk ox	—	1	19.0	5.3	3.8	8.2	1.7
Reindeer	4–5	8	27.1	11.1	3.0	11.1	1.5
Fur seal*	20–180	83	57.4	12.1	—	42.8	—

*Subantarctic fur seals; adapted from Georges *et al*. (2011).
Source: adapted from Park (2006).

variations in composition, due to environmental conditions, feeding, management, season, locality, disease, and yield per day, as is also the case for the major domestic milk producers the cow, buffalo, goat, sheep, camel, and yak (Schmidt, 1971; Park, 2006).

As in the case of cow and other major dairy species, the colostrum of all minor domesticated and wild mammalian species contains much higher levels of total solids, protein, and minerals than the mature milk obtained 2 or 3 weeks after parturition. The high protein content in colostrum is due to globulins, which contain antibodies. Since the antibody titer of blood of the newborn is low, mammals such as cow, sheep, goat, horse, and pig require passive immunity from colostrum and its immunoglobulins (Schmidt, 1971; Park, 2011).

The milk of most wild mammals contains much higher levels of major nutrients including protein, fat and minerals than the milk of major dairy species such as cow and goat. Dietary roughage is important to maintain the level of milk fat in ruminant milk. A decrease in roughage intake depresses the milk fat content, causes changes in rumen fermentation, and possibly even parakeratosis. Research has shown that at least 17% crude fiber is needed in ruminant diets to prevent a decrease in molar percentage of acetic acid and increase in propionic acid in the rumen, which causes a low fat content in milk (Schmidt, 1971).

30.3 PRODUCTION, COMPOSITION, AND UTILIZATION OF MILK FROM MINOR DAIRY SPECIES

30.3.1 Reindeer

At least 2000 years ago, reindeer husbandry and milking evolved in the taiga region of eastern Siberia around Lake Baikal and spread to nearby ethnic groups (Fondahl, 1989). Cultural exchange and expansion of pastoral nomads living on the northern fringe of the Asian steppe developed reindeer milking along the borders of Russia, Mongolia, and China (Fondahl, 1989). The famous horse and cattle breeders, the Yakuts, adapted reindeer raising as they migrated north and introduced an advanced milking culture into the region (Fondahl, 1989; Holand *et al*., 2006). In addition, in Scandinavia the Nordic Saami people of Lapland evolved reindeer milking independently. In the late 1800s, Saami reindeer herding families practiced small-scale reindeer pastoralism and the milk was manufactured into cheese and butter for their own consumption and for sale (Holand *et al*., 2006).

Reindeer/caribou (*Rangifer tarandus*) has a “follower” type mother–young relationship characterized by great seasonal mobility (Geist, 1999). Calving occurs at the end of the northern winter and the lactation period usually terminates during the rutting/breeding season in October (Holand *et al*., 2002). Reindeer (*Rangifer tarandus tarandus*) and caribou (*Rangifer tarandus granti*) are biologically closely related and have ancient associations in northern lands. Reindeer/caribou have evolved in a harsh environment with a short summer season, suggesting rapid and efficient transmission of energy and protein from the mother to the calf to optimize lifetime reproductive success (Jönsson, 1997).

Although it depends on latitude and environmental conditions, reindeer milking usually begins a month after calving during May, and continues up to the rut in late September and early October (Holand *et al*., 2006). Among advanced south-eastern Siberian reindeer herders, the calves and females are normally tethered during alternate periods to ensure that both remain close to the campsite, but are kept separated during part of the day. The females are milked up to three times daily and the period of separation of the calf from the mother varies with stage of lactation (Holand *et al*., 2006; Park, 2011).

30.3.1.1 Production of reindeer milk

The lactation curve of reindeer is similar to that of other ungulates (Holand *et al*., 2002). The milk yield of reindeer is significantly affected by week of lactation and individual
AQ2 performance, and the lactation curve has an asymmetrical peak 3 weeks after parturition. Milk yield at peak lactation was reported as 983 g/day (range 595–1239 g/day) (Fig. 30.1; Gjostein *et al*., 2004). The length of lactation varied from 24 to 26 weeks and average total milk production was 99.5 kg. From peak lactation, milk production decreased linearly until it terminated. The energy output averaged 7996 kJ/day at peak lactation, and significantly decreased to the end of lactation.

The potential milk production of reindeer and caribou has been studied using isotope tracer techniques, which are accurate but elaborate and expensive (Holand *et al*., 2006; Park, 2011). The estimated total milk yield of reindeer isw-lower than that of red deer (150 kg) and Iberian red deer (224 kg), but slightly higher than that of black tailed deer (93 kg) (Holand *et al*., 2006).

30.3.1.2 Nutritional composition of reindeer milk

Although it is difficult to present a typical composition of reindeer milk due to variations in sampling, feeding regime, and lactation stage among different studies, wild and semi-domestic ruminants generally produce richer milk, particularly in late lactation, than domesticated species (Park, 2006, 2011). Reindeer milk at peak and mid lactation has a relatively high fat (11–15%) and protein (7–10%) content, but a moderately low level of lactose (about 3.5%) (Holand *et al*., 2006; Table 30.2). Reindeer milk has a high milk solids content compared with other ungulates and undergoes great compositional changes during a relatively short lactation cycle (Luhtala *et al*., 1968; Robbins *et al*., 1987).

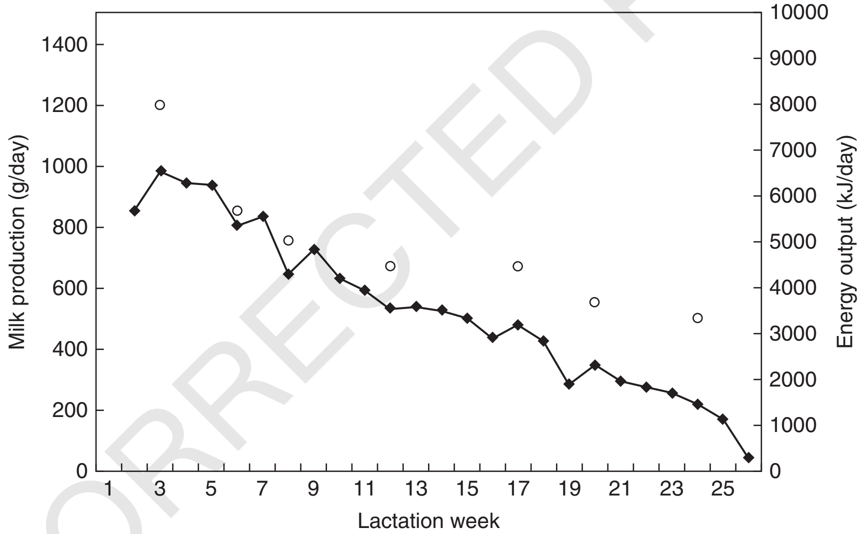


Figure 30.1. Mean milk production (solid symbols, g/day) and total energy output (open symbols, kJ/day) during lactation in reindeer (*Rangifer tarandus*). The milk production data are based on means of 2 years' study. Reproduced with permission from Gjostein *et al*. (2004).

Table 30.2. Gross composition (%) of reindeer milk from peak lactation for 3–5 weeks postpartum.

Week of lactation	No.	Total solids	Fat	Protein	Lactose	Ash
4–5	8	27.1	11.1	11.1	3.0	1.5
4	3	23.7	10.2	7.5	3.7	1.2
5	5	38.1	19.6	13.0	3.7	2.7
3–5	7	31.6	15.5	10.7	3.7	1.3
5	2	32.8	17.1	10.9	2.8	1.5

Source: Holand *et al*. (2006).

Mean content of fat, protein, and lactose of reindeer milk were reported as 15.5, 9.9, and 2.5%, respectively, by Gjostein *et al*. (2004). The fat and protein contents increased markedly with stage of lactation and there was a decrease in the protein/fat ratio as protein was substituted by fat with advancing stage of lactation. The caloric value of the milk averaged 8.7 kJ/g and increased significantly with stage of lactation.

Average protein content of reindeer milk is around 9% in early lactation and about 11% in late lactation, while the relative percentages of different amino acids are rather constant throughout lactation (Luhtala *et al*., 1968). The amino acid profile resembles that in sheep and goat milk, except for low cysteine and high tyrosine content. Casein is the predominant protein fraction in reindeer milk (7–9%). β-Lactoglobulin is the main whey protein, comprising162 amino acids (Rytkönen *et al*., 2002). Reindeer milk contains abundant non-protein nitrogen (NPN), urea (about 48 mg/dL), ammonium, carnitine (84–118 mg/dL) and free carnitine (about 71 mg/L) (Malinen *et al*., 2002).

The major energy source of reindeer milk is fat, which represents 67% of the energy content at peak lactation and 75% at late lactation (Gjostein *et al*., 2004). Fatty acids of reindeer milk are dominated by palmitic acid (16:0), which accounts for one-third of the total fatty acids, and stearic (18:0), oleic (18:1), and myristic (14:0) acids, which each contribute around 13%. The levels of short-chain fatty acids, especially butyric (4:0) and capric (6:0), are higher in reindeer than in red deer, roe deer, and fallow deer milk (Csapó *et al*., 1987). Reindeer milk contains about 3–3.5% lactose at peak lactation and this is lower than in other wild ungulates; it also contains small amounts of oligosaccharides.

Reindeer milk contains moderate to high levels (1–1.5%) of minerals compared with most other ungulates (Luhtala *et al*., 1968; Csapó *et al*., 1987). Reindeer milk is high in fat- and water-soluble vitamins. The vitamin C content is around 2 mg/dL, which is similar to that in the milk of red deer and fallow deer. Reindeer milk contains several times higher amounts of vitamin D_3 (0.5–2.0 mg/kg) than bovine milk (Luhtala *et al*., 1968; Csapó *et al*., 1987), and about twice as high levels of potassium (0.06–0.08 mg/kg) (Csapó *et al*., 1987).

30.3.1.3 Contribution of reindeer milk to human foods

Reindeer milk is produced and consumed in fluid and processed products. Children of reindeer herders drink fresh milk while adult people consume it in tea and coffee. The milk is also powdered and/or processed into cheese, butter, and sour cream, and is also used in medications (Table 30.3). The milk is curdled and often mixed with tasty herbs (*Oxyria* spp. and *Angelica* spp.). Reindeer milk is also stored frozen and often mixed with berries (*Vaccinium* spp., *Empetrum nigrum*) (Aikio *et al*., 2002).

Normally, reindeer milk from the first stage of lactation is consumed fresh, that from the second stage of lactation is used mainly for cheese production, while milk from the last stage of lactation is used more appropriately for churning butter. Reindeer milk and its products are highly priced, and are also used for medical purposes such as cures for digestive problems due to its antidiarrheic properties and for healing wounds. Fat oozed by heat from reindeer cheese is used to cure nursing pains, frostbite, and other injuries. Colostrum is used for children's ailments (Fondahl, 1989; Holand *et al*., 2006).

30.3.2 Caribou

As cervids, caribou (*Rangifer tarandus granti*) and reindeer (*Rangifer tarandus tarandus*) are biologically very similar and share ancient association in northern lands. Caribou

Table 30.3. Traditional products and uses of reindeer milk.

Fresh milk
Consumed by children often diluted with water, used in tea and coffee and in medical treatments
Stored milk
Frozen: stored for consumption during winter, ice cream mixed with berries
Fermented
Short: sour cream and cultured milk inoculated by a bacterial starter, for consumption
Long: stored in wooden containers often mixed with herbs, curdled, consumed during winter and spring migration, both the liquid and solid phase
Dried: tent dried in stomach compartment (reticulum) for a longer period, winter consumption
Manufactured milk
Cheese: curdled by heating or dried abomasums, dried and stored for consumption and sale
Butter: churned both from fresh and fermented milk, consumption and sale
Other products: buttermilk and whey, consumed fresh and reduced and eaten as soup

Source: reproduced with permission from Holand *et al*. (2006).

have provided the indigenous northern Americans with meat, skins for clothing and shelter of exceptional warmth and lightness, and implements made from bones and antlers (Irving, 1975), and were also exploited for the fur trade.

Several different groups of caribou exist in North America, where some herds have different migratory patterns (Jernsletten & Klokov, 2002). The Porcupine herds have major migration routes between Canada and Alaska at least twice annually. The Nelchina herd ranges over south central Alaska, which is a diversified area of ragged glacier-capped mountains, rolling uplands, and broad forested plains. The Kaminuriak population ranges over barren grounds of northern Manitoba, north-eastern Saskatchewan, south-eastern District of Keewatin, and the Northwest Territories of Canada (Hemming, 1975; Jernsletten & Klokov, 2002).

Nursing is usually terminated during the rutting/breeding period for well-conditioned caribous. The neonates of caribou and musk oxen are followers, accompanying their mothers most of the time, and nursing is characterized by frequent nursing bouts of short duration (Parker *et al*., 1990).

Caribou milk has significantly higher protein, dry matter, and energy content than that of musk oxen (Table 30.1 and Fig. 30.2). Parker *et al*. (1990) attributed these compositional differences to the time of weaning at the end of summer. The caribous wean their calves in early October, whereas musk oxen continue to nurse their young until the third week of January. Milk intake by caribou neonates gradually declines throughout the summer from a peak value during the first week of age at 1792 ± 51 mL/day (Parker *et al*., 1990), when milk composition typically increases in ungulates prior to weaning (Oftedal, 1984).

Chan-McLeod *et al*. (1994), in a study with captive caribou and reindeer, found that energy intake increased protein deposition in lactating animals while fat deposition increased in non-lactating females. They also showed that the levels of dry matter, fat, and energy in milk were not affected by maternal energy or protein intake, maternal body condition, or calf age. Lactose content of the milk was correlated with maternal energy intake. During the 12-week experimental period (May to August), body mass changed dramatically between individual lactating animals, ranging from a net loss of 6.4 kg to a net gain of 31.1 kg (Lavigueur & Barrette, 1992; Chan-McLeod *et al*., 1994). At the end of the 12-week study, all caribou gained body weight, while two lactating reindeer showed net losses of body mass and one non-lactating reindeer gained only 2.2 kg.

Using captive woodland caribou in another study, Lavigueur and Barrette (1992) observed that growth rates of woodland caribou from birth to 45 days were positively correlated with suckling rate during the first 35 days. They also noted that growth rates of the young caribou were positively correlated with time spent feeding on pelleted ration

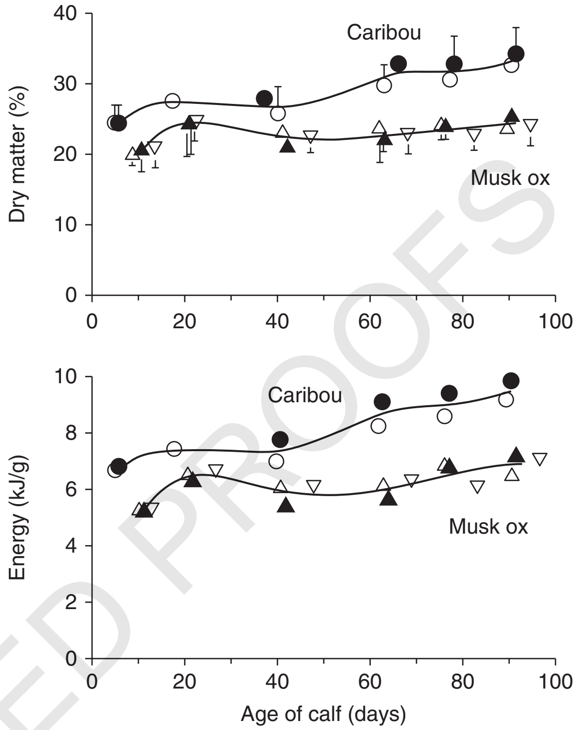


Figure 30.2. Dry matter and energy content of milk from caribou and musk ox during the 100 days following parturition. Adapted from Parker *et al*. (1990) and reproduced with permission from Park & Haenlein (2006).

and on hay from 46 to 100 days. On the other hand, caribou are not milked for human consumption and thereby make a minimal contribution to human nutrition and health in contrast to the reindeer of northern Scandinavia and Siberia.

30.3.3 Musk ox

Musk ox (*Ovibos moschatus*) historically ranged across northern Alaska, Canada, and Greenland (Groves, 1992). History reveals that musk ox was extinct in Alaska by the mid 1800s, possibly due to hunting by native people, explorers, and whalers. In the early 1900s, the worldwide musk oxen population was estimated as few as 5000 animals which were considered to be in danger of extinction (Groves, 1992). Beginning in 1917, the Canadian government enforced the protection of the species from hunting and made efforts to save musk oxen (Burch, 1977). Some animals were translocated from Greenland to Alaska and held in captivity in Fairbanks for feeding, growth, and breeding studies until 1935–36, then released into the wild on Nunivak Island (Klein, 1988).

Table 30.4. Gross composition of musk ox milk (mean values).

	Study 1*	Study 2†
Total solids (%)	27.1	–
Water (%)	72.9	–
Fat (%)	10.9	9.45 (range 6.18–12.88)
Solids-not-fat (%)	16.2	–
Ash (%)	1.20	–
Protein (%) (N × 6.38)	11.9	7.33 (range 5.91–9.00)
Lactose (%)	2.1	4.35 (range 3.44–5.03)
Specific gravity	1.023	–
pH	5.4	6.39 (range 6.25–6.54)
Osmolarity (mmol/kg)	–	313.0 (range 293–337)
Sodium (mmol/L)	–	39.1 (range 31–57)
Potassium (mmol/L)	–	34.5 (range 30–40)
Chloride (mmol/L)	–	19.5 (range 14–30)
Urea (mmol/L)	–	25.0 (range 17–31)
Creatinine (µmol/L)	–	197.6 (range 28–354)
Volume (mL/4 h)	–	161 (range 94–280)

*Baker *et al*. (1970); average values of five animals.
†Chaplin & Follensbee (1991); hand-milked, average values of two musk oxen.

White *et al*. (1989) reported that musk oxen and caribou live in similar arctic environments, and eat similar forages, although their lactational strategies differ in length. Healthy musk oxen continue to nurse their young throughout the rutting period, until December to February, and they may lactate throughout the winter in the field.

The musk ox is an arctic mammal that belongs to the subfamily Caprinae, as do goats and sheep. Musk oxen comprise three recognized subspecies: *Ovibos moschatus moschatus*, *Ovibos moschatus niphoecus* and *Ovibos moschatus wardi*. Musk oxen in Alaska are descendants of the transplanted animals from Greenland, i.e. *O. m. wardi*. A comparative study of allozyme electrophoresis has shown that little genetic variation exists within and between populations of Alaskan and Greenlandic musk oxen (Fleischman, 1986).

Tables 30.1 and 30.4 show the gross composition of musk ox milk, which contains much higher total solids than cow milk with some variations between reports. The higher fat and protein content of musk ox milk is a common characteristic of the milk of arctic and sub-arctic species. Total solids, solids-not-fat, and lactose content significantly increased from day 1 to 3 months of lactation (Table 30.4). Musk oxen have the highest milk production at 3 weeks after parturition, and production remains high for about 1 month, then tapers off gradually (White *et al*., 1989).

Musk ox calves fed milk replacer showed approximately 25% slower growth rates (347 g/day) compared with calves raised naturally suckling their dam (423 g/day) (Chaplin & Follensbee, 1991). Diarrhea was observed as a common problem for those fed milk replacer. Frisby *et al*. (1984) reported the compositional ranges of musk ox milk as milk fat 11.0–15.5%, protein 5.3–15.6%, and lactose 2.9–3.6%, indicating that there are variations in the gross composition of musk oxen milk compared with those values in Tables 30.1 and 30.4.

Concerning the fatty acid composition of musk ox milk, approximately 38% of the total fatty acids is oleic acid, with only trace amounts of butyric acid (Baker *et al*., 1970). Short- and medium-chain fatty acids (C4–C14) of musk ox milk ranged from 9.8 to 17.4%, which is significantly lower than in bovine or caprine milk. Compared with other arctic species, musk ox milk also contains lower levels of long-chain fatty acids (above C18).

30.3.4 Llama milk

The value of South American camelids has been re-recognized in recent decades, and efforts to restore their populations have been made (Sell, 1993; Fowler, 1998). Llama (*Lama glama*) is one of the four main species of New World camelids (Sell, 1993; Fowler, 1998). The llama was domesticated in the Andean puna (elevation 4000–4900 m), probably around Lake Titicaca at about 4000–5000 BC.

Following their domestication, llama herding economies spread beyond the limits of the puna and became a major component in the economy of the Andeans (Fowler, 1998). The Incas depended on llama (and alpaca) for food, fuel, fibers, transport of commodities, and religious rituals (Bastinza, 1979; Fowler, 1998).

In recent decades, llamas have gained increasing interest in the USA and Canada, and the llama industry in these countries continuous to grow. The number of registered owned animals increased from about 70 000–75 000 in 1994 (Morin *et al*., 1995) to about 155 000 in 2003 (International Llama Registry, 2003).

30.3.4.1 Milk yield

The llama has a milk secretory system consisting of four mammary glands, similar in structure to the cow, with four teats each having two streak canals, which enter into separate teat and gland cisterns (Rosenberg, 2006). Milk is collected from variable numbers and sizes of milk ducts from the gland and emptied into the gland cistern. The amount of milk produced daily by individual llamas varies significantly and ranges from 16 to 413 mL per animal, with a median of 62 mL per animal (Morin *et al*., 1995).

30.3.4.2 Milk composition

Llama milk contains an average of 13.1% total solids, 6.5% lactose, 3.4% protein, and 2.7% fat (Morin *et al*., 1995). The energy content of llama milk varies between 50.0 and 95.8 kcal/100 g with an average of 70.0 kcal/100 g, which is lower than that of bovine (85.2 kcal/100 g), caprine (103.6 kcal/100 g) and ovine (155.6 kcal/100 g) milk. Llama milk has a density of 1.033 g/mL, a milk fat density of 0.935 g/mL, and pH of 6.52 at 20 °C. Riek and Gerken (2006) reported mean concentrations of the major milk components across the lactation period as 4.70% fat, 4.23% protein, 5.93% lactose, 15.61% dry matter, and 22.62 mg/dL of milk urea nitrogen (Fig. 30.3). All constituents were affected by stage of lactation for these lactating llamas under controlled stable conditions during the first 27 weeks of lactation.

A recent study (Schoos *et al*., 2008) on the fatty acid composition of llama milk showed that the proportions of saturated fatty acids (C4–C10), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids in llama milk fat were comparable to the values in cow milk. The predominant fatty acids in llama milk were C16:0, C18:0, C14:0, and C18:1. The milk also contained *trans* fatty acids at 3 g/100 g total fatty acids (mainly C18:1 *trans*-11), and a small quantity of conjugated linoleic acid (0.4 g/100 g total fatty acids).

Llama milk proteins contain significant proportions of phosphorus, i.e., 0.36, 0.45, 0.30, and 0.15% for α-, β- and γ-casein

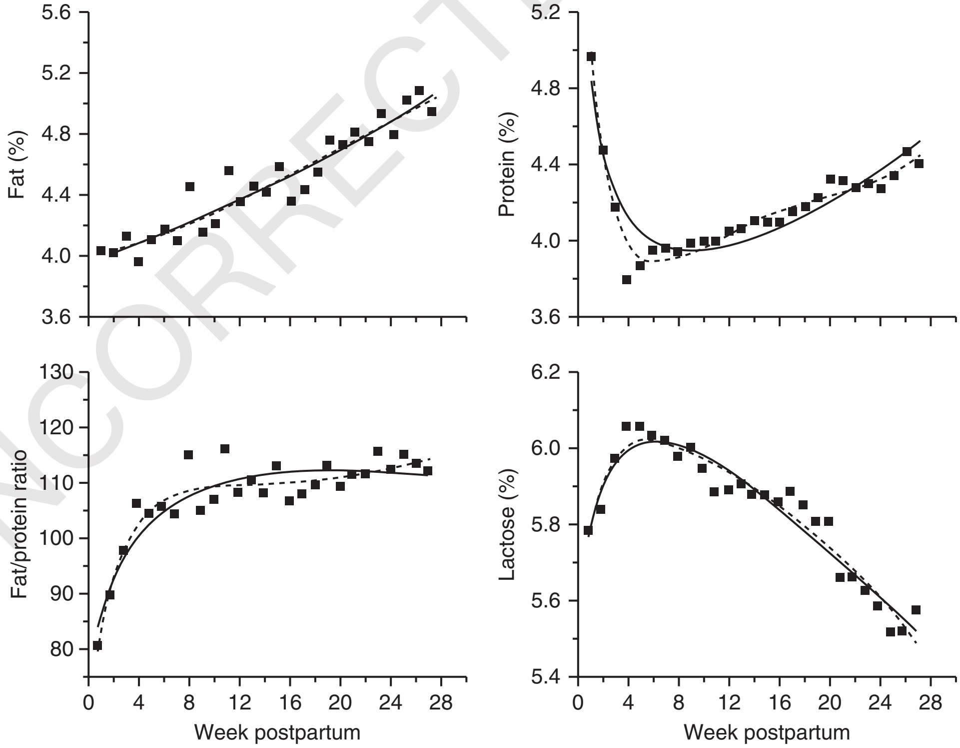


Figure 30.3. Changes in fat, protein, and lactose contents and fat/protein ratio of llama milk during the 27-week lactation period. Reproduced with permission from Riek & Gerken (2006).

and the proteose peptone fraction, respectively. However, llama milk does not contain β-lactoglobulin (Fernandez & Oliver, 1988; Morin *et al*., 1995). Carbohydrates in llama milk are associated with α-lactalbumin, proteose peptone fractions, immunoglobulins, α-casein, and β-casein. The distribution of sialic acid among protein fractions of llama milk is 84.4% in the milk whey fraction and 15.6% in casein (Fernandez & Oliver, 1988; Rosenberg, 2006).

The mineral content of llama milk is different from human and bovine milk, in which potassium is the most abundant mineral, whereas in llama milk calcium is the main mineral, followed by phosphorus and potassium (Flynn & Cashman, 1997). The calcium content of llama milk is higher (1310–2210 mg/kg) than that in human, cow, and goat milk (280, 1120 and 1400 mg/kg, respectively) but similar to that in camel milk. The sodium concentration in llama milk (193–413 mg/kg) is lower than that in cow milk (530 mg/kg) but higher than that in human milk (180 mg/kg) (Morin *et al*., 1995).

Zinc is the most abundant trace element in llama milk, similar to milk of other species (Anderson, 1992; Rosenberg, 2006). The mean zinc content in llama milk (about 4.2 mg/kg) is higher than that in human milk (1.2 mg/kg) but similar to that in cow milk (3.9 mg/kg) and camel milk (4.0–5.0 mg/kg). Llama milk contains 0.278 mg/kg barium, which is higher than that in cow milk (188 mg/kg). The mean copper concentration in llama milk (0.109 mg/kg) appears to be lower than that in mare (0.155 mg/kg), human (0.250–0.314 mg/kg) or guinea-pig (0.500 mg/kg) milk. Llama milk contains relatively low copper concentrations, consistent with low blood serum copper concentrations in this species compared with other domestic animals. Compared with the iron content in camel milk (1.3–2.5 mg/kg), llama milk has a lower mean level of iron (0.65 mg/kg), comparable to that in cow milk (0.50 mg/kg) but higher than that in human milk (0.3 mg/kg).

30.3.5 Alpaca

The alpaca is one of the two species of domestic South American camelids adapted to live at high altitudes, over 3800 m above sea level (Parraguez *et al*., 2003). There are four species of South American camelids: vicuña, guanaco, llama, and alpaca (Burton *et al*., 2003). The vicuña and guanaco are wild species. The vicuña is native to the altiplano regions of Chile, Bolivia, and Peru. The guanaco is native to the Patagonia regions of southern Chile and Argentina. Llamas and alpacas are the two domesticated species in this camelid family (Fowler, 1998).

Alpacas are an essential source of income and provide meat and wool for the native people who live in the high altiplano regions, but neither alpaca nor llama are milked for human consumption. This camelid is very important for the village economy in Chile, Bolivia, Peru, Ecuador, and Argentina (Burton *et al*., 2003). Alpaca reared in these countries have a conception rate of 50% or lower and a 20% mortality rate of the young (called "crias"). Nutritional inadequacies, infectious diseases, and changes in the environment may cause these reproductive problems (Raggi *et al*., 1994).

Studying the composition of alpaca colostrum at 48 hours after birth for the Andean high plateau and Patagonia populations (Table 30.5), Parraguez *et al*. (2003) reported that the two breeds had 21 and 19% total solids, 9.8 and 9.2% protein, 4.8 and 2.7% fat, 4.4 and 5.3% lactose, and 1.6 and 1.8% ash, respectively. The colostrum of the Andean altiplano breed had higher dry matter, protein and fat, but lower lactose than the Patagonian breed. A similar trend was

Table 30.5. Comparison of gross compositions of alpaca colostrum and mature milk from two regions of Chile.

	Dry matter	Protein	Fat*	Lactose*	Ash
Colostrum					
AHP†	20.66 ± 1.3	9.84 ± 0.6	4.80 ± 1.2	4.41 ± 0.1	1.63 ± 0.0
Patagonia‡	19.06 ± 0.5	9.24 ± 0.5	2.71 ± 0.6	5.33 ± 0.1	1.78 ± 0.1
Mature milk					
AHP†	16.8 ± 0.7	6.9 ± 0.3	3.8 ± 0.6	4.4 ± 0.5	1.7 ± 0.3
Patagonia‡	15.8 ± 0.6	6.5 ± 0.3	2.6 ± 0.5	5.2 ± 0.5	1.4 ± 0.1

*Differences in fat and lactose contents of both colostrum and mature milk between the two regions are significant ($P < 0.05$).

†Andean high plateau region (4400 m above sea level); 24 alpacas tested.

‡Patagonia region (12 m above sea level); 18 alpacas tested.

Source: based on data from Parraguez *et al*. (2003) and reproduced with permission from Park & Haenlein (2006).

observed for the major constituents of alpaca mature milk from 1 to 5 months of lactation (Table 30.5). The higher milk fat content of Andean high plateau alpaca compared with the lower-altitude Patagonian alpaca suggests that the animals at higher altitude may require more energy for body maintenance compared with those at lower altitude. The differences in fat and lactose composition between the two regions could also be explained by pasture composition and availability as well as the grazing behavior of the animals.

The main immunoglobulin of colostrum found in alpaca crias is IgG. Bravo *et al*. (1997) showed that the mean IgG concentrations were similar in llama (2370 mg/dL) and alpaca (2340 mg/dL) crias, and not different between male and females. Llama and alpaca crias are born agammaglobulinemic, with IgG concentrations increasing after suckling.

30.3.6 Moose

Studies on domesticated moose (*Alces alces*) have been very limited. Moose milk has the consistency of thick cream and the odor of fresh bovine milk. Moose milk contains less lactose than milk of elk, caribou, or most other wild or minor ruminant species, as shown in Table 30.1 (Park, 2006). In a study with singleton moose calves (*Alces alces gigas*) during the first 4 months after birth, per cent milk composition at peak output was 20.5 ± 1.5 total solids, 7.9 ± 1.5 fat, 7.2 ± 0.4 protein, 1.4 ± 0.1 ash, and 3.7 ± 0.2 lactose, indicating that gross composition of moose milk at peak lactation is lower than in other stages of lactation. Chalyshev and Badlo (2002) showed that initial increases in basic nutrient and fat contents in taiga moose milk during the peak lactation in June (1–25 days) is concurrent with the availability of high-quality forage. They also observed that mineral concentrations in moose milk gradually decreased during 26–100 days of lactation.

There is no marked difference in mineral composition between moose milk and other arctic deer milk, while the potassium content is lower than in other milks, except human milk (Lauer & Baker, 1969; Cook *et al*., 1970a). With regard to fatty acid composition, moose milk has about 53% saturated fatty acids, which is less than the saturated fatty acid content of the milk of most ruminants (Ling *et al*., 1961; Cook *et al*., 1970a). In a study of 21 Alaskan moose at the Kenai Moose Research Center, Soldotna, Alaska, Franzmann *et al*. (1976) reported that Al, Fe, Se, and Zn contents in moose milk were higher than in cow milk by factors of 1.6–290. Ca and Mg levels in hair were lower than those in milk of moose, and were subject to lactational stress such as feed availability and metabolic disease status.

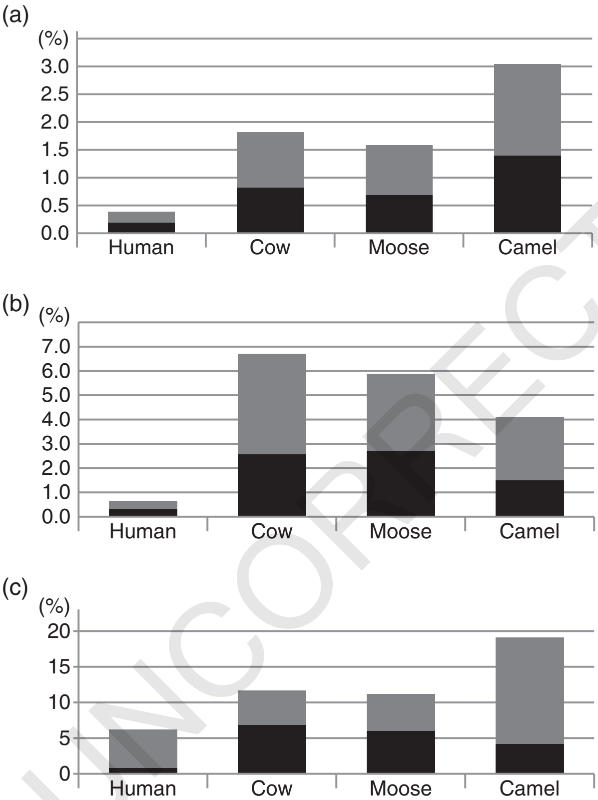
In studying feeding efficiency, Shochat and Robbins (1997) found that maternally raised singleton moose calves had greater milk intake than bottle-raised calves. Although the weight gains of bottle-raised moose calves generally increased as they began consuming significant quantities of forage, poor early growth rates relative to maternally raised calves (790 ± 120 g/day) confirmed the inadequacy of bottle-feeding protocols. In addition, high mortality rates of bottle-raised neonatal moose are frequently associated with improper nutritional management and poor husbandry techniques. Moose calves raised in captivity commonly show dietary-induced diarrhea caused by inappropriate milk replacers. Calves are often underfed to avoid diarrhea, causing poor growth during the first 4 weeks when the young are usually entirely dependent on mother's milk for their growth and survival (Shochat & Robbins, 1997).

Moose milk is commercially farmed in Russia (Fig. 30.4, see also Plate 30.1): one sanatorium, the Ivan Susanin Sanatorium, even serves moose milk to residents in the belief that it helps them recover from disease or manage chronic illness more effectively (Grocott, 1994). Some Russian researchers have recommended that moose milk could be used for the prevention of gastroenterological diseases in children, due to its lysozyme activity

Figure 30.4. A milkmaid at the Kostroma Moose Farm in Kostroma Oblast, Russia, prepares to milk a moose. From Wikipedia (2011) courtesy of Dr Alexander Minaev. For a color version of this figure, see Plate 30.1.

(Dorofeichuk *et al.*, 1987). The Elk House in Sweden has three milk-producing moose, whose milk yields roughly 300 kg of cheese per year, and the cheese sells for about $1000 per kilogram (Johansson, 2007).

In a comparative study on the fatty acid patterns of moose, camel, cow, and human milk, Dreiucker and Vetter (2011) reported that the animal milks contained up to eight *iso*-fatty acids (iFA) ranging from C13 to C22 as well as four *anteiso*-fatty acids (aFA) with odd chain length (C13–C19) (Fig. 30.5). The higher diversity of iFAs compensated for this, so that the iFA/aFA ratio was similar in all samples and slightly above 1 (Fig. 30.5a). The *trans*-MUFA pattern was dominated by *trans*-11 C18:1, which contributed between 30 and 50% to the *trans*-MUFA content (Fig. 30.5b) and which could be as high as 2.7%



AQ3 **Figure 30.5.** Content (g/100 g fatty acids) of (a) *iso*-(gray) and *anteiso*-fatty acids (black), (b) *trans*-mondunsaturated fatty acid (MUFA) other than 11-*trans* 18:1 (gray) and 11-*trans* 18:1 (black), and (c) *cis*-MUFA without 18:1(9) (gray) and *trans*-MUFA (black) in human, cow, moose, and camel milk. Reproduced with permission from Dreiucker & Vetter (2011).

(moose) and 2.6% (cow). The most remarkable fact in the group of *cis*-18:1 isomers was the relatively low content of C18:1 in human milk and higher proportions in moose and cow milk.

30.3.7 Elk

Very limited reports are available on production and composition of elk milk. Growth rates of hand-raised elk are lower than those of dam-raised elk. For hand-raising wild ungulates, evaporated milk fed *ad libitum* appeared to be an effective and practical approach. Robbins *et al.* (1981), studying the milk composition of a captive elk (*Cervus elaphus nelsoni*), have shown that it contained 19.8% dry matter, 6.2% protein, 7.5% fat, 4.1% lactose, and 1.1% ash during the first 3 months of lactation. The calf had its peak milk intake at 21 days, then milk intake gradually decreased during the following 2 months. A significant dry-feed intake was initiated prior to the decline in milk intake, indicating that meeting the calf's nutrient requirements would be increasingly important after 40 days. Wild *et al.* (1994) found that growth rates of hand-raised elk were lower than those of dam-raised elk.

Vasilenko *et al.* (2002) conducted a study on the milk productivity of five domesticated elk females during 17 lactation periods over 4 years at the Pechoro-Ilych State Nature Reserve, Russia. On average, the lactation period of elk cows was 105 days, peak daily milk production (3.4–7.6 L per elk cow) occurred at 20 days after birth, and milk production declined by 50–60 days after birth due to estrous activity.

Fat composition of elk milk is similar to that of cow milk, containing high levels of palmitic, stearic, oleic, and myristic acids along with smaller amounts of short-chain fatty acids. Smith *et al.* (1997) reported that early development of cervids is attributable to juvenile survival and lifetime reproductive success. Male calves of free-ranging elk are usually born late and weigh more than females, and supplemental feeding has revealed little effect on birthweight of elk calves. Nutritional benefits of winter feeding on maternal condition entering late gestation may improve milk yields of dams, benefiting the weight gains of the first week of life for elk neonates.

30.3.8 Mithun

The mithun (*Bos frontalis*) is a domesticated bovine species mainly found in the hill regions of India, Myanmar, Bhutan, and Bangladesh (Nath & Verma, 2000). The mithun plays an important role in the economic well-being and social and cultural life of the rural people in these countries. Hybrids of mithun and cattle are used as dairy animals in parts of north-eastern India and Bhutan (Indian Council of Agricultural Research, 2010).

Mithun milk contains higher total fat and protein than cow milk, and the total protein and fat content of individual mithun at late lactation have been reported as 6.78 g/100 g and 10.3 g/100 g, respectively (Mech *et al.*, 2008). This fat content is unusually high: the mithun is not an arctic animal, but its habitat is at an elevation of 1000–3000 m above sea level. The high levels of fat and protein in mithun milk may be attributable to the unique genetic composition and the low milk yield of the species (Mech *et al.*, 2008). Lactose content of mithun milk (4.44 g/100 g) is similar to that of cow and goat milk, while the ash content of mithun milk (0.9 g/100 g) is higher than that in cow and goat milk (Park, 2006; Mech *et al.*, 2008).

30.3.9 Other minor species

Interesting minor species for study of milk composition include pinnipeds, elephant and polar bear. These species are not domesticated but their milk can be accessible. Pinnipeds represent a group of marine mammals that includes the northern elephant seal, antarctic fur seal, California sea lion, and Australian sea lion.

30.3.9.1 Pinniped

Pinniped milk has a distinctly different gross composition compared with other mammalian species, being rich in fat, as high as 60% in phocids (seals) and about 20–35% in otariids (sea lions), with about 10–12% protein, the highest among mammals (Oftedal *et al.*, 1987; Davis *et al.*, 1995).

The mean milk composition of sub-antarctic fur seals is 42.8 ± 5.7% lipid, 12.1 ± 1.5% protein, and 42.6 ± 7.3% water (Table 30.6). Georges *et al.* (2001) found that the fur seals breeding on Amsterdam Island produced one of the richest milks ever reported in otariids (20.4 ± 2.9 kJ/g),

Table 30.6. Mean gross chemical composition of milk in sub-antarctic fur seals on Amsterdam Island, collected during the entire pup-rearing period.

	Mean	SD	*N*	Range
Lipid (%)	42.8	5.7	98	24.7–56.4
Protein (%)	12.1	1.5	83	9.2–15.4
Water (%)	42.6	7.3	83	26.2–64.2
Total mass (%)	98.1	0.9	83	95.5–99.9
Gross energy (kJ/g)	20.4	2.9	83	12.2–27.6

Note: mean values are means of individual average values, regardless of the time mothers spent fasting ashore before sampling occurred.

Source: reproduced with permission from Georges *et al.* (2001).

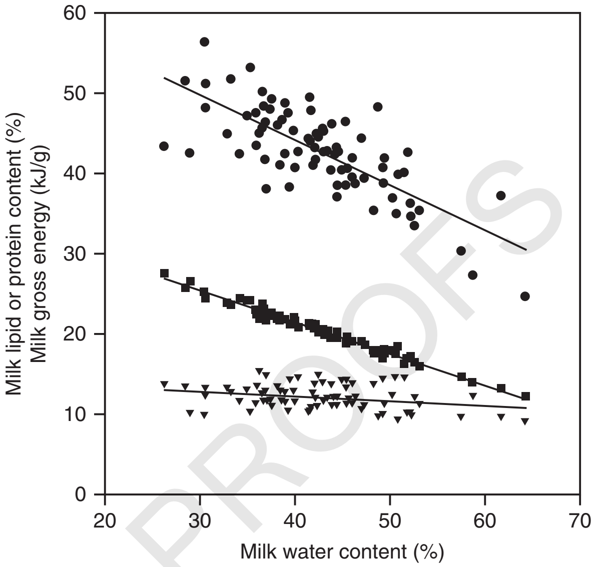


Figure 30.6. Relationships between water (%) and lipid (%; circles), protein (%; triangles), and gross energy (kJ/g; squares) in sub-antarctic fur seal milk at Amsterdam Island. Reproduced with permission from Georges *et al.* (2001).

with lipid content contributing 85% of total gross energy. On average, the sum of measured protein, lipid, and water accounted for 98.1 ± 0.9% of the milk mass. There were negative relationships (Fig. 30.6) between water content and lipid content [lipid (%) = 66.59 − 0.56 × water (%); $r^2 = 0.571$, $N = 83$, $P < 0.001$], protein content [protein (%) = 14.54 − 0.058 × water (%); $r^2 = 0.08$, $N = 83$, $P < 0.009$], and gross energy [gross energy (kJ/g) = 37.02 − 0.389 × water (%); $r^2 = 0.976$, $N = 83$, $P < 0.001$] (Georges *et al.*, 2001).

There was a commonality in milk amino acid patterns in pinniped milk relative to other species, despite wide variation in total amino acid concentrations (Davis *et al.*, 1995). The most abundant amino acids in pinniped milk are glutamate, proline, and leucine.

Lactoferrin is an iron-binding glycoprotein found in different biological fluids of mammals and in neutrophils. Conesa *et al.* (2008) purified lactoferrin using ion-exchange chromatography (SP-Sepharose) and sodium dodecyl sulfate (SDS)-polyacrylamide gel electrophoresis (PAGE) from milk of several species: sheep (*Ovis aries*), goat (*Capra hircus*), camel (*Camelus bactrianus*), alpaca (*Lama pacos*), elephant (*Elephas maximus*), and grey seal (*Halichoerus grypus*), as well as human (Fig. 30.7). The thermal stability of the purified lactoferrins,

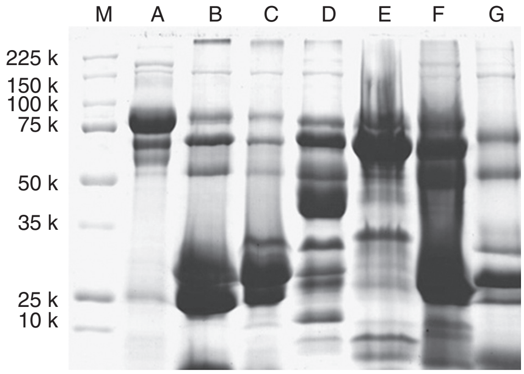


Figure 30.7. Isolation of lactoferrin (80 kDa) from milks of different species by SDS-PAGE: A, human; B, sheep; C, goat; D, camel; E, alpaca; F, elephant; G, grey seal. M, molecular weight marker. Reproduced with permission from Conesa *et al.* (2008).

in their native and iron-saturated forms, was also investigated by differential scanning calorimetry. Lactoferrin was identified by SDS-PAGE in all milks as a band of 80 kDa apart from the seal milk (Fig. 30.7). The chromatographic profile followed a similar pattern, with only one peak in the elution step with 1 mol/L NaCl and a main band of 80 kDa in the SDS-PAGE analysis. In the case of the grey seal milk, no protein was detected at 280 nm in the elution step with 1 mol/L NaCl and SDS-PAGE did not reveal the presence of any protein with a molecular mass of 80 kDa. Camel milk lactoferrin showed the most active antimicrobial activity against *Escherichia coli* O157:H7, whereas alpaca and human lactoferrins were the least active.

30.3.9.2 Polar bear

Polar bear milk is creamy white and has a strong fishy odor, whereas grizzly bear milk is pale yellow with a consistency of thick cream and the odor of fresh cow milk (Cook *et al*., 1970b). As the stage of lactation advances, total solids content of polar bear milk decreases slightly, but is considerably higher than in milk of other land mammals, ranging from 43 to 47%. Fat, solids-not-fat, and protein are extremely high, while lactose content is quite low compared with cow milk, but closer to marine mammals. Grizzly bear milk fat has a lower palmitoleic and higher linoleic acid content than does polar bear milk (Cook *et al*., 1970b).

In studying hexose and sialic acid content of seven polar bear milk samples, Urashima *et al*. (2000) found that hexose and sialic acid levels in polar bear milk ranged from 0.30 to 3.04 and from 0.18 to 0.43 g/dL, respectively. They also reported that the respective mean (±SD) values for hexose and sialic acid of the seven samples were 1.21 ± 1.13 and 0.32 ± 0.09. These AQ4 authors showed that lactose was present only in small amounts. Some of the milk oligosaccharides of the polar bear had α-Gal epitopes similar to some oligosaccharides in milk from the Ezo brown bear and the Japanese black bear. Some milk oligosaccharides had human blood group A antigens as well as B antigens; these were different from the oligosaccharides in Ezo brown and Japanese black bears.

30.3.9.3 Elephant

In a study of the milk of an Asian elephant (*Elephas maximus*) at 11 days after birth, Uemura *et al*. (2006) found that the milk contained 91 g/L of hexose and 3 g/L of sialic acid. The dominant saccharide in this milk sample was lactose, but it also contained isoglobotriose, i.e., Glc(α1→3)Gal(β1→4)Glc, as well as a variety of sialyloligosaccharides. The structures of the sialyloligosaccharides were determined to be those of 3′-sialyllactose, 6′-sialyllactose, monofucosyl monosialyl lactose, i.e., Neu5Ac(α2→3)Gal(β1→4)[Fuc(α1→3)]Glc, sialyllacto-*N*-neotetraose c (LSTc), galactosyl monosialyl lacto-*N*-neohexaose, galactosyl monofucosyl monosialyl lacto-*N*-neohexaose, and three novel oligosaccharides. The oligosaccharide in fraction Em 1-2-11 was characterized by comparison of its proton NMR spectrum (Fig. 30.8, chemical shifts) with that of Em 1-2-7 (LSTc). The spectrum had the anomeric signals of α-Glc, β-Glc, β(1→3)-linked GlcNAc, and two of β(1→4)-linked Gal at δ 5.219, 4.663, 4.726, 4.455, and 4.438, respectively. The oligosaccharide contained an additional Gal(β1→4)GlcNAc(β1→3) unit, namely it had a *para*-lacto-*N*-neohexaose unit, i.e., Gal(β1→4)GlcNAc(β1→3)Gal(β1→4)GlcNAc(β1→3)Gal(β1→4)Glc.

Osthoff *et al*. (2007) observed the dynamic changes in nutrients of the milk from three free-ranging African elephant (*Loxodonta africana africana*) cows during lactation. The respective nutrient contents over 12, 14, and 18 months of lactation were 47.3, 52.0, and 68.6 g protein; 60.7, 87.4, and 170.8 g fat; 1.6, 2.1, and 0.5 g lactose, and 20.9, 21.5, and 8.6 g oligosaccharides per kilogram milk. The protein fraction consisted of 18.0, 31.7, and 45.9 g caseins per kilogram milk and 29.3, 20.3, and 22.7 g whey proteins per kilogram milk, respectively (Osthoff *et al*., 2007). Electrophoresis and identification of protein bands showed that polymorphs of one whey protein may be present in elephant milk similar to polymorphs of α-lactalbumin found in cow milk.

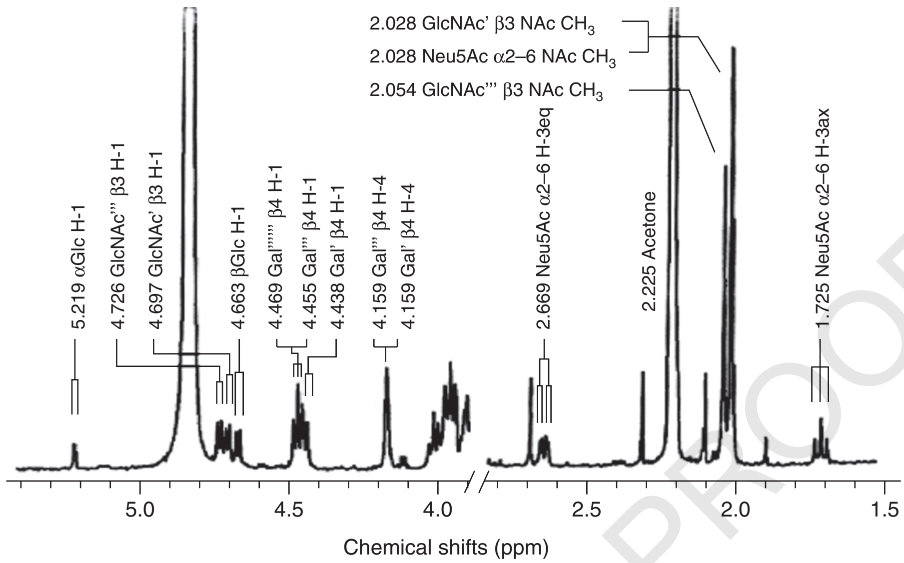


Figure 30.8. Oligosaccharides (600 MHz [1]H-NMR spectrum of Em 1-2-11) isolated from Asian elephant milk. The spectrum was obtained in D2O at 600 MHz with a Varian INOVA 600 spectrometer operated at a probe temperature of 293.1 K. From Uemura *et al.* (2006).

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