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Review

Consumption of raw or heated milk from different species: An evaluation of the nutritional and potential health benefits

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ABSTRACT

Based on literature data, the composition of milk from different ruminants (cow, sheep, goat, buffalo, camel, llama, yak and deer) and equidae (horse and donkey) and of human milk were compared to examine possible nutritional differences. Additionally, the alleged health benefits attributed to some of these milks and the effect of heating are discussed.

Very generally, ruminant milk has a lower lactose content, but a higher protein (and casein), fat (with a higher share of saturated and mono-unsaturated fatty acids and a higher cholesterol level), vitamin (except for vitamin C) and mineral content compared to horse or donkey milk. Milk composition may however vary largely, not only between ruminants and non-ruminants, but also between different breeding variants of the same species and between individual animals. Consequently, a constant health promoting potential is, if present, difficult to guarantee. Moreover, differences in milk composition do not only concern the relative proportions of the milk components, but also occur at the molecular level (e.g. monomeric versus dimeric proteins, different amino acid sequence).

Pasteurization is not expected to affect the nutritional (or presumed health) benefits significantly, regardless of differences observed in thermostability between components of considered types of milk. Even though the milk composition of some animal species resembles to a great extent the composition of human milk, it is recommended to give either human milk or formula milk to babies and infants. For people suffering from milk allergy, milk other than e.g. bovine milk may offer a solution, but this greatly depends from one person to another.

Contents

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1. Introduction

Bovine milk is by far the most commonly consumed type of milk, dominating global milk production. However, in certain parts of the world and local contexts, milk from other animal species has a significant share in milk consumption as well. Apart from bovine milk (representing 85% of milk produced worldwide), the worldwide milk production is highest for buffalo milk (11%), followed by goat (2.3%), sheep (1.4%) and camel milk (0.2%) (Gerosa & Skoet, 2012 , p. 40). For other animal species, such as horses and donkeys and yaks, no world statistics are available, but their contribution to the global milk production is less than 0.1%. Additionally, a marginal production of reindeer and llama milk is reported in literature, and even some wild species, such as zebra or eland, are described as potential dairy animals (Faye & Konuspayeva, 2012).

These alternative milks, horse and donkey milk in particular, seem to experience a revival in continental Europe with e.g. new horse dairies in Belgium, France, the Netherlands and Norway (Marchand, Merchiers, Messens, Coudijzer, & De Block, 2009; Uniacke-Lowe, 2011). A number of cosmetic, but also some therapeutic properties (e.g. for treating metabolic, gastrointestinal and liver problems, for curing or preventing atherosclerosis, arthritis and cancer) are attributed to these milks. However, ascribing such properties to milk of a given species not only requires a confirmation of a causal relationship, but also the guarantee that the responsible or active components are present at sufficiently high amounts, irrespectively of external factors. Whereas bovine milk is produced on an industrial scale and as such mostly standardized with respect to fat and protein content, equine milk or milk from other species is usually produced on a local scale and show consequently a higher variability in composition due to differences in breed, feeding regime, etc.

Another aspect, is the increasing popularity and the promotion of raw milk as "health food". Besides a detrimental effect of heating on the beneficial health effects of milk, the most frequently cited arguments of raw milk advocates are a reduced susceptibility to allergies, a higher nutritional quality and a better taste. However, the consumption of raw milk poses a realistic microbiological risk for the consumer. The presence of foodborne pathogens has been demonstrated in many surveys and foodborne infections have been repeatedly reported for *Campylobacter*, *Salmonella* spp. and human pathogenic verocytotoxin-producing *Escherichia coli* after raw milk consumption (Claeys et al., 2013; O'Mahony, Fanning, & Whyte, 2009; Robinson, Scheftel, & Smith, 2013; Verraes et al., in press).

The first aim of the present study is to list the compositions of milk of different species and to discuss their nutritional values. Given that some milks (e.g. horse, donkey and sheep milk) are promoted as a suitable alternative to breast milk and infant formula, a comparison is also made with human milk. Furthermore, the putative health promoting potential of some milk compounds as well as the effect of heating (mainly of pasteurization) on several milk parameters that could be of interest in terms of human nutrition are addressed.

2. Nutritional value: differences in milk composition and effect of heating

Milk of all mammals contains the same principal components, namely water, proteins, fats, carbohydrates, vitamins and minerals, but their content varies widely between ruminant and non-ruminant milk (Table 1). Even between various (non-)ruminants and within a same species the milk composition may differ considerably, given the influence of genetic factors (not only at species but also at breed level), physiological factors (e.g. lactation stage, milking interval), nutritional factors (e.g. feed energy value and composition) and environmental conditions (e.g. location, season). The values presented in this paper should therefore not be viewed as absolute but rather as indicative for the concentration range of milk components. Moreover, methodological differences regarding data collection between consulted papers may contribute to the spread of the presented values.

2.1. Milk protein fractions

2.1.1. General nutritional value

In general, a distinction is made between "casein" milk (i.e. ruminant milk which is relatively rich in casein) and "albumin" milk (i.e. non-ruminant milk which has proportionally a higher whey protein content as indicated by the lower casein/whey ratio) (Table 1). The casein fraction represents around 80% of bovine and sheep milk proteins, roughly 50% of horse milk proteins and less than 50% of human milk proteins (Malacarne, Martuzzi, Summer, & Mariani, 2002; Park, Juárez, Ramos, & Haenlein, 2007; Potočnik, Gantner, Kuterovac, & Cividini, 2011). As can be seen from Table 2, the relative proportion of the main milk casein components differ, not only between ruminants and non-ruminants, but also between ruminant species. Given these different relative proportions, casein micelle characteristics differ as well, in size but also in hydration and mineralization. For instance, sheep and goat casein micelles have on average higher mineralization levels, and are less hydrated, less solvated, and less heat stable than bovine casein micelles (Park et al., 2007). Moreover, the molecular form and amino acid sequence of the milk proteins may differ from one species to another (e.g. at neutral pH β-lg is present as monomer in horse milk, but as dimer in ruminant milk; Salimei & Fantuz, 2012), which additionally affects the protein digestibility, nutritional quality and thermostability.

The nutritional value of milk proteins depends to a great extent on the presence of essential amino acids. A comparison between different species is given in Table 3. When expressed in terms of 100 g protein, differences observed in milk amino acid levels between different species are small and seem to be most likely related to differences in total protein content (Guo et al., 2007).

As to the thermal stability of milk proteins, differences between species are mainly due to differences in amino acid sequence (and number of S–S bridges or sulphydryl groups) and in milk environment (e.g. slightly different pH, fat content). For example,

Table 1
Gross composition of mature milk from different mammals.[a]

	Human	Non-ruminants		Ruminants							
		Horse	Donkey	Cow	Sheep	Goat	Buffalo	Camel	Llama	Yak	(Rein)deer
Total dry matter (g/l)	107–129	93–116	88–117	118–130	181–200	119–163	157–172	119–150	131	135–184	201–271
Proteins (g/l)	9–19	14–32	14–20	30–39	45–70	30–52	27–47	24–42	34–43	42–59	75–130
Casein/whey ratio	0.4–0.5	1.1	1.28	4.7	3.1	3.5	4.6	2.7–3.2	3.1	4.5	∼4–5
Fat (g/l)	21–40	3–42	3–18	33–54	50–90	30–72	53–90	20–60	27–47	53–95	102–215
Lactose (g/l)	63–70	56–72	58–74	44–56	41–59	32–50	32–49	35–51	59–65	33–62	12–47
Ash (g/l)	2–3	3–5	3–5	7–8	8–10	7–9	8–9	6.9–9	5–9	4–10	12–27
Energy (kJ/l)	2843	1936–2050	1607–1803	2709–2843	4038–4439	2802–2894	4244–4779	2410–3286	2709–3358	3811–4295	5541–8436

[a] Based on minimal and maximal values found in literature; in some of the references no specification was given regarding the postpartum period or lactation stage.
Sources: Arman, Kay, Goodall, & Sharman, 1974; Guo et al., 2007; Hassan et al., 2009; Malacarne et al., 2002; Medhammar et al., 2012; Mittaine, 1962; Naert et al., 2013; Park et al., 2007; Potočnik et al., 2011; Salimei & Fantuz, 2012; Shamsia, 2009; Souci, Fachmann, & Kraut, 2008 , p. 1464; Uniacke-Lowe, 2011 , chap. 1 & 2; Xi, Li, & Gao, 2010.

lactoferrin and serum albumin have a similar thermostability in bovine and horse milk, whereas β-lg and α-lactalbumin have a higher thermostability in horse compared to bovine milk. The high thermal stability of equine β-lg may be related to its monomeric form and the lack of a free SH group (Bonomi, Iametti, Pagliarini, & Solaroli, 1994; Uniacke-Lowe, Huppertz, & Fox, 2010). Whey proteins of bovine milk are less resistant to heat denaturation compared to those of buffalo milk (Jainudeen, 2002), which in turn are less heat resistant than camel whey proteins (El-Agamy, 2000; Hassan, Farahat, & Abd El-Gawad, 2009). Even though camel whey proteins have a higher heat stability than bovine whey proteins at temperatures between 63 and 90 °C (Farah, 1986), bovine milk coagulates much slower at higher temperatures. This could be related to the absence or very low levels of β-lg and κ-casein in camel milk (Farah & Atkins, 1992) as milk is more resistant to heat when it is characterized by a molar β-lg to κ-casein ratio close to 1 (Barłowska, Szwajowska, Litwińczuk, & Król, 2011).

2.1.2. Nutritional functional properties

Milk contains a large number of enzymes, secreted by the mammary gland or of microbial origin, but their biological function is mostly unknown. Given the limited amount of data together with differences in measurement techniques (e.g. use of different substrates), only a qualitative comparison between different species for merely a number of enzymes is possible. Alkaline phosphatase (ALP), a thermal indicator for bovine milk pasteurization, is present in milk from all mammals. However, due to differences in activity (e.g. lower in goat milk and 35 to 350 times lower in horse milk, but higher in sheep milk compared to bovine milk) and thermal inactivation rate (e.g. slower in goat and sheep milk and faster in horse milk compared to bovine milk), the negative ALP test to assess the efficacy of pasteurization does not seem to be universally applicable (Lorenzen, Martin, Clawin-Rädecker, Barth, & Knappstein, 2010; Marchand et al., 2009; Raynal-Ljutovac, Park, Gaucheron, & Bouhallab, 2007; Tziboula-Clarke, 2002; Vamvakaki, Zoidou, Moatsou, Bokari, & Anifantakis, 2006). Xanthine oxidoreductase (XOR) is a major protein of the milk fat globule membrane and may play an antimicrobial defensive role in the neonatal gut, complementing endogenous enzyme of the intestinal epithelium (Harrison, 2006). Its activity is relatively high in bovine milk compared to milk from other species (e.g. goat, sheep, camel and human milk), of which the XORs are largely deficient in molybdenum (Mo), necessary for catalytic activity (e.g. up to 98% of the molecules in human milk lack Mo) (Fox & Kelly, 2006; Tziboula-Clarke, 2002; Uniacke-Lowe, 2011). Plasmin, a proteolytic enzyme, is reported to have a higher activity in horse milk compared to bovine milk. The lipolytic activity on the other hand, is similar in horse, bovine and buffalo milk, but lower in goat and human milk (Shakeel-ur-Rehman & Farkye, 2002; Uniacke-Lowe, 2011).

Other milk protein fractions that are linked to beneficial health effects, include immunoglobulins and growth factors. The main function of immunoglobulins (Igs) is to protect the newborn against infections. Their content is mainly high in colostrum and drops significantly during lactation (El-Agamy, 2000; Griffiths, 2010 p. 520; Korhonen, 2009; Pandya & Haenlein, 2009; Zagorska & Ciprovica, 2012). Horse milk, but particularly buffalo, camel and llama milk have a higher Ig content compared to bovine, sheep, goat and human milk (Table 2) (Bravo, Garnica, & Fowler, 1997; Pandya & Haenlein, 2009). The relative Ig ratios differ as well. For example, IgG is predominant in horse colostrum and in both bovine milk and colostrum, but IgA is the major Ig in mature horse milk and in human milk and colostrum (Elfstrand, Lindmark-Månsson, Paulsson, Nyberg, & Åkesson, 2002; Uniacke-Lowe, 2011; Zagorska & Ciprovica, 2012).

During high temperature/short time (HTST) pasteurization (72°C/15 s) only 10 to 30% of bovine milk Ig activity is lost, whereas ultrahigh temperature (UHT) treatment (138°C/4 s) destroys the majority of the specific immune activity of milk. It is however, difficult to determine Ig heat losses accurately or to compare the heat induced Ig losses between different species since chemical composition, pH and other milk factors affect Ig levels during thermal treatment. In general, studies suggest that the antigen-binding region of the Ig molecule is more thermolabile than the other molecule regions, and that IgG is the most and IgM the least thermostable (Elfstrand et al., 2002; Uniacke-Lowe, 2011; Zagorska & Ciprovica, 2012).

Growth factors (GF), such as epidermal (EGF), insulin-like (IGF-1 and -2), transforming (TGF-β1 and TGF-β2) and fibroblast (FGF-1 and -2) growth factors, play a role in growth and development and are present in the blood, the milk, the eggs and most tissues of the majority of animal species. Some growth factors are also discussed as health-impairing factor. For example, a positive correlation has been observed between IGF-1 blood levels and prostate, breast and colorectal cancer risk, but more research is needed on a possible association between exogenous GF intake (e.g. from milk or dairy products) and GF blood levels or cancer risk (Anses, 2012). Available data on the GF content in milk concern mainly bovine and human milk (Table 2). The GF content of milk not only depends on the animal species, but also on the lactation period, the time of milking and the number of parturitions (Anses, 2012; Odle, Zijlstra, & Donovan, 1996; Park, 2009). Similarly to Igs, GF preserve some activity after pasteurization, but are almost completely inactivated after UHT treatment. GF are not only inactivated by heating, but also during storage and the various stages of digestion (Anses, 2012; Elfstrand et al., 2002). Based on available data for IGF-1, it is presumed that if GF of dairy origin would enter the bloodstream, the amount would be too low compared to the circulating and endogenously produced amounts of GF (Anses 2012).

In contrast to the total amino acid composition, which is basically similar between species (Table 3), the composition of free amino acids (FAA) varies considerably. Human milk e.g., has a FAA

Table 2
Protein fractions (g/l) of mature milk from different species.[a]

	Human	Non-ruminants		Ruminants							
		Horse	Donkey	Cow	Sheep	Goat	Buffalo	Camel	Llama	Yak	(Rein)deer
Total casein	*2.4–4.2*	*9.4–13.6*	*6.4–10.3*	*24.6–28*	*41.8–46*	*23.3–46.3*	*32–40*	*22.1–26*		*34.3–45.8*	*70–80*
α_{s1}-Casein	0.77	2.4	Present	8–10.7	15.4–22.1[l]	0[m]–13.0[l]	8.9			9.3–13.1	
α_{s2}-Casein	–	0.20	Present	2.8–3.4		2.3–11.6[l]	5.1			3.6–6.5	
β-Casein	3.87	10.66	Present	8.6–9.3	15.6–17.6[l]	0[m]–29.6[l]	12.6–20.9			15.0–20.6	
κ-Casein	0.14	0.24[k]	Present	2.3–3.3	3.2–4.3[l]	2.8–13.4[l]	4.1–5.4	(–)[n]		4.9–8.5	
γ-Casein	–	Present		0.8							
Casein micel (nm)	64–80	255	~100–200	150–182	180–210	260	180	380			
Total whey proteins	*6.2–8.3*	*7.4–9.1*	*4.9–8.0*	*5.5–7.0*	*10.2–11*	*3.7–7.0*	*6*	*5.9–8.1*			*13.4*
β-Lactoglobulin	–	2.55	3.3	3.2–3.3	6.5–8.5[l]	1.5–5.0[l]	3.9	(–)[o]	(–)[q]	3.4–10.1	
α-Lactalbumin	1.9–3.4	2.37	1.9	1.2–1.3	1–1.9[l]	0.7–2.3[l]	1.4	0.8–3.5		0.2–1.7	
Serum albumin	0.4–0.5	0.37	0.4	0.3–0.4	0.4–0.6[l]		0.29	7–11.9		0.2–3.1	
Proteose pepton				0.8–1.2			3.31				
Lactoferrin	1.5–2.0	0.1–2.0	0.07–0.37	0.02–0.5	0.8[l]	0.02–0.2	0.03–3.4	0.02–7.28	(>)[r]		
Lysozyme	0.1–0.89	0.5–1.33	1.00–1.43	(70–600) x 10^{-6}	100 × 10^{-6}	250 × 10^{-6}	(120–152) x 10^{-6}	(60–1350) x 10^{-6}			
Immunoglobulins (Ig)	*0.96–1.3*	*1.63*	*1.30*	*0.5–1.0*	*0.7*[p]		*10.66*	*1.5–19.6*			
IgG	0.03	0.38		0.15–0.8		0.1–0.4	0.37–1.34	0.72–2.23	5.7–60.5		
IgA	0.96	0.47		0.05–0.14		0.03–0.08	0.01–0.04				
IgM	0.02	0.03		0.04–0.1		0.01–0.04	0.04–1.91				
Casein/whey ratio	*0.4–0.5*	*1.1*	*1.28*	*4.7*	*3.1*	*3.5*	*4.6*	*2.7–3.2*	*3.1*	*4.5*	*~4–5*
Growth factors (GF)											
EGF[b] (μg/l)	0.001–350	~8		<2–155	<0.8						
IGF-1[c] (μg/l)	0.1–19	11		<2–101		4.71–14.5					
IGF-2[c] (μg/l)	2.7–35			~2–117		106					
TGF-α[d] (μg/l)	~0.24–0.28			~0.1							
TGF-β[d] (μg/l)	935			4.3							
TGF-β1[d] (μg/l)	0.08–0.6			0.21–3.7							
TGF-β2[d] (μg/l)	0.8–5.3			0–71							
FGF-1[e] (μg/l)				0.02							
FGF-2[e] (μg/l)				0.5–1							
NPN[f]	*0.45*	*0.38*	*0.46*	*0.27–0.38*		*0.40–0.61*		*0.68*	*1.35*	*0.4–0.5*	*2.2*
Putrescine (μmol/l)	0.33–1.29		0.03–4.25[s]	1	0.40–0.53	0.01–6.00					
Spermidine (μmol/l)	2.20–7.11		0.04–0.23[s]	1–4.7	1.61–2.05	1.04–39.67					
Spermine (μmol/l)	1.00–6.63		0.03–0.25[s]	1–4.00	1.88–2.39	0.81–3.80					
CMP[g] (μmol/l)	18.3–66.0			2.9–49.0	21.6–362.0	8.7–80.7					
UMP[h] (μmol/l)	6.4–17.7			Traces-394.9	110.7–1451.5	123.7–558.6					
GMP[i] (μmol/l)	1.0–3.3			Traces-8.3	Traces-9.7	Traces-9.9					
AMP[j] (μmol/l)	1.4–33.4			Traces-53.8	17.2–286.8	5.5–110.0					
Sources	b, d, e, h, i, k, m, q, r	a, b, d, h, p, q, x, z	d, h, i, k, q, r	b, d, e, h, i, k, l, m, n, q, r, v, x	d, e, g, i, q, r, x	b, d, e, i, n, q, r, t, u, x	c, d, m, q, v, ab	d, k, o, q, s, v	w, y	f, j	aa, ab

a: Naert et al., 2013; b: Anses, 2012; c: Abd El-Salam & El-Shibiny, 2011; d: Barłowska et al., 2011; e: Bernacka, 2011; f: Li et al., 2011; g: Potočnik et al., 2011; h: Uniacke-Lowe, 2011 , chap. 1 & 2; i: La Torre et al., 2010; j: Li et al., 2010; k: El-Agamy, 2009; l: Korhonen, 2009; m: Pandya & Haenlein, 2009; n: Park, 2009; o: Shamsia, 2009; p: Sheng & Fang, 2009; q: Benkerroum, 2008; r: Michaelidou, 2008; s: El-Hatmi, Girardet, Gaillard, Yahyaoui, & Attia, 2007; t: Park et al., 2007; u: Tziboula-Clarke, 2002; v: El-Agamy, 2000; w: Bravo et al., 1997; x: Odle et al., 1996; y: Morin, Rowan, Hurley, et al., 1995; z: Murray, Schaudies, & Cavey, 1992; aa: Arman et al., 1974; ab: Mittaine, 1962.

[a] Based on minimal and maximal values found in literature; in some of the references no specification was given regarding the postpartum period or lactation stage.
[b] EGF = epidermal GF.
[c] IGF = insulin-like GF.
[d] TGF = transforming GF.
[e] FGF = fibroblast GF.

[f] NPN = non-protein nitrogen fraction.
[g] CMP = cytidyl-5′-monophosphate.
[h] UMP = uridyl-5′-monophosphate.
[i] GMP = guanosyl-5′-monophosphate.
[j] AMP = adenosyl-5′-monophosphate.
[k] The presence of κ-casein in horse milk was for several years subject to discussion; some authors reported κ-casein to be absent whereas others found low levels.
[l] Based on percentage.
[m] Absence of β- or α_{s1}-casein in milk from animals carrying the respective null alleles.
[n] Camel milk contains probably too little κ-casein to be detectable, and
[o] The presence of β-lactoglobulin in camel milk is subject to discussion (Farah & Atkins, 1992).
[p] In skimmed milk.
[q] Was not detected.
[r] Llama milk is reported to have a higher lactoferrin level than to cow milk (Morin, Rowan, Hurley, et al., 1995).
[s] Converted from µg/l.

content of 3020 µmol/l compared to 578 µmol/l in bovine and 1960 µmol/l in horse milk (Uniacke-Lowe et al., 2010). FAA, which are more easily absorbed than protein-bound amino acids, mainly consist of the non-essential amino acids glutamate, glycine, aspartate and alanine (Park et al., 2007). Glutamate and glutamine are a source of α-ketoglutaric acid in the citric acid cycle and also act as neurotransmitters in the brain (Agostini, Carratù, Boniglia, Riva, & Sanzini, 2000; Uniacke-Lowe et al., 2010). The content of free glutamate and glutamine is respectively around 1184 and 285 µmol/l in human milk, 568 and 485 µmol/l in horse milk, and 117 and 12 µmol/l in bovine milk (Uniacke-Lowe et al., 2010). The FAA taurine (an aminosulfonic acid derived from methionine and cysteine, and in strict sense no amino acid) and carnitine (synthesized from lysine and methionine), do not occur as protein-bound amino acids. Taurine and carnitine are essential nutrients for newborns due to their insufficient endogenous synthesis. Taurine may act as a membrane stabilizer and growth modulator, and plays a role in the formation of bile acids, which facilitate lipid digestion and absorption. Human milk contains significantly more taurine (300 µmol/l) compared to sheep (140 µmol/l), horse (30 µmol/l) or bovine milk (10 µmol/l) (Park et al., 2007; Uniacke-Lowe et al., 2010). The level of carnitine, which plays an important role in fatty acid transport, ketogenesis and thermogenesis, is, on the other hand, higher in bovine compared to human milk (160–200 vs. 30–80 µmol/l) (Park, 2009).

The FAA represent 10–20% of the milk non-protein nitrogen (NPN) fraction. The NPN fraction consists furthermore mainly of urea, peptides and ammonium. Additionally, the NPN fraction includes some polyamines and nucleotides that can supplement the human biosynthesis (e.g. during growth when the need of children for polyamines is higher). Bovine milk has on average a smaller NPN fraction than human, horse, donkey or goat milk (Table 2). Similarly, milk polyamine and nucleotide levels differ significantly between species, but also between breeds of the same species (La Torre, Saitta, Potortí, Di Bella, & Dugo, 2010). Upon heating, cytidine and guanine levels increase, whereas the adenosine level decreases. This is mainly related to an increased catalytic activity of milk adenosine deaminase and of ALP at lower heating temperatures, followed by hydrolysis of the nucleotide phosphate group (Schlimme, Martin, & Tait, 2002).

2.2. Milk fat

The fat content of donkey and horse milk is remarkably lower than the fat content of human and ruminant milk, which is also reflected by their calorific value (Table 1). Milk from reindeer and other deer species is in particular characterized by a high fat content. Horse and donkey milk fat consist for 80–85% of triglycerides, for 9.5% of free fatty acids and for 5–10% of phospholipids. Bovine, sheep, goat and human milk fat consist for 97–98% of triglycerides, but have only low levels of phospholipids (0.5–1.5%) and free fatty acids (0.7–1.5%) (Doreau & Martin-Rosset, 2002; Jensen, Ferris, Lammi-Keefe, & Henderson, 1990; Malacarne et al., 2002; Park et al., 2007; Uniacke-Lowe, 2011). Compared to ruminants, horse and donkey milk fat contain a higher percentage of polyunsaturated fatty acids (PUFA) and (to a lesser extent) a lower percentage of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) (Table 4). In absolute values, donkey milk contains on average 1.69 g/l PUFA, 5.46 g/l SFA and 1.96 g/l MUFA compared to respectively 5.78, 15.2 and 16.9 g/l in human milk and 1.31, 25.8 and 9.2 g/l in bovine milk (Gastaldi et al., 2010). The fatty acids of horse and donkey milk are mainly unsaturated or short-chained, which is interesting from a nutritional point of view. For example, horse milk contains about 10 times more caprylic acid ($C_{8:0}$), 3 times more capric acid ($C_{10:0}$) and

Table 3
Amino acid distribution of mature milk from different species (expressed as mg/100 g milk).[a]

	Human	Non-ruminants		Ruminants							
		Horse	Donkey	Cow	Sheep	Goat	Buffalo	Camel	Llama	Yak	(Rein)deer
Protein content (g/100 g milk)	0.9–1.9	1.4–3.2	1.4–2.0	3.0–3.9	4.5–7.0	3.0–5.2	2.7–4.7	2.4–4.2	3.4–4.3	4.2–5.9	7.5–13
Essential amino acids											
Histidine	30	56	36	100	167	98	78	69	110		292
Isoleucine	75	90	87	140	338	207	203	162	209	228	460
Leucine	131	229	135	290	587	314	366	201	376	636	971
Lysine	81	189	115	270	513	290	280	132	315	375	909
Methionine	23	35	28	60	155	80	97	66	118	143	271
Phenylalanine	57	111	68	160	284	155	162	132	175	233	466
Threonine	60	101	56	150	268	240	182	135	167	214	471
Tryptophan	23	28	n/a[b]	50	84	44	53	40	n/a	85	144
Valine	78	97	102	160	448	240	219	135	209	313	606
Non-essential amino acids											
Alanine	52	76	55	100	269	118	132	69	95	137	320
Arginine	52	123	72	110	198	119	114	66	137	197	309
Aspartate	108	246	140	260	328	210	309	228	270	348	668
Cysteine	22	14	7	20	35	46	48	63	27	51	78
Glycine	34	45	19	60	41	50	80	69	53	138	233
Glutamate	231	474	358	770	1019	626	477	597	836	864	2116
Proline	112	197	138	320	580	368	364	396	388	128	963
Serine	66	147	98	160	492	181	227	142	156	202	568
Tyrosine	61	101	58	150	281	179	183	102	152	172	563
Total											
Essential amino acids	558	936	627	1380	2844	1668	1640	1073	1680	2227	4590
Amino acids	1854	3295	2199	4710	8931	5233	5214	3878	5472	6691	14,998

[a] In some of the references no specification was given regarding the postpartum period or lactation stage.
[b] Not available.
Sources: U.S. Department of Agriculture, Agricultural Research Service. 2013; Medhammar et al., 2012; Uniacke-Lowe, 2011 , chap. 1 & 2; Guo et al., 2007; El-Agamy, 2006; Haenlein, 2004; Davis, Fiorotto, & Reeds, 1994.

2 times more lauric acid ($C_{12:0}$) than bovine milk. Horse and donkey have additionally higher levels of linoleic acid ($n-6$ C18: 2) and α-linolenic acid ($n-3$ C18: 3) than bovine milk (respectively 5 and 224 times more) (Salamon, Salamon, Csapó-Kiss, & Csapó, 2009).

Differences observed in milk fatty acid composition are to some extent related to differences in feed, but also to differences in mechanisms of fatty acid synthesis. Whereas the milk fat composition of non-ruminants reflects closely the composition of dietary lipids, fatty acids in the feed of ruminants are hydrogenated to SFA

Table 4
General fatty acid profile (% of total fatty acids) and cholesterol content of mature milk from different species.[a]

	Human	Non-ruminants		Ruminants							
		Horse	Donkey	Cow	Sheep	Goat	Buffalo	Camel	Llama	Yak	(Rein)deer
SFA[b]	39.4–45	37.5–55.8	46.7–67.7	55.7–72.8	57.5–74.6	59.9–73.7	62.1–74	47[e]–69.9	65	60–65	84[e]
MUFA[b]	33.2–45.1	18.9–36.2	15.31–35.0	22.7–30.3	23.0–39.1	21.8–35.9	24.0–29.4	28.1–31.1	31	18–3.8	20
PUFA[b]	8.1–19.1	12.8 –51.3	14.17–30.5	2.4–6.3	2.5–7.3	2.6–5.6	2.3–3.9	1.8–11.1	4	2[e]–6.2	4[e]
$C_{18:2}$[c]	6.0–17.7	3.6–20.3	6–15.2	1.2–3.0	1.6–3.6	1.9–4.3	2.0	1.2–2		1.5	2
$C_{18:3}$[c]	0.6–3.4	2.2–31.2	4–16.3	0.3–1.8	0.5–2.3	0.2–1.2	0.2–1.4	0.6–1		0.3	0.4
n-6:n-3 ratio	7.4–8.1	0.3–3.5	0.9–6.1	2.1–3.7	1.0–3.8	4.0					
CLA[d]	0.2–1.1	0.02–0.1[e]	nd[f]	0.2–2.4	0.6–1.1	0.3–1.2	0.4–1	0.4[e]	1	0.2[e]	
Cholesterol (mg/100 ml milk)	14–20	5.0–8.8		13.1–31.4	14–29.0	10.7–18.1	4–18.0	31.3–37.1		22	
Fat globule diameter (μm)	4	2–3	1–10	2.8–4.6	3.0–3.8	2.6–3.5	4.1–8.7	3.0		4.4	
Ref.	e, g, j, l, p, q, m, n	a, b, d, e, l, p, q	b, d, e, g, l, m, p	b, d, f, g, h, l, j, m, n, p, q, r	b, c, f, g, h, l, k, n, o, q	b, c, f, g, h, l, n, o, q	d, f, g, n, r	g, j	d	d, i, j, r	d

a: Naert et al., 2013; b: Devle et al., 2012; c: Mayer & Fiechter, 2012; d: Medhammar et al., 2012; e: Salimei & Fantuz, 2012; f: Abd El-Salam & El-Shibiny, 2011; g: Barłowska et al., 2011; h: Bernacka, 2011; i: Liu et al., 2011; j: Nikkah, 2011; k: Radzik-Rant, Rozbicka-Wieczorek, Czauderna, Rant, & Kuczyńska, 2011; l: Uniacke-Lowe, 2011 , chap. 1 & 2; m: Gastaldi et al., 2010; n: Park, 2009; o: Park et al., 2007; p: Malacarne et al., 2002; q: Jahreis et al., 1999; r: Mittaine, 1962.
[a] Based on minimal and maximal values found in literature; in some of the references no specification was given regarding the postpartum period or lactation stage.
[b] Saturated, mono- and poly-unsaturated fatty acids respectively.
[c] Linoleic/linolenic acid.
[d] Conjugated linoleic acid.
[e] Values were calculated as the sum of reported individual values (Medhammar et al., 2012).
[f] Not detected.

by ruminal microbes before absorption (Jahreis et al., 1999; Korhonen, 2009; Stender, Astrup, & Dyerberg, 2008). During this biohydrogenation process trans fatty acids are formed as well, including vaccenic ($C_{18:1\ 11t}$) and rumenic acid ($C_{18:2\ 9c,11t}$), an isomer of the conjugated linoleic acids (CLA) (Jahreis et al., 1999; Korhonen, 2009; Stender et al., 2008). Some positive health effects are attributed to CLA isomers such as lowering the risk of cardiovascular diseases, carcinogenesis, diabetes and osteoporosis, and modulation of the immune system (Barłowska et al., 2011; German & Dillard, 2006; Uniacke-Lowe, 2011). The presence of trans fatty acids in horse milk suggests some fatty acid hydrogenation by intestinal microorganisms before absorption (Hoffman et al., 1998). Additionally, not only ruminants, but also non-ruminants and humans are able to convert vaccenic acid into rumenic acid, but to a much lesser extent (Stender et al., 2008).

Besides the composition of milk fat, also the distribution of fatty acids on the glycerol backbone needs to be considered, as it determines the lipolysis and thus bioavailability of fatty acids and, therefore, their possible beneficial or detrimental effects on health (German & Dillard, 2006). For example the position of the fatty acids on the glycerol chain, and especially of the saturated long-chain fatty acids, is similar in donkey and human milk, where the *sn*-2 position is mainly occupied by palmitic acid ($C_{16:0}$) (around 74% of the total compared to around 47% in bovine milk). In bovine milk, mainly fatty acids with a length of $C_{4:0}$ to $C_{10:0}$ are esterified at the *sn*-3 position (Gastaldi et al., 2010; Jensen et al., 1990).

The milk of most of the considered ruminants contains a similar cholesterol level as human milk, whereas the cholesterol level of horse and donkey milk appears to be much lower (Table 4). Cholesterol is mostly associated with cardiovascular diseases, but is also an important component of body cell membranes and of the central nervous system (Dietschy & Turley, 2004; Gidding et al., 2006). It has been suggested that human milk cholesterol may be responsible for long-term regulation of cholesterol metabolism and myelin synthesis, although results are not univocal (Gidding et al., 2006; Schanler, 2011).

Heat treatment of milk mainly affects the milk fat globule membrane (MFGM) and a number of heat-sensitive MFGM protein components, changing the agglomeration and creaming of fat globules (Raynal-Ljutovac et al., 2007; Spreer, 1998 , p. 483). Some of the heat-induced changes of the MFGM include the association of whey proteins and casein with the MFGM through sulphydryl–disulphide interchange reactions, the release of sulphydryl compounds, most notably H_2S, and the removal of phospholipids at elevated temperature (van Boekel & Walstra, 1995). Thermal degradation of milk lipids is generally not observed, because the temperature required for non-oxidative decomposition of fatty acids (>200 °C) is well outside the range in which milk products are heated. On the other hand, oxidation reactions may occur, even at low temperatures, via active oxygen species generated by enzymatic reaction or exposure to light. However, at more intense heating (>100°), fat autoxidation is restrained due to, amongst others, the formation of antioxidants in the Maillard reaction (van Boekel & Walstra, 1995). It can thus be presumed that heating has only a minor effect on the nutritional value of milk fat. Moreover, changes observed in the CLA content of bovine and buffalo milk after heating appeared to be less relevant than breed or feed related variations (Mattila-Sandholm & Saarela, 2003 , p. 416; Pandya & Haenlein, 2009).

2.3. Milk sugars

Lactose is quantitatively the main milk sugar. Its concentration is similar in horse, donkey and human milk, but lower in bovine or other ruminant milk (Table 1). Other milk carbohydrates, which are free or bounded to lipids, proteins or phosphate, include a small fraction of oligosaccharides. They are composed of galactose, fucose, N-actylglucosamine and/or N-acetyl neuramic acid (sialic acid) and contain mostly a lactose unit at their reducing end. They have the potential to modulate the growth of intestinal flora, to influence different gastro-intestinal and inflammatory processes and to provide protection against bacterial and viral infections (Kunz & Rudloff, 2006). Their structural complexity however, renders a functional comparison between species difficult (Potočnik et al., 2011; Urashima, Saito, Nakamura, & Messer, 2001). In general, the oligosaccharide level is much lower in animal milk (0.25–0.30 g/l in goat milk, >0.1 g/l in buffalo milk, 0.03–0.09 g/l in bovine milk and 0.02–0.04 g/l in sheep milk) compared to human milk (5–10 g/l) (Abd El-Salam & El-Shibiny, 2011; Martinez-Ferez et al., 2006; Mehra & Kelly, 2006). No data were found in literature on the oligosaccharide level of horse milk, but it is probably much lower than the level of horse colostrum. The latter is reported to contain 18.6 g/l oligosaccharides compared to 20 g/l in human colostrum (Nakamura et al., 2001; Uniacke-Lowe, 2011 , chap. 1 & 2).

Oligosaccharide-bound sialic acid (but also glycoprotein-bound and free sialic acid) is reported to affect the intestinal flora development and, most probably, the level of glycosylation of gangliosides of the brain and the central nervous system (Malacarne et al., 2002; Potočnik et al., 2011; Urashima et al., 2001). Sialic acid levels measured in human milk (1 g/l) are significantly higher than the levels measured in bovine or horse milk (around 0.05–0.2 g/l) (Malacarne et al., 2002; Potočnik et al., 2011).

During heating, only a small fraction of lactose is converted into lactulose (around 0.5% during UHT treatment and 1–2% by sterilization). Lactulose has, similarly to lactose, prebiotic properties (Berg & van Boekel, 1994; Schaafsma, 2002). Pasteurization does not affect the oligosaccharide level of human milk (Bertino et al., 2008). Heating, but also bacterial proteolysis may release sialic acid from κ-casein (Khalifa, Niki, & Arima, 1985; Zalazar, Palma, & Candioti, 1996).

2.4. Milk vitamins

The total vitamin content of milk is highly variable and depends on the vitamin status and the feeding regime of the mother (with the level of water-soluble vitamins being more influenced by the feed than the level of the fat-soluble vitamins). The vitamin content of horse and donkey milk is on average lower than the vitamin content of ruminant milk. This is illustrated in Table 5, in which the vitamin content is additionally expressed in terms of percentage of the recommended daily intake (RDI) based on the consumption of one small glass (100 ml) of milk. An exception is the vitamin C level, which is relatively high in horse milk (Csapó, Stefler, Martin, Makray, & Csapó-Kiss, 1995; Doreau & Martin-Rosset, 2002; Mittaine, 1962). Camel milk as well, has a high vitamin C and can contain three times as much vitamin C than bovine milk (Farah, Rettenmaier, & Atkins, 1992) (Table 5). Additionally it is noted that sheep, goat and buffalo milk have a higher vitamin A content than bovine milk. Their milk is whiter than other milk due to their ability to convert the yellow β-carotene to vitamin A (Abd El-Salam & El-Shibiny, 2011; Jainudeen, 2002; Park et al., 2007).

For bovine milk, only small or no losses have been reported for vitamins B_6 (pyridoxine), B_3 (niacin), B_5 (panthothenic acid), B_7 (biotin), A, D and E, even during conventional sterilization (Andersson & Öste, 1995; Burton, 1984; Claeys et al., 2013; Mac Donald et al., 2011; Schaafsma, 1989). Owing to differences in milk composition, the effect of heating on the vitamin content will slightly differ from one milk type to another. As such, the heat sensitivity of vitamin C is higher in camel than in bovine milk (Medhammar et al., 2012) and upon different heat treatments,

Table 5
Vitamin content (μg/100 ml) of mature milk from different mammals[a] and their contribution to the recommended daily intake (% RDI)[b] through the consumption of 100 ml of milk.

	Human	Non-ruminants		Ruminants				
		Horse	Donkey	Cow	Sheep	Goat	Buffalo	Camel
Water soluble vitamins								
Thiamin (B_1)	14–17	20–40	21–60	28–90	28–80	40–68	40–50	10–60
	2% (3%)	*4% (8%)*	*5% (12%)*	*8% (18%)*	*7% (16%)*	*6% (14%)*	*5% (10%)*	*5% (12%)*
Riboflavin (B_2)	20–60	10–37	30–97	116–202	160–429	110–210	100–120	42–168
	5% (15%)	*3% (9%)*	*8 (24%)*	*17% (15%)*	*36% (107%)*	*18% (53%)*	*10% (30%)*	*14% (42%)*
Niacin (B_3)	147–178	70–140	57–90	50–120	300–500	187–370	80–171	400–770
	1% (22%)	*1% (18%)*	*1% (11%)*	*1% (15%)*	*4% (63%)*	*3% (46%)*	*1% (21%)*	*6% (96%)*
Pantothenic acid (B_5)	184–270	277–300		260–490	350–408	310	150–370	88–368
	5% (14%)[c]	*6% (15%)*[c]		*10% (25%)*[c]	*8% (20%)*[c]	*6% (16%)*[c]	*7% (19%)*[c]	*7% (18%)*[c]
Pyridoxine (B_6)	11–14	30		30–70	27–80	7–48	25–330	50–55
	1% (4%)	*2% (8%)*		*4% (18%)*	*4% (20%)*	*3% (12%)*	*18% (83%)*	*3% (14%)*
Biotin (B_7)	0.4–0.6			2–4	0.9–9.3	1.5–3.9	11–13	
	2% (12%)			*13% (80%)*	*31% (186%)*	*13% (78%)*	*43% (260%)*	
Folic acid (B_9)	5.2–16	0.13		1–18	0.24–5.6	0.24–1	0.6	0.4
	8% (32%)	*0% (0%)*		*9% (36%)*	*3% (11%)*	*1% (2%)*	*0% (1%)*	*0% (1%)*
Cobalamin (B_{12})	0.03–0.05	0.3	0.11	0.27–0.7	0.30–0.71	0.06–0.07	0.3–0.4	0.2
	4% (10%)	*21% (60%)*	*8% (22%)*	*50% (140%)*	*51% (142%)*	*5% (14%)*	*29% (80%)*	*14% (40%)*
Ascorbic acid (C)	3500–10,000	1287–8100	2000	300–2300	425–6000	900–1500	1000–2540	2400–18,400
	9% (20%)	*7% (16%)*	*2% (4%)*	*2% (5%)*	*5% (12%)*	*1% (3%)*	*2% (5%)*	*17% (37%)*
Fat soluble vitamins								
Vitamine A (RE)[d]	30–200	9.3–34	1.7	17–50	41–50	50–68	69	5–97
	40% (53%)	*7% (9%)*	*0% (0%)*	*10% (13%)*	*10% (13%)*	*14% (18%)*	*14% (18%)*	*19% (26%)*
Chole-calciferol (D_3)	0.04–0.1	0.32		0.3	0.18–1.18	0.25		0.3–1.6
	1% (1%)	*3% (3%)*		*3% (3%)*	*12% (12%)*	*3% (3%)*		*16% (16%)*
α-Tocopherol (E)	300–800	26–113	5.1	20–184	120		190–200	21–150
	5% (20%)	*1% (3%)*	*0% (0%)*	*1% (5%)*	*1% (3%)*		*1% (5%)*	*1% (4%)*
Phyllo-quinone (K)	0.2–1.5	2.9		1.1–3.2				
	3% (15%)	*6% (29%)*		*6% (32%)*				
References	b, c, d, e	a, b, g, h, i, l	a, b, d, i	a, c, d, e, g, l, m, n	c, d, f, i, k, n	c, d, i, k, n	a, d, n	a, c, e, j, m

a: Medhammar et al., 2012; b: Salimei & Fantuz, 2012; c: Barłowska et al., 2011; d: Uniacke-Lowe, 2011 , chap. 1 & 2; e: El-Agamy, 2009; f: Recio, de la Fuente, Juárez, & Ramos, 2009; g: Salamon et al., 2009; h: Sheng & Fang, 2009; i: Souci et al., 2008 , p. 1464; j: Alhadrami, 2002; k: Jandal, 1996; l: Csapóet al., 1995; m: Farah et al., 1992; n: Mittaine, 1962.

[a] Based on minimal and maximal values found in literature; in some of the references no specification was given regarding the postpartum period or lactation stage.
[b] % RDI adults (% RDI infants < 1 year old, between brackets) given in italics, based on highest reported level and lowest RDI value given by the BSHC, 2009 , p. 114.
[c] Niacin equivalents.
[d] Retinol equivalents.

higher vitamin losses are reported in bovine milk compared to buffalo milk (Pandya & Haenlein, 2009). However, the effect of heating on milk vitamins seems to be negligible from a nutritive point of view, since many vitamins are naturally found in relatively low levels in milk (Claeys et al., 2013; Mac Donald et al., 2011). Moreover, storage conditions (light, oxygen) may be as detrimental to vitamins as heating.

2.5. Milk minerals

The ash content is lower in non-ruminant milk compared to ruminant milk (Table 1). Although there are major differences in the mineral content of milk from different species, the concentration of most minerals is higher in donkey and horse milk than in human milk, but significantly lower than in ruminant milk (Fantuz et al., 2012; Uniacke-Lowe, 2011 , chap. 1 & 2). Both the content and the contribution to the RDI of milk minerals from different species are given in Table 6. Milk is mainly a good source of calcium (Ca) and phosphorus (P), which are necessary for bone growth, development, metabolism and maintenance (Adolphi et al., 2009; Cashman, 2006), but is less important with respect to the other minerals. Bovine milk contains about 50% more Ca and twice as much P and potassium (K) than horse and donkey milk, but horse and donkey milk contain about 2–3 times more Ca and P than human milk (Anderson, 1991; Csapó, Salamon, Lóki, & Csapó-Kiss, 2009; Salimei & Fantuz, 2012). Sheep, goat, buffalo and (rein)deer milk contain on average more Ca and P than bovine milk (Abd El-Salam & El-Shibiny, 2011; Jainudeen, 2002; Morin, Rowan, Hurley, & Braselton, 1995; Park, 2009; Tziboula-Clarke, 2002), although these levels may vary greatly.

Comparison of raw bovine milk with UHT-treated and sterilized bovine milk shows essentially no differences in milk salt and trace element levels (Claeys et al., 2013). Intestinal absorption and utilization, and thus the bioavailability of minerals, depend on their chemical form. Upon heating, the diffusible salt content decreases due to a shift to the colloidal form, the extent of which is proportional to the severity of the treatment. The majority of changes are reversible on cooling, but more severe heat treatments (>90 °C) may give rise to some irreversible modifications (Gaucheron, 2005). In a study comparing two groups of low birth-weight preterm infants who were fed raw and heat-treated (63°C/30 min) human milk, no difference was observed in the absorption and retention of Ca, P, and sodium (Na) (Williamson, Finucane, Ellis, & Gamsu, 1978). Similarly in another study, where animals were fed raw, homogenized HTST and homogenized UHT bovine milk, no difference in Ca bioavailability was observed (Weeks & King, 1985).

Not only the chemical form or heating, but also other milk components may affect the bioavailability of milk minerals. As such, lactose, lactulose, CLA, vitamin D and casein phosphopeptides have been suggested as potential enhancers of calcium absorption (Adolphi et al., 2009; Cashman, 2006; Guéguen & Pointillart, 2000). Goat milk (but also milk from other ruminants) has a high casein and Ca content compared to human, horse and donkey milk (Tables 2and 6) (Barłowska et al., 2011). On the other hand, the Ca to

Table 6
Mineral content (mg/100 ml) of mature milk from different mammals[a] and their contribution to the recommended daily intake (% RDI)[b] through the consumption of 100 ml of milk.

	Human	Non-ruminants		Ruminants							
		Horse	Donkey	Cow	Sheep	Goat	Buffalo	Camel	Llama	Yak	(Rein)deer
Ca	28–34	50–135	33–115	112–123	159–242	85–198	112–220	105–157	131–221	119–156	163–320
	4% (16%)	*15% (64%)*	*13% (55%)*	*14% (59%)*	*27% (115%)*	*22% (94%)*	*24% (105%)*	*17% (75%)*	*25% (105%)*	*17% (74%)*	*36% (152%)*
P	14–43	20–121	32–73	59–119	124–175	79–153	85–293	58–104	92–163	77–135	64–270
	5% (36%)	*15% (101%)*	*9% (6%)*	*15% (99%)*	*22% (146%)*	*19% (128%)*	*37% (244%)*	*13% (97%)*	*20% (136%)*	*17% (113%)*	*34% (225%)*
K	53–62	25–87	24–75	106–163	94–162	140–242	92–182	124–179	75–179	83–107	80–156
	21% (201%)[c]	*3% (28%)*[c]	*3% (24%)*[c]	*5% (52%)*[c]	*5% (52%)*[c]	*8% (78%)*[c]	*6% (58%)*[c]	*6% (57%)*[c]	*6% (57%)*[c]	*4% (34%)*[c]	*5% (50%)*[c]
Mg	3–4	3–12	2–8	7–12	16–25	10–36	2–39	8–16	11–19	8–15	11–22
	1% (8%)	*3% (24%)*	*2% (16%)*	*3% (24%)*	*7% (50%)*	*10% (72%)*	*11% (78%)*	*4% (32%)*	*5% (38%)*	*4% (30%)*	*6% (44%)*
Na	10–18	8–58	10–27	58	30–75	28–59	35–95	36–73	19–41	21–38	25–50
	3% (10%)[d]	*10% (32%)*[d]	*5% (15%)*[d]	*10% (32%)*[d]	*13% (41%)*[d]	*10% (32%)*[d]	*16% (52%)*[d]	*12% (40%)*[d]	*7% (22%)*[d]	*6% (21%)*[d]	*8% (27%)*[d]
Citrate				160–176.8	104–205	70–180	144–224	128–185			
Cl	60–63	19	14–50	100–119	99–160	104–209	57–75	132	28–144		68–80
	8% (23%)	*2% (7%)*	*6% (18%)*	*15% (43%)*	*20% (57%)*	*26% (75%)*	*9% (27%)*	*17% (47%)*	*18% (51%)*		*10% (29%)*
Fe	0.04–0.2	0.02–0.15	0.04–0.26	0.03–0.1	0.08–0.1	0.05–0.1	0.042–0.2	0.07–0.37	0.07	0.04–1.0	0.065
	2% (3%)[e]	*2% (2%)*[e]	*3% (4%)*[e]	*1% (2%)*[e]	*1% (2%)*[e]	*1% (2%)*[e]	*2% (3%)*[e]	*4% (6%)*[e]	*1% (1%)*[e]	*11% (16%)*[e]	*1% (1%)*[e]
Zn	0.2–0.4	0.09–0.64	0.1–0.3	0.3–0.55	0.4–0.9	0.4–0.6	0.15–0.73	0.19–0.6	0.26–0.71	0.7–1.1	1.0–1.3
	5% (20%)	*8% (32%)*	*4% (15%)*	*7% (28%)*	*11% (45%)*	*8% (30%)*	*9% (37%)*	*8% (30%)*	*9% (36%)*	*14% (55%)*	*16% (65%)*
Cu	0.02–0.06	0.02–0.11	0.01–0.03	0.01–0.08	0.03–0.05	0.02–0.05	0.007–0.04	0.01–0.19	0.01	0.04–0.41	
	5% (15%)	*9% (28%)*	*3% (8%)*	*7% (20%)*	*4% (13%)*	*4% (13%)*	*3% (10%)*	*16% (48%)*	*1% (3%)*	*34% (103%*	
Ref.	d, f, k, m	c, d, f, h, l, r	a, c, d, f, o	c, f, i, j, m, y	b, f, m, u, v, y	b, f, m, s, u, v, y	c, e, f, j, y	c, f, i, k, q, t	c, w	c, g	c, n, p, x

a: Fantuz et al., 2012; b: Mayer & Fiechter, 2012; c: Medhammar et al., 2012; d: Salimei & Fantuz, 2012; e: Abd El-Salam & El-Shibiny, 2011; f: Barłowska et al., 2011; g: Li et al., 2011; h: Csapó et al., 2009; i: El-Agamy, 2009; j: Pandya & Haenlein, 2009; k: Shamsia, 2009; l: Sheng & Fang, 2009; m: Park et al., 2007; n: Gallego, Landete-Castillejos, Garcia, & Sánchez, 2006; o: Salimei et al., 2004; p: Vergara, Landete-Castillejos, Garcia, Molina, & Gallego, 2003; q: Alhadrami, 2002; r: Doreau & Martin-Rosset, 2002; s: Tziboula-Clarke, 2002; t: Attia, Kherouatou, & Dhouib, 2001; u: de la Fuente, Olano, & Juárez, 1997; v: Jandal, 1996; w: Morin, Rowan, Hurley, et al., 1995; x: Arman et al., 1974; y: Mittaine, 1962.

[a] Based on minimal and maximal values found in literature; in some of the references no specification was given regarding the postpartum period or lactation stage.
[b] % RDI adults (% RDI infants $<$ 1 year old, between brackets) given in italics, based on highest reported level and lowest RDI value given by the BSHC, 2009 , p. 114.
[c] Based on a body weight of 8 kg for infants.
[d] Note that salt (NaCl) intake is generally too high.
[e] 15% Bio-availability.

P ratio on a weight basis of human milk (about 2.1) and of horse, donkey and camel milk (1.5–1.6) are reported to be more favorable for Ca uptake compared to the Ca to P ratio of bovine milk (about 1.2) (Anderson, 1991; El-Agamy, 2009; Salimei et al., 2004). Another example is iron (Fe), which is naturally low in milk. Despite a similar Fe content, the Fe bioavailability is higher in goat compared to bovine milk. Goat milk has a higher share of nucleotides that contribute to an enhanced Fe absorption in the intestine (Barłowska et al., 2011; Park, 2009). On the other hand, other variables play a role as well. For instance, calcium and casein that have on average higher levels in goat milk although levels may vary greatly (Tables 2and 6), inhibit the absorption of dietary nonheme iron (Ziegler, 2007).

3. Antimicrobial systems

The antimicrobial systems or components of milk that inhibit microbial growth and contribute to the immunity of the neonate, are often used as an argument for attributing health beneficial effects to a given milk type or for consuming raw milk. The available information on the main antimicrobial systems and the effect of heating on these systems, although scarce with respect to milk from animals other than cow, are summarized in Table 7.

The antimicrobial activity of human, horse and donkey milk is mainly determined by lysozyme and lactoferrin, whereas lactoperoxidase and the Igs are the main defense systems in bovine milk. Generally, the scientific evidence supporting the claim that raw milk from cow or from other animals provides immunity to consumers, is only limited and based on *in vitro* experiments often using purified milk components. Moreover, an appropriate delivery system and a controlled release of the components in question are likely to play a crucial role in the pharmacological efficacy as well as the passage through the digestive tract (Cross & Gill, 2000; Korhonen, Marnila, & Gill, 2000). For example, Roos et al. (1995) demonstrated that about 19% of ingested bovine IgG and IgM was found to retain immunological activity in the ileum of healthy human adults. No IgA was detected in the ileum. Besides, the activity or content of most antimicrobial systems or components varies strongly in milk and is mainly high in colostrum with a rapid decline during further lactation (Korhonen, 2009; Malacarne et al., 2002; Šarić et al., 2012; Uniacke-Lowe et al., 2010; Zagorska & Ciprovica, 2012). As such, the effect of heating on antimicrobial systems of milk seems to be of little relevance in this context. On the other hand, lysozyme is reported to increase strongly after the second month of lactation (in human milk), and, being very resistant to acid and proteolysis (in horse milk), to reach presumably the gut relatively intact (Uniacke-Lowe, 2011 , chap. 1 & 2).

4. Milk digestibility

Coagulation or curd formation of milk in the stomach delays the degradation of proteins and improves their assimilation. Differences in total protein composition (casein content and casein/whey protein ratio) and in micelle structure (size, casein distribution, mineralization) (Table 2) determine the rheological properties of milk rennet and affect as such the milk nutrient uptake. High casein-containing milk, like bovine milk, produces a firm and dense coagulum. Like human milk, horse and donkey milk, but also camel and goat milk form soft curds in the stomach, which are more easy to digest (and are physiologically more apt for infant nutrition) (Barłowska et al., 2011; El-Agamy, 2009; Malacarne et al., 2002; Uniacke-Lowe, 2011 , chap. 1 & 2; Uniacke-Lowe et al., 2010). The digestibility of individual milk proteins from different species differs as well. For example, horse β-lg is more easy to digest than goat

Table 7
Antimicrobial components/systems in milk.

Milk component	Antimicrobial properties	Remarks	Effect of heating	Ref.
Lactoferrin (Lf)	-Iron (Fe) binding protein (bacteriostatic) + renders bacterial cell wall permeable -Inhibitor viral infection -Stimulates beneficial intestinal microflora -Synergetic action with Lyz -Cow/human milk: proteolysis to lactoferricin = bactericidal	- Lf content is mainly high in colostrum - On average: Lf content human > horse > camel/buffalo (>llama) ≥ cow (0.1 g/kg) > donkey milk; high variation in buffalo and camel milk - Fe-binding capacity Lf horse ≈ human > cow milk	- Human milk: 56 °C/15 min = 91%; 62,5 °C/5 min = 59%; 62.5 °C/30 min = 27% Lf activity - Cow milk: pasteurization: similar properties as raw milk - Horse milk: comparable stability as cow milk Lf - 100% Inactivation in cow, buffalo and camel milk at 85 °C/30 min	a, b, d, f, k, n
Lysozyme (Lyz) (EC 3.1.2.17)	Bactericidal in combination with Lf	- On average: Lyz content horse & donkey > human >> buffalo and cow > goat and sheep milk; high variation in camel milk - Horse milk Lyz is very resistant to acid and proteolysis and reaches consequently fairly intact the intestines	- Human milk: 56 °C/15 min = 106%; 62.5 °C/5 min = 96%; 62.5 °C/30 min = 67% Lyz activity - Horse milk: at 62 °C/30 min more stable than human milk Lyz, but similar inactivation at 71 °C/2 min or 82 °C/15 s - Cow milk: 65–75 °C/30 min = no significant effect; 80 °C/15 s = >75%.; 85°C/30 min = ~26% Lyz activity - Buffalo milk: 65–75°C/30 min = no significant effect; 85 °C/30 min = ~18% - Camel milk: 65–75 °C/30 min = no significant effect; 85 °C/30 min = ~44%	a, b, c, d, f, h, j, k, n
Immunoglobulins IgG, IgA, IgM	Immunity against pathogens; may provide some lactogenic immunity in the intestinal tract (a)	- Mainly in colostrum - Relative proportion of Ig types in milk differs strongly between species (Table 2) and can change from colostrum to further lactation stadia	- Human milk IgA: 56 °C/15 min = 90%; 62.5 °C/5 min = 77%; 62.5 °C/30 min = 67% - Cow milk: no activity losses at 62.7 °C/30 min; 59–76% activity after HTST pasteurization - Buffalo milk: incomplete denaturation of IgG and IgM at 88 °C/15 min, IgA completely denatured at 63 –88 °C - At 75 °C/30 min: 100% inactivation of IgG in cow and buffalo milk; 68.7% inactivation in camel milk	d, f, g, i, k, l, n
Lactoperoxidase (lactenin) (Lpo) (EC 1.11.1.7)	Bacteriostatic; antimicrobial activity requires the presence of H_2O_2 (produced by some bacteria) and thiocyanate (endogenous). Although both are present in milk, their addition is necessary	Lpo activity : human milk < camel, llama < cow < sheep < goat milk	- Used as an indicator for HTST treatment of cow milk - Sheep and goat milk Lpo are more resistant to heat than cow milk Lpo	d, e, m

a: Šarić et al., 2012; b: Abd El-Salam & El-Shibiny, 2011; c: Uniacke-Lowe, 2011 , chap. 1 & 2; d: Griffiths, 2010 p. 520; e: Lorenzen et al., 2010; f: Uniacke-Lowe et al., 2010; g: Pandya & Haenlein, 2009; h: Benkerroum, 2008; i: Park et al., 2007; j: Tziboula-Clarke, 2002; k: El-Agamy, 2000; l: Korhonen et al., 2000; m: Morin, Rowan, & Hurley, 1995; n: Wills, Han, Harris, & Baum, 1982.

β-lg (Inglingstad et al., 2010), and goat and sheep β-lg are more easily digestible than bovine β-lg (Michaelidou, 2008; Uniacke-Lowe et al., 2010). Whereas α-lactalbumin of all species appears to be relatively hard to digest, the other whey proteins, including lactoferrin and serum albumin, seem to be easily digestible, in human and horse milk as much as in bovine and goat milk (Inglingstad et al., 2010). Heating (95°C/1min) appears to have only a minor effect on the gastrointestinal degradation of caseins, but seems to improve the digestibility of whey proteins (Inglingstad et al., 2010; Kitabatake & Kinekawa, 1998). Digestibility of human, horse, bovine and goat α-lactalbumin for example, is reported to improve upon heating (12–20% at 95°C/1min) (Inglingstad et al., 2010). Heating (pasteurization, UHT) mainly modifies the functional properties of milk proteins (e.g. emulsifying and water binding properties, solubility), but has little effect on their digestibility and nutritional properties (Douglas, Greenberg, & Farrell, 1981; Farrell & Douglas, 1983; Lacroix et al., 2006).

With respect to the digestibility of milk fat, the smaller the fat globule, the more efficient the lipid metabolism. Camel milk has on average smaller fat globules than horse, sheep and goat milk, which in turn have smaller fat globules than bovine milk (Table 4). The milk fat globules of reindeer and buffalo have generally a larger diameter than those of other species (Barłowska et al., 2011; Jandal, 1996; Mittaine, 1962; Park et al., 2007; Salimei & Fantuz, 2012). However, the structure of the fat globule interface plays also a role in fat digestibility as gastric lipases must gain access to the triacylglycerols through this interface. Similarly to human milk fat globules, the surface of horse milk fat globule contains branched oligosaccharide structures, which may enhance digestion by binding lipases. Bovine milk fat globules are coated with a protective layer constituted of proteins and phospholipids (Malacarne et al., 2002). Generally, physico-chemical changes at the interface due to heating, but also due to homogenization (resulting in much finer casein-coated lipid droplets), seem to positively affect lipase access to the triacylglycerols and thus milk digestibility (Armand et al., 1999; Favé, Coste, & Armand, 2004; Michalski & Januel, 2006).

5. Milk allergy & lactose intolerance

Different milk proteins (e.g. α-lactalbumin, serum albumin, lactoferrin) can elicit an allergic reaction, but casein fractions and β-lg appear to be the most common milk allergens (El-Agamy, 2007).

β-lg is absent from human milk and has not been detected in camel and llama milk, but is present at relatively high concentrations in bovine, buffalo, sheep and goat milk as well as in horse and donkey milk (Table 2). Compared to human and equine casein, ruminant casein (except for some goat milks) is relatively abundant with α_{s1}-casein, which is assumed to be a predominant factor in the development of or sensitization to milk allergy (Barłowska et al., 2011; Malacarne et al., 2002; Potočnik et al., 2011).

There are some clinical studies available that examine the use of goat, sheep, camel, buffalo, horse and donkey milk as an alternative in case of cow milk allergy or in hypoallergenic baby formula (Alessandri & Mari, 2007; El-Agamy, 2007; Monti et al., 2007; Restani, Beretta, Fiocchi, Ballabio, & Gali, 2002; Tesse, Paglialunga, Braccio, & Armenio, 2009). Results regarding the advantages of these milks are contradictory and persons suffering cow milk allergy can also react to buffalo, goat, sheep, horse and donkey milk proteins due to a positive cross reaction with their counterparts in bovine milk (Alessandri & Mari, 2007; Caira et al., 2012; El-Agamy, 2007; Restani et al., 2002; Uniacke-Lowe et al., 2010). Milk from animals other than cow are consumed much less, so allergies to these milks seem to occur less frequently although they do occur. Buscino et al. (2000) observed an allergic response to horse milk in 1 out of the 25 tested children with cow milk allergy. Nonetheless, horse, donkey and camel milk could present an alternative in case of cow milk allergy as they have a lower cross reactivity with bovine milk compared to sheep, goat and buffalo milk (Buscino et al., 2000; Restani et al., 2002). On the other hand, sheep and goat milk proteins are more closely related to each other than to bovine milk proteins, explaining why a person allergic to goat cheese shows a higher IgE cross reactivity with sheep milk proteins, but may tolerate bovine milk and bovine milk products.

The high variety of genetic polymorphisms of caseins and whey proteins (e.g. some goat milk lack α_{s1}-caseïne; Table 2) contributes to the complexity of milk allergy (Caira et al., 2012), and each protein may elicit an allergic reaction. Consequently, it will depend from one person to another if milk other than e.g. bovine milk offers an alternative in case of milk allergy and only individual testing on allergenicity will be conclusive.

Thermal processing may destroy epitope structures, but can also unmask them or create new ones. So, heating can increase or decrease allergenicity, depending upon the protein (or component) involved and on the individual patient.

In case of lactose intolerance (i.e. the inability to digest lactose due to a deficiency of lactase), milk other than bovine milk nor heating will offer a solution since milk from all species, raw and heated, contain lactose. Horse and donkey milk contain a similar amount of lactose as human milk, but 1.5 times as much as bovine (or other ruminant) milk (Table 1). The lactose content of milk can be reduced by hydrolysis to glucose and galactose. Different technologies are developed for producing 'lactose-free' or 'lactose-reduced' milks (Harju, Kallioinen, & Tossavainen, 2012). As such, many traditional (fermented) dairy products like buttermilk, kefir, koumiss, and yoghurt, are 'lactose-reduced'. Cheese is 'lactose-free', mainly due to loss in the whey and use by starter cultures.

6. Infant nutrition

Based on a similar protein, lactose and mineral content as human milk, horse and donkey milk are viewed as a better alternative for breast milk compared to e.g. bovine or other ruminant milk (Malacarne et al., 2002; Salimei & Fantuz, 2012). This together with the good digestibility and the lower renal solute load (Uniacke-Lowe, 2011 , chap. 1 & 2; Ziegler, 2007), seem to confirm that horse and donkey milk are suitable in infant nutrition. However, in addition to the differences reported for specific milk components (e.g. oligosaccharides, CLA, cholesterol), horse and donkey milk contain substantially less fat compared to breast milk, whereas fat is the main energy source for the growth spurt for infants during the first year of life.

7. Conclusions

To ascertain if nutritional (health) benefits can be attributed to the consumption of a certain milks, the composition of milk from different animal species (and of human milk) was compared. Although milk of all mammals contains the same main components, the composition may vary largely, not only between ruminants and non-ruminants, but also between different species of these two groups, between different breeding variants within the same species, and between individual animals. The differences in milk composition do not only concern the relative proportions of the milk components, but also occur at the molecular level (e.g. monomeric versus dimeric proteins, different amino acid sequence). Very generally, milk from ruminants contains a higher protein ("casein milk") and fat content (with in terms of percentage, more saturated fatty acids and MUFAs, but less PUFAs) compared to milk from non-ruminants ("albumin milk"). The content of most minerals and vitamins is also higher in ruminant milk. Ruminant milk has on the other hand, a lower lactose content.

Health beneficial effects are mostly attributed to the consumption of raw milk. Since raw milk entails a realistic health risk for the consumer due to a possible contamination with human pathogens originating from animals (even clinically healthy animals) or from environmental contamination during milk collection or storage, it is recommended to heat milk before consumption (Claeys et al., 2013; O'Mahony et al., 2009; Robinson et al., 2013; Verraes et al., in press). Information on the effect of a heat treatment on the milk components from animal species other than cows is scarce. Despite the fact that milk composition and thermal stability of certain milk components may differ between species, the main conclusions that were drawn in a former study in which the effect of a heat treatment on the risks and benefits of the consumption of raw bovine milk were discussed (Claeys et al., 2013), can be extrapolated to milk from other species. As such, it can be assumed that the nutritional benefits associated with the consumption of raw milk, including its contribution to the uptake of calcium, phosphor, proteins and essential amino acids (especially lysine), and a number of vitamins, are generally maintained after pasteurization or UHT treatment. The other nutrients in milk that may (partially or fully) or may not be destroyed by heating, contribute less to the daily nutritional needs. The main negative effect of biochemical nature of a heat treatment is the modified organoleptic profile of milk, although this is more a matter of individual perception. (Heat-related changes of technological significance, e.g. with respect to emulgating and water binding properties of proteins, are not addressed.).

Other arguments against heating milk, including a less good digestibility of milk, an increased susceptibility for allergies and a counteracting of health beneficial properties, can be largely refuted or strongly nuanced. For a founded evaluation of putative therapeutic or health beneficial effects attributed to the consumption of raw milk from certain species and of the impact of a heat treatment on these effects, a confirmation of these effects is needed by sufficiently large, epidemiological studies. Moreover, the milk components responsible for these effects need to be identified and the interaction of these components with other milk components has to be accounted for.

Despite the fact that there are some similarities with human milk, horse, donkey and goat milk or milk from other species are no viable alternatives for human milk. For children younger than 1 year, it is recommended to give either human milk or formula milk (which is subject to legislative provisions and control). For people suffering milk allergy, milk from other animals than cow can offer an alternative. However, given the complexity of the issue, individual tests (e.g. allergen provocation test) are required.

Conflict of interest

The authors declare no conflict of interest.

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References

Abd El-Salam, M. H., & El-Shibiny, S. (2011). A comprehensive review on the composition and properties of buffalo milk. *Dairy Science & Technology, 91*, 663–699.

Adolphi, B., Scholz-Ahrens, K. E., de Vrese, M., Açil, Y., Laue, C., & Schrezenmeir, J. (2009). Short-term effect of bedtime consumption of fermented milk supplemented with calcium, inulin-type fructans and casein phosphopeptides on bone metabolism in healthy, postmenopausal women. *European Journal of Nutrition, 48*, 45–53.

Agostini, C., Carratù, B., Boniglia, C., Riva, E., & Sanzini, E. (2000). Free amino acid content in standard infant formulas: comparison with human milk. *Journal of the American College of Nutrition, 19*, 434–438.

Alessandri, C., & Mari, A. (2007). Letter to the editor: efficacy of donkey's milk in treating cow's milk allergic children: major concerns. *Pediatric Allergy and Immunology, 18*, 625–626.

Alhadrami, G. A. (2002). Dairy animals: camel. In H. Roginsky, J. W. Fuquay, & P. F. Fox (Eds.), *Encyclopedia of dairy sciences* (pp. 616–622). Amsterdam London: Academic Press.

Anderson, R. R. (1991). Comparison of minerals in milk of four species. *Comparative Biochemistry and Physiology, 100*, 1045–1048.

Andersson, I., & Öste, R. (1995). Chapter 13: nutritional quality of heat processed liquid milk. In P. F. Fox (Ed.), *Heat-induced changes in milk* (2nd ed.) (pp. 279–307). Brussels: International Dairy Federation.

Anses – Agence nationale de sécurité sanitaire. (Avril 2012). *Etude des liens entre facteurs de croissance, consommation de lait et de produits laitiers et cancers*. Avis de l'Anses, Rapport d'expertise collective. Maisons-Alfort, France http://www.anses.fr/Documents/NUT2009sa0261Ra.pdf.

Armand, M., Pasquier, B., André, M., Borel, P., Senft, M., Peyrot, J., et al. (1999). Digestion and absorption of 2 fat emulsions with different droplet sizes in the human digestive tract. *American Journal of Clinical Nutrition, 70*, 1096–1106.

Arman, P., Kay, R., Goodall, E. D., & Sharman, G. A. (1974). The composition and yield of milk from captive red deer (*Cervus elaphus* L.). *Journal of Reproduction and Fertility, 37*, 67–84.

Attia, H., Kherouatou, N., & Dhouib, A. (2001). Dromedary milk lactic acid fermentation: microbiological and rheological characteristics. *Journal of Industrial Microbiology & Biotechnology, 26*, 263–270.

Barłowska, J., Szwajowska, M., Litwińczuk, Z., & Król, J. (2011). Nutritional value and technological suitability of milk from various animal species used for dairy production. *Comprehensive Reviews in Food Science and Food Safety, 10*, 291–302.

Benkerroum, N. (2008). Antimicrobial activity of lysozyme with special relevance to milk. *African Journal of Biotechnology, 725*, 4856–4867.

Berg, H., & van Boekel, M. (1994). Degradation of lactose during heating of milk. I. Reaction pathways. *Netherlands Milk and Dairy Journal, 48*, 157–175.

Bernacka, H. (2011). Health-promoting properties of goat milk. *Medycyna Weterynaryjna, 67*, 507–511.

Bertino, E., Coppa, G. V., Giuliani, F., Coscia, A., Gabrielli, O., Sabatino, G., et al. (2008). Effect of holder pasteurization on human milk oligosaccharides. *International Journal of Immunopathology and Pharmacology, 2*, 381–385.

van Boekel, M. A. J. S., & Walstra, P. (1995). Chapter 3: effect of heat treatment on chemical and physical changes to milkfat globules. Special issue No. 9501. In P. F. Fox (Ed.), *Heat-induced changes in milk* (pp. 51–65). Brussels: International Dairy Federation.

Bonomi, F., Iametti, S., Pagliarini, E., & Solaroli, G. (1994). Thermal sensitivity of mares' milk proteins. *Journal of Dairy Research, 61*, 419–422.

Bravo, P. W., Garnica, J., & Fowler, M. E. (1997). Immunoglobulin G concentrations in periparturient llamas, alpacas, and their crias. *Small Ruminant Research, 26*, 145–149.

BSHC –; Belgian Superior Health Council. (2009). *Recommandations nutritionnelles pour la Belgique (Révision 2009) HGR/CSS 8309*. Brussels: BSHC. http://www.health.belgium.be/internet2Prd/groups/public/@public/@shc/documents/ie2divers/18014679_fr.pdf.

Burton, H. (1984). Reviews of the progress of dairy science: the bacteriological, chemical, biochemical and physical changes that occur in milk at temperatures of 100–150 °C. *Journal of Dairy Research, 51*, 341–363.

Businco, L., Giampietro, P. G., Lucenti, P., Lucaroni, F., Pini, C., Di Felice, G., et al. (2000). Allergenicity of mare's milk in children with cow milk allergy. *Journal of Allergy and Clinical Immunology, 105*, 1031–1034.

Caira, S., Pizzano, R., Picariello, G., Pinto, G., Cuollo, M., Chianese, L., et al. (2012). Chapter 7: allergenicity of milk proteins. In W. L. Hurley (Ed.), *Milk protein* (pp. 173–214). Intech. http://www.intechopen.com/books/milk-protein.

Cashman, K. (2006). Milk minerals (including trace elements) and bone health. *International Dairy Journal, 16*, 1389–1398.

Claeys, W. L., Cardoen, S., Daube, G., De Block, J., Dewettinck, K., Dierick, K., et al. (2013). Raw or heated cow milk consumption: review of risks and benefits. *Food Control, 31*, 251–262.

Cross, M. L., & Gill, H. S. (2000). Immunomodulatory properties of milk. *British Journal of Nutrition, 84*, S81–S89.

Csapó, J., Salamon, Sz, Lóki, K., & Csapó-Kiss, Z. (2009). Composition of mare's colostrum and milk. II. Protein content, amino acid composition and contents of macro- and micro-elements. *Acta Universitatis Sapientiae, Alimentaria, 2*, 133–148.

Csapó, J., Stefler, J., Martin, T. G., Makray, S., & Csapó-Kiss, Z. (1995). Composition of mares' colostrums and milk. Fat content, fatty acid composition and vitamin content. *International Dairy Journal, 5*, 393–402.

Davis, T. A., Fiorotto, M. L., & Reeds, P. J. (1994). Amino acid composition of human milk is not unique. *The Journal of Nutrition, 124*, 1126–1132.

Devle, H., Vetti, I., Naess-Andresen, C. F., Rukke, E. O., Vegarud, G., & Ekeberg, D. (2012). A comparative study of fatty acid profiles in ruminant and non-ruminant milk. *European Journal of Lipid Science and Technology, 114*, 1036–1043.

Dietschy, J. M., & Turley, S. D. (2004). Cholesterol metabolism in the central nervous system during early development and in the mature animal. *Journal of Lipid Research, 45*, 1375–1397.

Doreau, M., & Martin-Rosset, W. (2002). Dairy animals: horse. In H. Roginsky, J. W. Fuquay, & P. F. Fox (Eds.), *Encyclopedia of dairy sciences* (pp. 358–365). London, Amsterdam: Academic Press.

Douglas, F., Greenberg, R., & Farrell, H. M. (1981). Effects of ultra-high-temperature pasteurization on milk proteins. *Journal of Agricultural and Food Chemistry, 29*, 11–15.

El-Agamy, E. I. (2000). Effect of heat treatment on camel milk proteins with respect to antimicrobial factors: a comparison with cows' and buffalo milk proteins. *Food Chemistry, 68*, 227–232.

El-Agamy, E. I. (2006). Chapter 6: camel milk. In Y. W. Park, & G. F. W. Haenlein (Eds.), *Handbook of milk of non-bovine mammals* (pp. 297–344). Iowa (USA): Blackwell Publishing.

El-Agamy, E. I. (2007). The challenge of cow milk protein allergy. *Small Ruminant Research, 68*, 64–72.

El-Agamy, E. I. (2009). Chapter 6: bioactive components in camel milk. In Y. W. Park (Ed.), *Bioactive components in milk and dairy products* (pp. 159–194). Iowa (USA): Wiley-Blackwell.

El-Hatmi, H., Girardet, J.-M., Gaillard, J.-L., Yahyaoui, M., & Attia, H. (2007). Characterization of whey proteins of camel (*Camelus dromedaries*) milk and colostrums. *Small Ruminant Research, 70*, 267–271.

Elfstrand, L., Lindmark-Månsson, H., Paulsson, M., Nyberg, L., & Åkesson, B. (2002). Immunoglobulins, growth factors and growth hormone in bovine colostrum and the effects of processing. *International Dairy Journal, 12*, 879–887.

Fantuz, F., Ferraro, S., Todini, L., Piloni, R., Mariani, P., & Salimei, E. (2012). Donkey milk concentration of calcium, phosphorus, potassium, sodium and magnesium. *International Dairy Journal, 24*, 143–145.

Farah, Z. (1986). Effect of heat treatment on whey proteins of camel milk. *Milchwissenschaft, 41*, 763–765.

Farah, Z., & Atkins, D. (1992). Heat coagulation of camel milk. *Journal of Dairy Research, 59*, 229–231.

Farah, Z., Rettenmaier, R., & Atkins, D. (1992). Vitamin content of camel milk. *International Journal for Vitamin and Nutrition Research, 62*, 30–33.

Farrell, H., & Douglas, F. (1983). Effects of ultra-high-temperature pasteurization on the functional and nutritional properties of milk proteins. *Kieler Milchwirtschaftliche Forschungsberichte, 35*, 345–356.

Favé, G., Coste, T., & Armand, M. (2004). Physicochemical properties of lipids: new strategies to manage fatty acid bioavailability. *Cellular and Molecular Biology, 50*, 815–831.

Faye, B., & Konuspayeva, G. (2012). The sustainability challenge to the dairy sector – the growing importance of non-cattle milk production worldwide. *International Dairy Journal, 24*, 50–56.

Fox, P. F., & Kelly, A. L. (2006). Review: indigenous enzymes in milk: overview and historical aspects – part 1 & 2. *International Dairy Journal, 16*, 500–532.

de la Fuente, M. A., Olano, A., & Juárez, M. (1997). Distribution of calcium, magnesium, phosphorus, zinc, manganese, copper and iron between the soluble and colloidal phases of ewe's and goat's milk. *Lait, 77*, 515–520.

Gallego, L., Landete-Castillejos, T., Garcia, A., & Sánchez, P. J. (2006). Seasonal and lactational changes in mineral composition of milk from Iberian red deer (*Cervus elaphus hispanicus*). *Journal of Dairy Science, 89*, 589–595.

Gastaldi, D., Bertino, E., Monti, G., Baro, C., Fabris, C., Lezo, A., et al. (2010). Donkey's milk detailed lipid composition. *Frontiers in Bioscience, E2*, 537–546.

Gaucheron, F. (2005). The minerals of milk. *Reproduction Nutrition Development, 45*, 473–483.

German, J. B., & Dillard, C. J. (2006). Composition, structure and absorption of milk lipids: a source of energy, fat-soluble nutrients and bioactive molecules. *Critical Reviews in Food Science and Nutrition, 46*, 57–92.

Gerosa, S., & Skoet, J. (2012). *Milk availability – Trends in production and demand and medium-term outlook*. Rome (Italy): FAO, United Nations. http://www.fao.org/docrep/015/an450e/an450e00.pdf.

Gidding, S. S., Dennison, B. A., Birch, L. L., Daniels, S. R., Gilman, M. W., Lichtenstein, A. H., et al. (2006). Dietary recommendations for children and adolescents: a guide for practitioners. *Pediatrics, 117*, 544–559.

Griffiths, M. W. (2010). *Improving the safety and quality of milk*. In *Volume 1: Milk production and processing*. Guelph (Canada): Woodhead Publishing Limited, University of Guelph.

Guéguen, L., & Pointillart, A. (2000). The bioavailability of dietary calcium. *Journal of the American College of Nutrition, 19*, 119S–136S.

Guo, H. Y., Pang, K., Zhang, X. Y., Zhao, L., Chen, S. W., Dong, M. L., et al. (2007). Composition, physicochemical properties, nitrogen fraction distribution, and amino acid profile of donkey milk. *Journal of Dairy Science, 90*, 1635–1643.

Haenlein, G. F. W. (2004). Goat milk in human nutrition. *Small Ruminant Research, 51*, 155–163.

Harju, M., Kallioinen, H., & Tossavainen, O. (2012). Lactose hydrolysis and other conversions in dairy products: technological aspects. *International Dairy Journal, 22*, 104–109.

Harrison, R. (2006). Milk xanthine oxidase: properties and physiological roles. *International Dairy Journal, 16*, 546–554.

Hassan, Z. M. R., Farahat, A., & Abd El-Gawad, M. (2009). Effect of cold storage and heating of camel's milk on functional properties and microstructure in comparison with cow's and buffalo's milk. *Annals of Agricultural Science, 54*, 137–147.

Hoffman, R. M., Kronfeld, D. S., Herbein, J. H., Swecker, W. S., Cooper, W. L., & Harris, P. A. (1998). Dietary carbohydrates and fat influence milk composition and fatty acid profile of mare's milk. *The Journal of Nutrition, 128*, 2708S–2711S.

Inglingstad, R., Devold, T., Eriksen, E., Holm, H., Jacobsen, M., Liland, K., et al. (2010). Comparison of the digestion of caseins and whey proteins in equine, bovine, caprine and human milks by human gastrointestinal enzymes. *Dairy Science and Technology, 90*, 549–563.

Jahreis, G., Fritsche, J., Möckel, P., Schöne, F., Möller, U., & Steinhart, H. (1999). The potential anticarcinogenic conjugated linoleic acid, cis-9, trans-11 C18:2, in milk of different species: cow, goat, ewe, cow, mare, women. *Nutrition Research, 19*, 1541–1549.

Jainudeen, M. R. (2002). Buffalo husbandry. In H. Roginsky, J. W. Fuquay, & P. F. Fox (Eds.), *Encyclopedia of dairy sciences* (pp. 186–193). London, Amsterdam: Academic Press.

Jandal, J. M. (1996). Comparative aspects of goat and sheep milk. *Small Ruminant Research, 22*, 177–185.

Jensen, R., Ferris, A., Lammi-Keefe, C., & Henderson, R. (1990). Lipids of bovine and human milks : a comparison. *Journal of Dairy Science, 73*, 223–240.

Khalifa, M. Y., Niki, R., & Arima, S. (1985). Effect of heat treatments on κ-casein. I. Heat-induced changes of κ-casein fractions. *Journal of the Faculty of Agriculture, Hokkaido University, 62*, 283–301.

Kitabatake, N., & Kinekawa, Y.-I. (1998). Digestibility of bovine milk whey protein and β-lactoglobulin in vitro and in vivo. *Journal of Agricultural and Food Chemistry, 46*, 4917–4923.

Korhonen, H. J. (2009). Chapter 2: bioactive components in bovine milk. In Y. W. Park (Ed.), *Bioactive components in milk and dairy products* (pp. 15–42). Iowa (USA): Wiley-Blackwell.

Korhonen, H., Marnila, P., & Gill, H. S. (2000). Milk immunoglobulins and complement factors. *British Journal of Nutrition, 84*, S75–S80.

Kunz, C., & Rudloff, S. (2006). Health promoting aspects of milk oligosaccharides. *International Dairy Journal, 16*, 1341–1346.

La Torre, G. L., Saitta, M., Potortí, A., Di Bella, G., & Dugo, G. (2010). High performance liquid chromatography coupled with atmospheric pressure chemical ionization mass spectrometry for sensitive determination of bioactive amines in donkey milk. *Journal of Chromatography A, 1217*, 5215–5224.

Lacroix, M., Léonil, J., Bos, C., Henry, G., Airinei, G., Fauquant, J., et al. (2006). Heat markers and quality indexes of industrially heat-treated [15N] milk protein measured in rats. *Journal of Agricultural and Food Chemistry, 54*, 1508–1517.

Li, H., Ma, Y., Dong, A., Wang, J., Li, Q., He, S., et al. (2010). Protein composition of yak milk. *Dairy Science and Technology, 90*, 111–117.

Li, H., Ma, Y., Li, Q., Wang, J., Cheng, J., Xue, J., et al. (2011). The chemical composition and nitrogen distribution of Chinese yak (Maiwa) milk. *International Journal of Molecular Sciences, 12*, 4885–4895.

Liu, H. N., Ren, F. Z., Jiang, L., Ma, Z. L., Qiao, H. J., Zeng, S. S., et al. (2011). Fatty acid profile of yak milk from the Qinghai-Tebetan plateau in different seasons and for different parities. *Journal of Dairy Science, 94*, 1724–1731.

Lorenzen, P., Martin, D., Clawin-Rädecker, I., Barth, K., & Knappstein, K. (2010). Activities of alkaline phosphatase, γ-glutamyltransferase and lactoperoxidase in cow, sheep and goat's milk in relation to heat treatment. *Small Ruminant Research, 89*, 18–23.

MacDonald, L. E., Brett, J., Kelton, D., Majowicz, S. E., Snedeker, K., & Sargeant, J. M. (2011). A systematic review and meta-analysis of the effects of pasteurization on milk vitamins, and evidence for raw milk consumption and other health-related outcomes. *Journal of Food Protection, 74*, 1814–1832.

Malacarne, M., Martuzzi, F., Summer, A., & Mariani, P. (2002). Review: protein and fat composition of mare's milk: some nutritional remarks with reference to human and cow's milk. *International Dairy Journal, 12*, 869–877.

Marchand, S., Merchiers, M., Messens, W., Coudijzer, K., & De Block, J. (2009). Thermal inactivation kinetics of alkaline phosphatase in equine milk. *International Dairy Journal, 19*, 763–767.

Martinez-Ferez, A., Rudloff, S., Guadix, A., Henkel, C. A., Pohlentz, G., Boza, J. J., et al. (2006). Goats' milk as a natural source of lactose – derived oligosaccharides: isolation by membrane technology. *International Dairy Journal, 16*, 173–181.

Mattila-Sandholm, T., & Saarela, M. (2003). *Functional dairy products* (Vol. 1). New York: CRC Press.

Mayer, H., & Fiechter, G. (2012). Physical and chemical characteristics of sheep and goat milk in Austria. *International Dairy Journal, 24*, 57–63.

Medhammar, E., Wijesinha-Bettoni, R., Stadlmayr, B., Nilsson, E., Charrondiere, U. R., & Burlingame, B. (2012). Composition of milk from minor dairy animals and buffalo breeds: a biodiversity perspective. *Journal of the Science of Food and Agriculture, 92*, 445–474.

Mehra, R., & Kelly, P. (2006). Milk oligosaccharides: structural and technological aspects. *International Dairy Journal, 16*, 1334–1340.

Michaelidou, A. M. (2008). Factors influencing nutritional and health profile of milk and milk products. *Small Ruminant Research, 79*, 42–50.

Michalski, M. C., & Januel, C. (2006). Does homogenization affect the human health properties of cow's milk? *Trends in Food Science & Technology, 17*, 423–437.

Mittaine, J. (1962). Milk other than cows' milk. In *, 48. Milk hygiene, World Health Organization monograph* (pp. 681–694). Geneva: WHO/FAO.

Monti, G., Bertino, M., Muratore, M. C., Coscia, A., Cresi, F., Silvestro, L., et al. (2007). Efficacy of donkey's milk in treating highly problematic cow's milk allergic children: an in vivo and in vitro study. *Pediatric Allergy and Immunology, 18*, 258–264.

Morin, D. E., Rowan, L. L., & Hurley, W. L. (1995). Comparative study of proteins, peroxidase activity and N-acetyl-β-D-glucosaminidase activity in llama milk. *Small Ruminant Research, 17*, 255–261.

Morin, D. E., Rowan, L. L., Hurley, W. L., & Braselton, W. E. (1995). Composition of milk from llamas in the United States. *Journal of Dairy Science, 87*, 1713–1720.

Murray, M. J., Schaudies, R. P., & Cavey, D. M. (1992). Epidermal growth factor-like activity in mares' milk. *American Journal of Veterinary Research, 53*, 1729–1731.

Naert, L., Vande vyvere, B., Verhoeven, G., Duchateau, L., De Smet, S., & Coopman, F. (2013). Assessing heterogeneity of the measured composition of mare's milk in Flanders. *Vlaams Diergeneeskundig Tijdschrift, 82*, 23–30.

Nakamura, T., Amikawa, S., Harada, T., Saito, T., Arai, I., & Urashima, T. (2001). Occurrence of an unusual phosphorylated N-acetyllactosamine in horse colostrum. *Biochimica et Biophysica Acta, 1525*, 13–18.

Nikkah, A. (2011). Science of camel and yak milks: human nutrition and health perspectives. *Food and Nutrition Sciences, 2*, 667–673.

Odle, J., Zijlstra, R. T., & Donovan, S. M. (1996). Intestinal effects of milkborne growth factors in neonates of agricultural importance. *Journal of Animal Science, 74*, 2509–2522.

O'Mahony, M., Fanning, S., & Whyte, P. (2009). Chapter 6: the safety of raw liquid milk. In A. Y. Tamine (Ed.), *Milk processing and quality management* (pp. 139–167). West Sussex (UK): Blackwell Publishing Ltd./John Wiley & Sons Ltd. In *http://www.foodtechnologist.yolasite.com/resources/Milk%20Processing%20and%20Quality%20Management.pdf*.

Pandya, A. J., & Haenlein, G. F. W. (2009). Chapter 5: bioactive components in buffalo milk. In Y. W. Park (Ed.), *Bioactive components in milk and dairy products* (pp. 105–158). Iowa (USA): Wiley-Blackwell.

Park, Y. W. (2009). Chapter 3: bioactive components in goat milk. In Y. W. Park (Ed.), *Bioactive components in milk and dairy products* (pp. 43–81). Iowa (USA): Wiley-Blackwell.

Park, Y. W., Juárez, M., Ramos, M., & Haenlein, G. F. W. (2007). Physico-chemical characteristics of goat and sheep milk. *Small Ruminant Research, 68*, 88–113.

Potočnik, K., Gantner, V., Kuterovac, K., & Cividini, A. (2011). Mare's milk: composition and protein fraction in comparison with different milk species. *Mljekarstvo, 61*, 107–113.

Radzik-Rant, A., Rozbicka-Wieczorek, A., Czauderna, M., Rant, W., & Kuczyńska, B. (2011). The chemical composition and fatty acid profile in milk of Polish mountain sheep and Polish merino. *Annals of Warsaw University of Life Sciences – SGGW, Animal Science, 49*, 163–172.

Raynal-Ljutovac, K., Park, Y. W., Gaucheron, F., & Bouhallab, S. (2007). Heat stability and enzymatic modifications of goat and sheep milk. *Small Ruminant Research, 68*, 207–220.

Recio, I., de la Fuente, M. A., Juárez, M., & Ramos, M. (2009). Chapter 4: bioactive components in sheep milk. In Y. W. Park (Ed.), *Bioactive components in milk and dairy products* (pp. 83–104). Iowa (USA): Wiley-Blackwell.

Restani, P., Beretta, B., Fiocchi, A., Ballabio, C., & Gali, C. L. (2002). Cross-reactivity between mammalian proteins. *Annals of Allergy, Asthma and Immunology, 89*, 11–15.

Robinson, T. J., Scheftel, J. M., & Smith, K. E. (2013). Raw milk consumption among patients with non-outbreak-related enteric infections, Minnesota, USA, 2001–2010. *Emerging Infectious Diseases, 20*, 38–44.

Roos, N., Mahé, S., Benamouzig, R., Sick, H., Rautureau, J., & Tomé, D. (1995). ^{15}N-labeled immunoglobulins from bovine colostrum are partially resistant to digestion in human intestine. *The Journal of Nutrition, 125*, 1238–1244.

Salamon, R. V., Salamon, Sz, Csapó-Kiss, Zs, & Csapó, J. (2009). Composition of mare's colostrums and milk. I. Fat content, fatty acid composition and vitamin contents. *Acta Universitatis Sapientiae, Alimentaria, 2*, 119–131.

Salimei, E., & Fantuz, F. (2012). Equid milk for human consumption. *International Dairy Journal, 24*, 130–142.

Salimei, E., Fantuz, F., Coppola, R., Chiofalo, B., Polidori, P., & Varisco, G. (2004). Composition and characteristics of ass's milk. *Animal Research, 53*, 67–78.

Šaríc, L.Ć., Šaríc, B. M., Mandíc, A. I., Torbica, A. M., Tomić, L. M., Cvetković, D. D., et al. (2012). Antibacterial properties of Domestic Balkan donkeys' milk. *International Dairy Journal, 25*, 142–146.
Schaafsma, G. (1989). Effects of heat treatment on the nutritional value of milk. *Bulletin of the International Dairy Federation, 238*, 68–70.
Schaafsma, G. (2002). Nutritional significance of lactose and lactose derivates. In H. Roginsky, J. W. Fuquay, & P. F. Fox (Eds.), *Encyclopedia of dairy sciences* (pp. 1529–1533). London, Amsterdam: Academic Press.
Schanler, R. J. (2011). Outcomes of human milk-fed premature infants. *Seminars in Perinatology, 35*, 29–33.
Schlimme, E., Martin, D., & Tait, D. (2002). Nucleosides and nucleotides in milk. In H. Roginsky, J. W. Fuquay, & P. F. Fox (Eds.), *Encyclopedia of dairy sciences* (pp. 2100–2107). London, Amsterdam: Academic Press.
Shakeel-ur-Rehman, & Farkye, N. Y. (2002). Enzymes indigenous to milk: lipases and esterases. In H. Roginsky, J. W. Fuquay, & P. F. Fox (Eds.), *Encyclopedia of dairy sciences* (pp. 926–929). London, Amsterdam: Academic Press.
Shamsia, S. M. (2009). Nutritional and therapeutic properties of camel and human milks. *International Journal of Genetics and Molecular Biology, 1*, 52–58.
Sheng, Q., & Fang, X. (2009). Chapter 7: bioactive components in mare milk. In Y. W. Park (Ed.), *Bioactive components in milk and dairy products* (pp. 195–213). Iowa (USA): Wiley-Blackwell.
Souci, S. W., Fachmann, W., & Kraut, H. (2008). *Food composition and nutrition tables* (7th ed.). Stuttgart: Wissenschaftliche Verlagsgesellschaft mbH.
Spreer, E. (1998). *Milk and dairy product technology*. Dresden: Marcel Dekker Inc.
Stender, S., Astrup, A., & Dyerberg, J. (2008). Ruminant and industrially produced trans fatty acids: health aspects. *Food & Nutrition Research, 52*. http://dx.doi.org/10.3402/fnr.v52i0.1651.
Tesse, R., Paglialunga, C., Braccio, S., & Armenio, L. (2009). Adequacy and tolerance to ass's milk in an Italian cohort of children with cow's milk allergy. *Italian Journal of Pediatrics, 53*, 19. http://dx.doi.org/10.1186/1824-7288-35-19.
Tziboula-Clarke, A. (2002). Goat milk. In H. Roginsky, J. W. Fuquay, & P. F. Fox (Eds.), *Encyclopedia of dairy sciences* (pp. 1270–1279). London, Amsterdam: Academic Press.
U.S. Department of Agriculture, Agricultural Research Service. (2013). *USDA national nutrient database for standard reference, release 26*. Nutrient Data Laboratory. Home Page http://www.ars.usda.gov/ba/bhnrc/ndl.
Uniacke-Lowe, T. (2011). *Studies on equine milk and comparative studies on equine and bovine milk systems*. PhD thesis. Cork: University College Cork.
Uniacke-Lowe, T., Huppertz, T., & Fox, P. F. (2010). Equine milk proteins: chemistry, structure and nutritional significance. *International Dairy Journal, 20*, 609–629.
Urashima, T., Saito, T., Nakamura, T., & Messer, M. (2001). Oligosaccharides of milk and colostrum in non-human mammals. *Glycoconjugate Journal, 18*, 357–371.
Vamvakaki, A.-N., Zoidou, E., Moatsou, G., Bokari, M., & Anifantakis, E. (2006). Residual alkaline phosphatase activity after heat treatment of ovine and caprine milk. *Small Ruminant Research, 65*, 237–241.
Vergara, H., Landete-Castillejos, T., Garcia, A., Molina, P., & Gallego, L. (2003). Concentration of Ca, Mg, K, Na, P and Zn in milk in two subspecies of red deer: *Cervus elaphus hispanicus* and *C. e. scoticus*. *Small Ruminant Research, 47*, 77–83.
Verraes, C., Claeys, W., Cardoen, S., Daube, G., De Zutter, L., Imberechts, H., et al. (2014). *An evaluation of the microbiological risks of the consumption of raw milk from animal species other than cows*. In press.
Weeks, C. E., & King, R. L. (1985). Bioavailability of calcium in heat-processed milk. *Journal of Food Science, 50*, 1101–1105.
Williamson, S., Finucane, E., Ellis, H., & Gamsu, H. R. (1978). Effect of heat treatment of human milk on absorption of nitrogen, fat, sodium, calcium, and phosphorus by preterm infants. *Archives of Disease in Childhood, 53*, 555–563.
Wills, M. E., Han, V. E. M., Harris, D. A., & Baum, J. D. (1982). Short-time low-temperature pasteurization of human milk. *Early Human Development, 7*, 71–80.
Xi, B., Li, W.-h., & Gao, Y.-q (2010). Comparative analysis of nutrient components of yak milk from different regions. *Animal Husbandry and Feed Science, 2*, 26–27, 48.
Zagorska, J., & Ciprovica, I. (2012). The influence of heat treatment on antimicrobial proteins in milk. *World Academy of Science, Engineering and Technology, 64*, 832–836.
Zalazar, C., Palma, S., & Candioti, M. (1996). Increase in free sialic acid and gelation in UHT milk. *Australian Journal of Dairy Technology, 51*(1).
Ziegler, E. E. (2007). *Adverse effects of cow's milk in infants*. In C. Agostini, & O. Brunser (Eds.), *Issues in complementary feeding. Nestle nutrition workshop series pediatric program, 60*; (pp. 185–199).