Swedish University of Agricultural Sciences
The Faculty of Veterinary Medicine and Animal Science
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Introduction

The mare's milk is essential to the foal during its first time of life, and it is therefore important for us to know what characterizes it. In case a foal would lose its mother, it is crucial that the foal receives a milk replacer suitable for its needs.

The mares' udder consists of two smaller caudal glands and two larger cranial glands, but sometimes six glands can occur. No milk can pass from one gland to another. The pairs of glands and udder half are separated by the medial suspensory ligament along the intermammary groove. Each quarter consists of one gland cistern and one teat cistern. Since the horse has two teats and four quarters, each teat has two orifices where two quarters exits (Davis Morel, 2008).

Mares' milk is also an important foodstuff to the human population (Montanari et al., 1996) and it has also been considered if mares' milk can replace cows' milk in infants and children that has IgE-mediated milk allergy (Businco *et al.*, 2000). The aim of this review is to investigate the milk yield and composition of mares' milk and to describe causes for variation in milk yield and composition.

Literature review

Milk yield

Colostrum is produced the 1-3 first days post partum (Doreau *et al.*, 1992) and after 2.5-3 months the peak in milk yield is reached and thereafter milk yield decreases (Bouwman & Van der Schee, 1978; Gibbs *et al.*, 1982; Santos & Silvestre 2008). The average milk production for a lactating mare is 2-3.5 % of the horse's bodyweight per day (Gibbs *et al.*, 1982; Jansson *et al.*, 2004; Santos & Silvestre, 2008), which means that a mare weighing 500kg produces 10-18kg milk in average per day. There are differences in milk production between individuals, where small horses in general produce more milk (3-3.5 %) per kg body weight (Jansson *et al.*, 2004).

It has been shown that it is possible to affect the milk yield in mares through the mare's diet (Gibbs *et al.*, 1982; Doreau *et al.*, 1992). A diet with a low hay:concentrate ratio results in a higher milk production than a diet with a high hay:concentrate ratio (Doreau *et al.*, 1992). Also, the protein source in the diet does matter. When comparing soy bean meal and soy bean meal with urea as protein sources, the soybean meal alone results in a higher milk production than with addition of urea (Gibbs *et al.*, 1982). Another factor that may affect the milk yield is the milking technique. Caroprese *et al.* (2007) compared milk yield from hand milked horses with machine milked horses, and showed a higher milk yield and a shorter milking time when the mares were machine milked than hand milked.

Dry Matter

The dry matter (DM) content is about 25 % in colostrum (Ullrey *et al.*, 1966; Csapó *et al.*, 1995). Salimei *et al.* (2002) measured a DM content of colostrum of 20.3 %, which differs a bit from the results by Ullrey *et al.* (1966) and Csapó *et al.* (1995). The lower DM content received by Salimei *et al.* (2002) may be due to the different breeds and different amounts of feed among the studies. However one of the four breeds used by Csapó *et al.* (1995) was also used by Salimei *et al.* (2002). Mature milk has a DM content of around 10-12 % which decreases throughout the lactation (Ullrey *et al.*, 1966; Gibbs *et al.*, 1982; Schryver *et al.*, 1986b; Salimei *et al.*, 2002).

Fat

The fat content in the milk of mares is relatively low with an average of around 1-1.5 % (Gibbs *et al.*, 1982; NRC, 1989; Csapó *et al.*, 1995; Malacarne *et al.*, 2002). Lower and higher average values are also received (Bouwman & Van der Schee, 1978; Santos and Silvestre, 2008), where the lowest values are obtained from diets rich in concentrate. Low values can also be obtained due to incomplete milk removal because of a higher concentration of fat in the end of milking (Doreau & Boulot, 1989). The fat content also varies during the lactation period, with an overall decrease in fat content from colostrum to the end of lactation (Bouwman & Van der Schee, 1977; Gibbs *et al.*, 1982; Doreau & Boulot, 1989; NRC, 1989). It has also been shown that machine milked mares' gives milk more rich in fat compared to hand milked mares, which is probably because of a more complete emptying of the udder (Caroprese *et al.*, 2007). Another factor that affects the fat content in mares' milk is obesity of the mare at parturition, where a thin mare produces milk that contains less fat than an obese mare (Doureau & Boulot, 1989). A factor that only affects the fat content in the colostrum is the number of parturitions the mare has gone through. The more foals, the higher fat content in colostrum (Pikul *et al.*, 2008).

It has already been mentioned that a diet rich in concentrate will lower the fat content in milk (Doreau & Boulot, 1989). A diet with oil and fiber will give a higher content of fat in milk than a diet rich in starch and sugar (Hoffman *et al.*, 1998). However, it is shown that an addition of urea to a concentrate based on soybean meal as a source of protein did not affect the fat content in milk (Gibbs *et al.*, 1982), indicating that the protein source does not affect the fat content in milk.

The mare's milk fat contains a relatively high concentration of free fatty acids and phospholipids (Doreau & Boulot, 1989) and about 80 % is triacylglycerides (Malacarne *et al.*, 2002). Milk fat from mares has a high amount of unsaturated fatty acids where approximately half of the fatty acids are unsaturated (Malacarne *et al.*, 2002; Pikul *et al.*, 2008; Pikul & Wójtowski, 2008). Also 20-25 % of the milk fat consists of less than 16 carbon atoms (Doreau & Boulot, 1989), and the content of linoleic and linolenic acids is high (Doreau & Boulot, 1989; Doreau *et al.*, 1992; Malacarne *et al.*, 2002). The high concentration of linoleic and linolenic acid is due to the lack of biohydrogenation of long chain fatty acids in the gut of horses, leading to a high influence of diet on the amount of long chain fatty acids in milk (Doreau & Boulot, 1989). The amount of these two acids can be changed through the diet, where a high hay:concentrate ratio results in a lower concentration of linoleic acid and a higher concentration of linolenic acid (Doreau *et al.*, 1992).

Protein

The protein in mares' milk decreases over the lactation period (Bouwman & Van der Schee, 1978; Oftedal *et al.*, 1983) and the protein fraction of the milk is in average about 2 % (Gibbs *et al.*, 1982; Doreau & Boulot, 1989; Csapó-Kiss *et al.*, 1995; Santos & Silvestre, 2008). The highest decrease in protein occurs during the colostral period (Ullrey *et al.*, 1966; Bouwman & Van der Schee, 1978; Salimei *et al.*, 2002), but a study by Cieśla *et al.* (2009) showed higher protein content after the colostral period with no significant change during the colostral period. Independent if protein is expressed as nitrogen or amino acids, the content decreases during the beginning of the lactation period (Doreau *et al.*, 1992; Csapó-Kiss *et al.*, 1995).

The protein in mares' milk consists of non protein nitrogen (NPN), whey protein and casein. The fraction of NPN is about 10 % (Doreau & Boulot, 1989) and is 40 % higher in colostrum than in mature milk (Csapó-Kiss *et al.*, 1995). Up to 50 % of the NPN fraction consists of urea (Doreau & Boulot, 1989; Salimei *et al.*, 2002). The fraction of whey protein is about 40 % of the total protein in mares' milk (Csapó-Kiss *et al.*, 1995; Malacarne *et al.*, 2002), while the casein fraction is about 50 % (Doreau & Boulot, 1989; Csapó-Kiss *et al.*, 1995; Malacarne *et al.*, 2002). Pre-albumin is a protein included in whey proteins and is only present in the colostrum (Cieśla *et al.*, 2009). Another whey protein are the immunoglobulins (Malacarne *et al.*, 2002) which have a high concentration in the beginning of the colostral period but decreases both during the colostral period and during the whole lactation period (Csapó-Kiss *et al.*, 1995; Cieśla *et al.*, 2009). The α-globulins and albumins, which also are whey proteins (Davies Morel, 2008), increases from the colostral period to the mature milk (Cieśla *et al.*, 2009).

It has been shown by Doreau *et al.* (1992) that a diet rich in concentrate results in lower content of nitrogen in milk even if the diet has a higher crude protein level than the control diet based on forage. However, another study made by Gibbs *et al.* (1982) resulted in no change of protein content in milk when urea was added to the concentrate diet based on soybean meal. Like the fat content, the protein content is also influenced by number of parturitions. If the mare has passed more than two parturitions, the protein content in milk is lower than after one or two parturitions (Gibbs *et al.*, 1982).

Carbohydrate

The carbohydrates in mares' milk consist mostly of lactose with only a very small amount of glucose and galactose (Doreau & Boulot, 1989). The average amount of lactose in milk is about 6 % (Malacarne *et al.*, 2002; Santos & Silvestre, 2008). In the beginning of the lactation period there is a low amount of lactose in milk, about 3.4 % (Salimei *et al.*, 2002), which increases during the lactation period (Ullrey *et al.*, 1966; Doreau *et al.*, 1992; Mariani *et al.*, 2001; Salimei *et al.*, 2002). In a study by Doreau *et al.* (1992) it was shown that lactose content in milk is higher when the horses are fed a diet rich in concentrate, than when fed a diet rich in forage.

Ash

Ash content is determined by reducing the organic material from a sample, which means that the mineral content is a part of the ash content (McDonald *et al.*, 2002). The content of ash in mares' milk is highest during early lactation and decreases towards the end (table 1), which thereby also is the case for several minerals (table 2). The different values obtained in the colostral period were taken in different times. Csapó-Kiss *et al.* (1995) measured a mean value between days 0-2 and Ullrey *et al.* (1966) took a milk sample immediately after parturition. Even when the same analyzing method were used, as in the studies of Ullrey *et al*. (1966) and Schryver *et al.* (1986a), there were differences in the results (table 1). These differences could be explained by the use of different breeds, housing systems or diets in several of the studies.

Table 1. Ash (%) content in mares' colostrum and milk

		Ash %			
Colostrum	**4-7 DIM**	**4months**	**Mean**	**Breed**	**Source**
0.72	0.54	0.27	0.49	Quarter and Arabian	Ullrey *et al.*, 1966
0.59	0.53	N.S	N.S	Draft Breeds[1]	Csapó-Kiss *et al.*, 1995
N.S	0.58	N.S	N.S	Thoroughbred horses	Schryver *et al.*, 1986b
N.S	0.58	0.28	0.37	Haflinger	Summer *et al.*, 2004
N.S	0.61	0.32	0.44	Thoroughbred horses	Schryver *et al.*, 1986a
N.S	N.S	N.S	0.41	Thoroughbred horses	Oftedal *et al.*, 1983
N.S	N.S	N.S	0.48	Dutch warmblooded saddlehorses	Bouwman & Van der Schee, 1978

DIM: Days in milk. N.S: Not Specified. Draft breeds[1]: Hungarian draught, Haflinger, Breton and Boulonnais

The mineral content in table 2 may vary depending on diet. Doreau *et al.* (1992) received milk containing more calcium and phosphorus from a diet rich in forage than on a diet rich in concentrate. The diets had no effects on concentrations of sodium, potassium and magnesium (Doreau *et al.*, 1992). The variation in mineral content (table 2) may also be explained by the different times where the content was measured in the studies (Ullrey *et al.*, 1974; Ullrey *et al.*, 1966; Csapó-Kiss *et al.*, 1995). There is also a variation when the different minerals reaches their peak, for calcium the peak is about a week after parturition and thereafter the concentration decreases. In comparison, phosphorus reaches its peak within a couple of days and then the concentration decreases (Bouwman & Van der Schee, 1978; Doreau *et al.*, 1992). However, the contents of magnesium, potassium and sodium decrease directly after parturition (Ullrey *et al.*, 1966).

Table 2. Mineral content in mares' milk (µg/g) during colostrum and mature milk week 16

	Colostrum	**Mature milk**
Ca	748-847 [1,2]	614-700 [2,4]
P	389-742 [2,1]	216-540 [2,4]
Mg	140-473 [1,2]	43 [2,4]
K	928-1143 [1,2]	341-370 [4,3]
Na	320-524 [1,2]	115-161 [4,2]
Zn	2.95-6.40 [1,3]	1.80-2.40 [4,3]
Fe	1.00-1.31 [1,3]	0.49 [3]
Cu	0.61-0.99 [1,3]	0.20-0.28 [3,4]

[1]Csapó-Kiss *et al.* (1995), [2]Ullrey *et al.* (1966), [3]Ullrey *et al.* (1974), [4]Schryver *et al.* (1983).

Vitamin

The content of vitamin A, alfa-tocopherol and beta-carotene was highest during parturition and the contents decreased within two days. The concentration of beta-carotene was 64.7 times higher in the colostrum than in mature milk and for vitamin A and vitamin E the contents were 2.8 and 5.7 times lower in mature milk than in colostrum (Schweigert & Gottwald, 1999). The content of vitamins in colostrum and mature milk is shown in table 3.

Table 3. Vitamin content (mg/kg) in mare´s milk

	Colostrum	8-45 days post partum
Vitamin A	0.88	0.34
Vitamin D_3	0.0054	0.0032
Vitamin E	1.342	1.128
Vitamin K_3	0.043	0.029
Vitamin C	23.8	17.2

Table 3 adapted from Csapó *et al.* (1995).

Conclusions

The milk yield in horses is in average 2-3.5 % of the horses' body weight and the main components of milk are fat 1-1.5 %, protein 2 %, lactose 6 %, ash 0.37-0.49 % and different vitamins and minerals. There may also be some other trace minerals in mare´s milk not discussed in this work. The mature milk has an average DM of about 10-12 %. It seems to be possible to affect yield and composition of milk mainly through the diet. Other parameters that may affect the variation in the results between the different studies are number of animals, incomplete milking, milking intervals, handling of the suckling foal, sampling procedure and housing systems. Different breeds did not seem to cause any major differences in milk composition or yield. Almost no studies found, compares the milk composition and yield between different breeds. The vitamin content, mineral content and the carbohydrates in mares' milk are not well studied, why there is a need of studying these elements in mares' milk to be able to conclude their importance.

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