Artificial milk for wildlife orphaned neonates

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Abstract

Milk is a very complex nutrient and differs significantly between species. Monotreme and Marsupial milk contains only trace amounts of lactose, whereas in Eutherian species, lactose is the predominant saccharide. Within the Eutheria, the composition varies from 8.5% in Indian rhinoceros to 63.8% in Grey seal in concentration; from 0.3% in Indian rhinoceros to 9.3% in elephants in total fat; from 1.2% in Indian rhinoceros to 12.8% in Fin whale in total protein; and finally from 0.8% in Great panda to 6.5% in Indian rhinoceros in lactose. Milk components change during lactation and, especially in Marsupials, this should be considered in artificial feeding. Other factors to be taken into account are the amino acid panel, whey and casein fractions, iron and immunological components. In wildlife nursing, we often come across orphaned neonates that require artificial feeding. However, there are no specific formulas for each wildlife baby. The aim of this review is to compare which artificial milk replacer is best suited for selected species of wildlife neonates.

Key words: *wildlife orphaned neonates; artificial feeding; milk components; antimicrobial compounds of milk; microbiota of milk; milk replacers*

Importance of choosing the correct milk replacer

Milk replacers, often called "foreign foods", are presumed to be a factor in developing non-infectious diseases such as allergic diseases and types 1 and 2 diabetes in humans (Gribble and Hausman, 2012). Inaccurate measurement of infant formula powder and over-dispensing may contribute to increased adiposity and rapid weight gain in formula-fed infants (Altazan et al., 2020). Heiner syndrome is a food hypersensitivity pulmonary disease that affects primarily infants, and is mostly caused by cow's milk. Chronic respiratory symptoms began at age 1–9 months and included cough, wheezing, haemoptysis, nasal congestion, dyspnoea, diarrhoea, colic, anorexia, vomiting, haematochezia, and failure to thrive. Analysis showed pulmonary hemosiderosis, eosinophilia, anaemia and elevated levels of total IgM, IgE, or IgA. Following the elimination of bovine milk, remarkable improvement in symptoms was observed within days and clearing of the pulmonary infiltrate within weeks (Ioannis et al., 2005). Formula feeding may be associated with impaired cognitive development, perhaps because it lacks many ingredients thought to be involved in brain development (Gribble and Hausman, 2012).

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There is a number of studies that examine the effects of breastfeeding on later cholesterol levels, which are associated with mortality of ischaemic heart disease among adults. Although the evidence is not conclusive, there is a suggestion that breastfeeding provides infants with the optimal protection against future raised lipid levels and mortality from coronary heart disease (Golding et al., 1997). Further, Sudden Infant Death Syndrome (SIDS) is 3.7 times more prevalent in formula-fed babies than in their breastfed counterparts (Gribble and Hausman, 2012).

Comparison between milk components in wildlife species and selected milk substitutes

In wildlife neonate care, there are no uniform milk replacer that would be suitable for all species, and therefore in practice, the approximate milk used is chosen. Marked differences in milk composition throughout the mammalian class were gathered (Table 1) and compared to selected milk replacers (Table 2).

Platypus, Echidna, North American opossum and Koala milk may markedly differ in carbohydrate components from other species. Lactose is present only in trace amounts, and similar results are known from the literature. Urashima et al. (2022) reported oligosaccharides to be the predominant saccharide over lactose in Monotremes, Marsupials, and Caniformia species within the Eutherias. They attributed this to the pinocytosis of oligosaccharides into intestinal cells and hydrolysis to monosaccharides, whereas other mammals are able to digest lactose by intestinal lactase into glucose and galactose. Data for human infants indicate that oligosaccharides in other mammals

Table 1. Mean values of milk components in established lactation in percentages of dry mater.

Order	Species	DM	Ash	TP	TF	CH/Lactose	Ca	P	Mg	Other	References
Monotremata	**Platypus** *(Ornithorhynchus anatinus)*	39.1	0.5	8.2	22.2	3.3 (total hexose)/trace	0.117 [g/100ml]	0.285 [g/100ml]	0.016 [g/100ml]	Sialic acid 0.43	Griffiths et al., 1984
	Echidna *(Tachyglossus aculeatus)*	48.9	0.5	12.4	31.0	1.6/trace	0.191 [g/100ml]	0.133 [g/100ml]	0.016 [g/100ml]	Sialic acid 0.70 Iron 0.00333 [g/100ml]	Griffiths et al., 1984
Marsupialia	**North American opossum** *(Didelphis virginiana)*	27.0	—	10.0	17.0	7.0/trace	100 Mmol/L	—	9.2 Mmol/L	No lactose in later lactation	
	Grey Kangaroo *(Macropus sp)*	24.3	1.2	6.6	7.0	—	0.3	0.2	—	—	
	Koala *(Phascolarctos cinereus)*	33.6	—	8.5	15.9	6.4/0.2	—	—	—	N—acerylglu cosamine 0.4 Digalacto syllactose 1.2	Krockenberger et al., 1996

Euliporyphla	**Elephant** *(Loxodonta africana)*	20.1	0.73	5.1	9.3	-/3.7	0.13	0.08	0.01	Glucosamine 0.516% *	Mccullagh, 1970; *Takatsu et al., 2017
	(Elephas maximus)	17.56	0.87	5.23	15.1	—	—	—	—		Dierenfeld et al., 2020
Carnivora	**Cheetah** *(Acinonyx jubatus)*	16.4	—	9.96	6.48	-/4.02	—	—	—	—	Osthoff, 2006
	Grey seal *(Halichoerus grypus)*	63.8	0.8	12.0	50.0	-/0.7	—	—	—	—	Baker, 1990
	Giant panda *(Ailuropoda melanoleuca)*	26.04	0.92	10.06	11.17	6.2/0.78	0.82	0.68	0.056	—	Zhang et al., 2015
Artiodactyla	**Bactrian camel** *(Camelus bactrianus)*	20.16 13.07*	0.77	14.23 3.33*	0.27 6.67*	-/4.44 -2.77*	0.22	0.153	—	—	Zhang et al., 2005; *Konuspayeva et al., 2009
	Bottlenose dolphin *(Tursiops truncatus)*	27.0	—	8.9	12.8	1.0/-	—	—	—	—	West et al., 2007
	Fin whale *(Balaenoptera physalus)*	45.8	0.95	12.8	32.4	-/0.25	0.13	0.26	—	—	Ohta et al., 1953
	Indian rhinoceros *(Rhinoceros unicornis)*	8.47	0.30	1.17	0.3	-/6.5	0.54	0.48	0.09	—	Osthoff et al., 2021; Grimmel et al., 2018;
	Giraffe *(Giraffa camelopardalis)*	17.3	0.9	6.3	7.2	-/3.0	0.06	0.10	0.005	—	Hall-Martin et al., 1997
Chiroptera	**Bat** *(Leptonycteris nivalis)*	12.1	0.63	4.37	—	-/5.39	—	—	—	—	Huibregtse, 1936
Primates	**Cynomolhus monkey** *(Macaca fascicularis)*	12.17 [g/100ml]	0.40 [g/100ml]	1.74 [g/100ml]	5.22 [g/100ml]	-/4.81 [g/100ml]	0.038 [g/100ml]	0.015 [g/100ml]	0.0034 [g/100ml]	—	Nishikawa et al., 1976
Lagomorpha	**Rabbit** *(Oryctolagus cuniculus)*	28.3	1.85	10.0	12.7	—/2.0	—	—	—	—	Ludwiczak et al., 2020

DM: dry matter, TP: total protein, TF: total fat, CH: carbohydrate

Table 2. Milk components in selected milk replacers.

Order	Species	DM	Ash	CP	TF	CH/Lactose	Ca	P	Mg	References
Monotremata	**Echidna milk replacer**	–	–	34.0	38.0	16.0/0				Wombaloo, 2020
Marsupialia	**Kangaroo 0.6 milk replacer**	–	–	32.0	28.0	32.0				Wombaloo, 2020
	Koala milk replacer	–	–	32.0	43.0	14/-				Wombaloo, 2020
Carnivora	**Baby dog milk Royal Canine**	–	6.0	33.0	39.0	18.50	1.10	0.8	0.06	[1]
	Kitten milk replacer KMR	–	–	40.0	28.0	–				[2]
	Zoologic 30/52 diluted 1:1	30.8	–	9.2	16.0	-/1.6				Treiber et al., 2021
	Cow	12.5	0.7*	3.3	3.3	-/4.7	0.112	0.091	0.011	Verduci et al., 2020 *Nishikawa et al., 1976
Artiodactyla	**Horse**	10.5	0.42	2.14	1.29	-/6.37				Oftedal et al., 1983 Jastrzebska et al., 2017
	Goat	12.13	–	3.07	3.41	4.54				Jenness, 1980
	Pig milk replacer	–	7.5	22.0	14.0	–	0.8	0.7	–	Taylor Picard et al., 2017
Primates	**Human**	12.5	0.20*	1.0	4.4	6.9	0.032	0.014	0.003	Verduci et al., 2020 *Nishikawa et al., 1976
	Soy formula Soy based infant formula regulated by EU (mean values)	–	–	1.66	3.42	-/0	0.064	0.039	0.007	Verduci et al., 2020

DM: dry matter, CP: crude protein, TF: total fat, CH: carbohydrates are not absorbed in the small intestine, but reach the colon, where they act as prebiotics, anti-infection factor, immune modulation factor, nerve developing factor, and colonic barrier function strengthening factor (Urashima et al., 2022).

In Echidna and Platypus milk, the levels of calcium and magnesium are similar to those in the milk of Eutherians, but are much lower than those found in Marsupials (Green, 1996). Conversely, the concentrations of iron and copper in Monotreme milk are similar to those of Marsupials and much higher than levels in Eutherian milk. We can attribute that to the fact that newborn Eutherians have enough iron in their livers to support them until they can ingest iron in their definitive diets. On the other hand, the Marsupial neonate and the Monotreme hatchling, are minute and their livers cannot store enough iron to support them for a prolonged period on milk; therefore their milks are rich in iron (Griffiths et al., 1984).

Platypus milk is very concentrated, up to 3.13 times more concentrated than cow milk. It contains only trace amounts of lactose, therefore a soy formula or Echidna milk replacer would be the most similar artificial milks. Platypus milk is 4.94 times more concentrated in protein, 6.49 times more concentrated in fat, though is far poorer in carbohydrates. Therefore, even concentrated soy formula would not be similar to the Monotreme milk. In practice, Echidna milk replacers are used also for Platypus (Wobaroo, 2020).

It is interesting that Echidnas are not fed as often as Eutherias. Whereas neonatal cats and dogs are fed four times a day (Aschaffenburg et al., 1962), Echidna have slower digestion and it can take 36 hours in early lactation and 48 hours in late lactation before the baby's stomach and it can be fed again (Wombaroo, 2020).

Opossum, Kangaroo and Koala milk components are also different from Eutheria species milk, though commercial milk replacers are available for these species, and are also adjusted for their age and pouch exit time (Wombaroo, 2020).

Krockenberger et al. (1996) reported that high lipid levels throughout lactation provides most of the energy of Koala milk. Koala milk protein component represents only 53.5% of its protein component. A similar ratio is seen in Platypus, Echidna and Opossum milk, whereas in cat and dog milk substitute, this value reaches 84.6%.

For elephant orphans in practice, human baby formula, fortified powdered cow's milk or goat milk replacers are used. However, African elephant milk is 60.8% and 65.7% more concentrated than cow and goat milk, respectively. Compared to goat milk, African elephant milk is 1.66 times higher in total protein, and 2.72 times higher in total fat, however it has 1.22 times lower lactose. Furthermore, elephant milk contains a 14-fold higher glucosamine concentration than cow's milk. Takatsu et al. (2017) reported that bones account for 25% of elephants' bodyweight and amino sugars have a significant role in chondrocyte production. Therefore, commercially available milk replacers are not best suited for elephant neonates if the composition is not adjusted.

Using kitten milk replacer for cheetah neonates would make a good match. Although kitten milk is diluted 1:2 parts for domestic cat neonates, it would be better to dilute it 1:3 parts for use in cheetah species. The kitten milk replacer is 4.01 times and 4.32 times more concentrated than cheetah milk in total protein and total fat, respectively.

Grey seal milk is approximately twice as concentrated than 1:3 diluted puppy formula. If we diluted the puppy formula

1:2.75 this would approach the total protein level, however it would be 3.42 times too low on total fat. In practice, it is suggested to use fish soup (Enjapoori et al., 2014), which is made of liquidised fish and oral rehydration solution.

Marsupials produce the developmentally most immature neonates of all mammals, and *Ursidae* follow close behind despite the Eutherian physiology. The cause may lie behind overwintering, since transfer of fats through lactation is less metabolically costly to the mother than the transplacental transfer of glucose to support the foetus (Zhang, 2015).

Nakamura et al. (2003) found isoglobotriose to be the dominant saccharide in Giant panda milk instead of lactose. Great panda milk is similar compared to puppy formula diluted 1:2 parts. Total protein, fat and carbohydrates differed by 8.6%, 14.1% and 0.5%, respectively. Treiber et al. (2021) described that in the zoo they use Zoologic milk matrix. Use of PetAg milk matrix 33/40 in dilution 1:1 would also be very similar to panda's natural milk. Great panda milk compared to the milk matrix mentioned above differs in concentration, total protein, fat and carbohydrate by 4.6%, 5.9%, 6.1%, and 44.2%, respectively.

Camelidae are phylogenetically closer to *Suidae* than *Bovidae* (Barlah et al., 2014). Interestingly, Bactrian camel milk is more similar to cow milk in its concentration and total protein though in total fat it is closer to diluted pig milk replacer. It is 9.5% more concentrated and 0.1% higher in protein than cow's milk.

Cetaceans are phylogenetically closer to *Bovidae* than *Suidae* family (Nikaido et al., 2022). However, dolphin and whale milk is markedly different than cow and pig milk replacers. Bottlenose dolphin milk is 0.69 times higher in protein than 1:1 part diluted pig milk and 2.16 times more concentrated with 2.70 times higher protein than cow milk. In fat, it is 1.82 times higher than pig milk and 3.88 times higher than cow milk.

Fin whale milk is 1.16 times higher in protein than pig milk replacer diluted 1:1 and on the other hand 3.66 times more concentrated, 3.88 times higher in protein than cow milk. In fat it is 4.62 times higher than pig milk replacer and 9.81 times higher than cow milk. At the same time, it has only 5.32% of cow milk lactose.

Rhinocerotidae are phylogenetically closer to *Equidae* than *Bovidae* (Welker et al., 2017). Among the selected milk replacers, Indian rhino milk is most similar to horse milk. Milk concentration of Indian rhino is 19.33% less than horse milk. It has 1.82 times less protein and 4.3 times less fat and 2.04% more lactose.

Giraffe milk is 38.4% more concentrated than cow milk, it has 1.9 times more protein, 2.18 times more fat and 1.56 times less lactose. Feeding neonate giraffes with 2 times concentrated cow milk replacer would result in excessive lactose levels.

Bat milk is quite similar to goat milk. It differs in concentration only by 0.25%, however, it is 1.42 times higher in protein and 1.18 times higher in lactose.

Cynomolhus monkey milk is in concentration similar to goat and human milk. The lactose level is only 5.95% higher than in goat milk, however the protein and fat is closer to soy milk, and monkey milk is 4.82% higher in protein and 1.52 times higher in fat.

Rabbit milk is comparable to zoologic milk replacer, PetAg Milk matrix 33/40 in 1:1 dilution, where concentrations differ by 0.5-0.8% from natural rabbit milk.

Although this research compares the major components of milk, it must be stressed that many other factors may play a role in neonate nutrition. Stannard et al. (2020) reported that caseins are the major portion of proteins in ruminants, whereas in single stomach digesters, caseins are found in much smaller amounts. The fatty acid composition of fat is also important. In ruminants, fatty acids are mainly produced by microorganisms, whereas single stomach digesters seem to have a unique need of certain fatty acids and even their isomerism (Stannard et al., 2020).

Changes in milk components during lactation in wildlife species

Changes in milk components during lactation should also be taken into consideration when selecting the milk replacer (Table 3).

The sequential pattern of changes recorded in the milk composition of different species of Marsupials is generally similar, with increasing solids and a reversal of the carbohydrate and lipid fractions as lactation proceeds. Protein concentration remains at a relatively constant fraction of the solids component (Stannard et al., 2020).

In North American opossum, solids progressively increase until the 11^{th} week and then decrease after the 12^{th} week (Green et al., 1996). In Kangaroo, solids decrease during lactation, while total fat and protein increase (Poole et al., 1982). In Koala milk, solids increase until the 7^{th} week then decrease towards the 10^{th} week. In the 7^{th} week, carbohydrates reach maximum levels of 8.8%, which fall progressively to 1.1% by the 12^{th} week (Krockenberger et al., 1996).

Elephant milk increases in protein and fat until the 18^{th} month, and protein levels remain high until the end of lactation (Dierenfield et al., 2020).

Grey seal and Bottlenose dolphin milk increases in fat content and concentration throughout lactation (Baker, 1990).

Bactrian camel milk increases in total fat concentration in the first month and gradually decreases in total protein concentration in the first three months, whereas lactose remains stable (Zhang et al., 2005).

Immunological components of milk

Natural milk also has components with immunological function, including immune cells, lactoferrin, glycans and other glycoconjugates. Interestingly, they seem to be present in different amounts among the species.

Within the order of Monotremata and Marsupialia, Stannard et al. (2020) reported that neutrophils were the dominant cell type in colostrum and early stage milk of Tammars and Potoroos, and in late stage milk in Koalas. In contrast, lymphocytes are observed in early and late stage Tammar milk, but not in colostrum samples, and macrophages are only found in late stage Tammar and Wallaby milk (Stannard et al., 2020).

As Monotreme and Marsupial neonate are unable to mount a specific immune response shortly after birth, and due to a lack of circulating mature lymphocytes, they are believed to be highly reliant on maternally-derived strategies for immune defence, including immunoglobulins transferred prenatally via the yolk-sac in some species, immunological cells, and other immunologically important molecules in milk (Stannard et al., 2020).

Lactoferrin (Lf) is a major multifunctional protein in human milk, displaying antimicrobial, iron-chelating, anti-inflammatory, and prebiotic functions.

Table 3. Change in milk composition during lactation.

Order	Species	Lactation length	Time of change	Change in composition	References
Monotremata	**Platypus** *(Ornithorhynchus anatinus)*	–	–	–	
	Echidna *(Tachyglossus aculeatus)*	–	–	–	
Marsupialia	**North American opossum** *(Didelphis virginiana)*	15 weeks	2 day	9% DM	Green et al., 1996
			1st – 7th week	Increase in calcium from 13 to 100 mmol/L	
			9th – 11th week	Progressive increase to 17% TF	
			2 day – 11th week	Progressive increase to 34% DM	
			7th week	Maximum hexose 7%	
			12th week	27 % DM	
			13th week	Decrease to 11% TF	
	Grey Kangaroo *(Macropus sp)*	18 – 23 months	–	Decrease in DM to 3.6% Increase in TF to 13.4 % Increase in TP to 8.2 % Increase in casein from 3.6% to 4.3% Increase in ash from 1.2% to 1.6%	Poole et al., 1982
	Koala *(Phascolarctos cinereus)*	13 weeks	5th – 7th week	Increase in DM from 27.9% to 33.6% Increase in TL from 10.1% to 16.6% Increase in TP from 5.5% to 8.3% Maximum CH 8.8% Oligosaccharide predominant CH in early lactation	Krockenberger et al., 1996
			10th week	Decrease in DM to 28.3%	
			12th week	Gradual increase of TP to maximum level of 12.5% Minimum CH 1.1% Decrease of TL to 14% Lactose is predominant CH in later lactation	

Euliporyphla	**Elephant** *(Elephas maximus)*	2 — 8 years	Few days — 12 months	Large variation in nutrient composition	Dierenfeld et al., 2020
			12 — 18 months	Increase in TP and TF, decrease in CH	
			18 — end	high TP	
Carnivora	**Cheetah** *(Acinonyx jubatus)*	3 months	—	—	Osthoff, 2006
	Grey seal *(Halichoerus grypus)*	3 — 4 weeks	—	Higher TF, Lower water	Baker, 1990
	Giant panda *(Ailuropoda melanoleuca)*	—	—	—	
Artiodactyla	**Bactrian camel (Camelus bactrianus)**	14 — 16 months	12h	Decrease in TP from 14.23% to 9.63%	Zhang et al., 2005
			24h	Increase in TF from 0.27% to 4.18	
			1 month	TF maximum concentration 6.91%	
			3 months	Increase in casein, decrease in whey protein Gradual decrease in TP to 3.55% and TF to 5.65% Lactose remains stable	
	Bottlenose dolphin *(Tursiops truncatus)*	3 —6 years	Early to late	Increased TF and TP; Decreased water Sugar remains	West et al., 2007
	Fin whale *(Balaenoptera physalus)*	—	—	—	
	Indian rhinoceros *(Rhinoceros unicornis)*	20 months	—	—	Grimmel et al., 2018; Osthoff et al., 2021
	Giraffe *(Giraffa camelopardalis)*	12 — 13 months	Early to late	Decrease in DM from 32.2% to 17.3% Decrease in TP from 13.3% to 6.3% Decrease in TF from 15.1% to 7.2%	Hall-Martin et al., 1997
Chiroptera	**Bat** *(Leptonycteris nivalis and Tadarida brasiliensis)*	—	—	—	
Primates	**Cynomolhus monkey** *(Macaca fascicularis)*	1 — 3 months	—	—	Nishikawa et al., 1976
Lagomorpha	**Rabbit** *(Oryctolagus cuniculus)*	6 —8 weeks	—	—	Ludwiczak et al., 2020

DM: dry matter, CP: crude protein, TF: total fat, CH: carbohydrates

Lactoferricin is released in pepsin digestion of hLf and bLf and binds lipopolysaccharides from Gram-negative bacteria such as *Escherichia coli* and *Salmonella* (Pacheco et al., 2014).

Glycans may display pleiotropic functions, conferring protection against infectious diseases and also acting as prebiotics, selecting for the growth of beneficial intestinal bacteria. The prebiotic effect of milk glycans act in prevention of diseases such as necrotizing enterocolitis, a common and devastating disease of preterm infants. Infant formulas are typically based in part on bovine milk components for this reason they may have lower concentration or even lack the specific bioactive glycans that are presumably important for infant development (Pacheco et al., 2014).

Evidence indicates that additional glycoconjugates in milk are also important players in infant protection via breastfeeding, displaying several functions, such as acting as decoys for pathogens, reducing virulence gene expression, preventing binding to host receptors, and impairing colonisation by pathogens in animal models (Pacheco et al., 2014).

Microbiota of milk

Milk microbiota plays an important role in the stabilisation of gut microflora. In the womb, the foetal intestine is a semi-sterile environment and is colonised at birth, when the newborn is exposed to maternal vaginal and gastrointestinal microbiota as well as microbes from the external environment. Vaginal delivery accounts for higher levels of bifidobacteria and lactobacilli whereas infants born via caesarean delivery have low levels of bifidobacteria and high levels of Clostridia. Similar condition occurs in premature infants, who have an abundance of Proteobacteria and Enterobacterias. However, with breastfeeding, infants can retain a high level of bifidobacteria (Pacheco et al., 2014).

The neonatal intestine at birth is immature, and the complex composition of breast milk provides elements for a microenvironment that ensures gut maturation and protection (Pacheco et al., 2014).

Antimicrobial compounds of milk

Milk contains an antimicrobial substance, whey acidic protein four-disulfide domain protein-2, which is increased in pregnancy, and has been shown to have antibacterial activity against a range of pathogenic bacteria but not *Enterococcus faecalis*. The increased levels of expression at these times correlate to the time at which the mammary gland is most at risk of infection. The time of increased expression is also likely to provide the young with additional immune protection whilst they are developing immunocompetence and unable to mount their own immune specific response. Cathelicidins, a type of antimicrobial peptide found in most vertebrates, are also produced by Marsupials and have been identified in milk. Cathelicidins and defensins have also been detected in tissues (brain, kidney, liver, lung, spleen and testis), though they have not been found in Platypus milk (Stannards et al., 2020).

It has been proposed that monotreme lactation originally evolved to prevent desiccation of the eggs or for protection against microbes, and subsequently evolved a nutritional role. The Echidna milk protein gene (EchAMP) is highly expressed in both short-beaked Echidna and Platypus mammary cells during lactation, and it has been identified as an antibacterial protein implicated in milk protein-mediated innate immunity (Kumar et al., 2014). Monotremes express a unique Monotreme lactation protein (MLP) in a variety of tissues including milk, with the highest expression occurring in milk cells (Enjapoori et al., 2014).

Kumar et al. (2014) demonstrated that recombinant MLP selectively exhibited significant bacteriostatic activity against two Gram-positive bacteria, *Staphylococcus aureus* and *Enterococcus faecalis*, but not again *Staphylococcus epidermidis*, and it was not active against all Gram-negative bacteria examined (*Escherichia coli, Pseudomonas aeruginosa* and *Salmonella enterica*). The MLP expressed in milk could represent a more evolutionarily primitive mechanism of milk protein-mediated innate immunity to protect the young.

Adjustment of milk in specific diseases

Milk replacer can be adjusted to help combat specific neonatal disease. In practice, milk is sometimes diluted as a preventive measure against diarrhoea, however Touhami et al. (1989) found that in human medicine there is no immediate clinical advantage to diluting milk in the first 24 hours of feeding well-nourished children with moderate acute watery diarrhoea, if early feeding is associated with the oral rehydration therapy.

On the other hand, the meta-analysis by Basuki et al. (2019) found that infants on dilute formula with double-volume (half-strength) feeds attained their required energy intake earlier and had fewer complications, such as abdominal distension and persistent gastric aspirates, compared to infants on full-strength feeds. However, none of the included studies reported important outcomes like the length of hospital stay or the incidence of serious gastrointestinal problems, such as necrotising enterocolitis.

Prevention from the spread of diseases via milk

Aside from bacterial contamination of milk, we should keep in mind that donor milks may be infected by HIV (human immunodeficiency virus) in some primates. Heat treatment of donor breast milk can be used to inactivate any HIV present in milk. Holder pasteurisation is the treatment most commonly applied to milk in donor milk banks and involves heating the milk to 62.5°C for 30 minutes (Gribble and Hausman, 2012).

Conclusion

In conclusion, artificial feeding of wild orphaned neonates can be managed with milk replacers, which can be additionally adapted in concertation and nutritional values depending on the species and age of the baby to approximate their natural milk and thus limit side effects connected to the use of inappropriate milk.

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Umjetno mlijeko za novorođenu siročad divljih životinja

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Mlijeko je vrlo kompleksna hrana i znatno se razlikuje od vrste do vrste. Mlijeko jednootvora i tobolčara laktozu sadrži samo u tragovima, dok je u viših sisavaca ona prevladavajući ugljikohidrat. U viših sisavcima, koncentracija laktoze se kreće od: 8,5 % u indijskih nosoroga do 63,8 % u sivih tuljana. Ukupne masnoće kreću se od: 0,3 % u indijskih nosoroga do 9,3 % u slonova. Ukupne bjelančevine od 1,2 % u indijskih nosoroga do 12,8 % u kitova perajara i na kraju laktoza od 0,8 % u velikih panda do 6,5 % u indijskih nosoroga. Sastav mlijeka se tijekom laktacije mijenja, na što je posebno potrebno paziti prilikom hranjena tobolčara umjetnim mlijekom. Drugi čimbenici na koje je potrebno paziti su: panel aminokiselina, frakcije sirutke i kazeina, željezo i imunološke komponente. Kod skrbi za divlje životinje često pronalazimo novorođenu siročad koju je potrebno hraniti umjetnim mlijekom. Međutim, ne postoje posebne formule za svako mladunče divlje životinje. Cilj je ovog preglednog rada bio usporediti koja je umjetna zamjena za mlijeko najprikladnija za novorođenčad divljih životinja određene vrste.

Ključne riječi: *novorođena siročad, umjetna prehrana, sastav mlijeka, antimikrobni sastav mlijeka, mikrobiota mlijeka, mliječni nadomjestci*