Review Article

Nutritional composition of breast milk in Chinese women: a systematic review

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Background and Objectives: As breast milk is considered nature's best food for infant growth and development, understanding its nutritional composition is crucial for optimising the components of infant formula milk. In this study, we aimed to summarise the available evidence on the nutritional composition of breast milk from Chinese women, in particular, the macronutrients, fatty acids and minerals. **Methods and Study Design:** We searched PubMed, Embase, and Chinese databases for articles about human breast milk from Chinese women published in English or Chinese between 1999 and 2015. We classified the data in 35 articles from the literature search into three lactation stages: colostral, transitional and mature milk. **Results:** The content of each component varied greatly during the three lactation stages. Protein content decreased from colostral milk to mature milk (mean±SD, 1.64±0.32 g/dL vs 1.22±0.12 g/dL). In contrast, lipid content increased from colostral milk (2.36±1.17 g/dL) to mature milk (3.39±1.24 g/dL). Colostrum contained more linoleic acid (LA) than transitional and mature milk, while colostrum contained less α-linolenic acid (ALA) than transitional and mature milk. As lactation progressed, the ratios of docosahexaenoic acid (DHA) and arachidonic acid (AA) to total fatty acids decreased while the potassium (K), zinc (Zn), and copper (Cu) concentrations decreased significantly, but their standard deviations were large. Magnesium (Mg) and manganese (Mn) concentrations showed significant differences across the three lactation stages. **Conclusions:** The stage of lactation was an important factor affecting the nutritional composition of breast milk from Chinese women.

Key Words: human breast milk, nutritional composition, macronutrients, fatty acids, minerals

INTRODUCTION

Human milk is universally recognised as the optimal food for the healthy growth and development of infants. Many benefits are associated with breastfeeding, such as decreased infant morbidity of diarrhoea, otitis media, pneumonia, asthma, and childhood leukaemia,[1-4] improved resistance to influenza,[5] and reduced risks of obesity and diabetes compared with formula-fed infants.[6] Evidence also suggests that breastfeeding may have long-term benefits, such as effectively preventing the occurrence of non-infectious chronic diseases (e.g. hypercholesterolemia, hypertension, and obesity) in adulthood.[7,8] Macronutrients such as proteins, lipids, and carbohydrates are the essential main nutrients found in breast milk. Micronutrients in breast milk such as vitamins and minerals also play a critical role in promoting infant health.

Given the importance of breast milk for growing, many studies have been conducted internationally to investigate new components and features. China is a vast country with a diverse population, so the composition of breast milk from Chinese women could vary widely across its regions so prompting much research in recent years. China has also undergone a significant transition in economic development, food supply structure, and nutritional status over decades. These factors may have had an influence on the composition of human milk.

Currently, the standards and policy for producing infant formula milk in China rely mostly on foreign data and follow foreign standards. However, there are differences between Chinese and foreign breastfeeding mothers regarding their genetic background, physiological parameters, dietary habits and environment.[9-12] Therefore, a clear understanding of the nutritional composition of breast milk based on the available data from Chinese women is essential for developing standards and policy for producing infant formula milk and updating the infant Dietary Reference Intakes (DRIs) for China.

The present review aims to summarise the available evidence on the nutritional composition, in particular, macronutrients, fatty acids and minerals, of breast milk from Chinese women. We also aim to investigate how this varies during the three lactation stages: colostrum (1 to 6 d postpartum), transitional milk (7 to 14 d postpartum), and mature milk (after 14 d).

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METHODS

Literature search and study selection

We searched literature databases, in both the English and Chinese language (PubMed, Embase, CNKI and Wanfang Data), for original articles regarding the components of breast milk from Chinese women. We used a combination of the following keywords: “breast milk”, “composition”, and (“China” or “Chinese”). Articles published in English and Chinese between 1999 and 2015 were considered. Studies were included in the present review if they met the following conditions: (1) they were conducted on healthy, well-nourished Chinese women aged 20–35 y and reported the nutritional composition of breast milk; (2) the subjects were randomly selected from regions; and (3) the analysis methods were reliable. Studies that included too small a sample (less than six mothers) were excluded.

We extracted data on the geographical location, stages of lactation (colostral, transitional and mature milk), analysis methods and sample sources. Data on the nutritional composition of the breast milk covered the concentrations of protein, lipid, carbohydrate, lactose, fatty acids, and minerals.

Statistical analysis

The data are reported as the means ± standard deviation. All statistical analyses were carried out using SigmaStat3.5 (Systat Software Inc., MA). One-way ANOVA, the Student’s t-test and the Student-Newman-Keuls Test were used to compare any differences between mean values at lactation stages. A p value <0.05 was considered as statistically significant.

RESULTS

Macronutrients in the breast milk of Chinese women

The distribution of macronutrients is shown in Table 1, and the summary statistics of macronutrients in the three lactation stages are shown in Table 2 The concentrations of protein in colostral, transitional, and mature milk decreased significantly (p<0.001) with mean values of 1.64±0.32 g/dL, 1.40±0.16 g/dL, and 1.22±0.12 g/dL, respectively (Table 2). The protein content of the 240 breast milk samples from Jinan (3.78 g/dL) was significantly higher than the reference value (0.9 g/dL),[13] which resulted in mature milk protein content fluctuation. Therefore, the protein content of mature milk had excluded Jinan, and the result was meaningful. (The dietary protein intake of the breastfeeding mothers from Jinan had exceeded twice the RNI) The sequence of protein content from high to low was: colostrum, transitional milk, mature milk (p<0.001). In contrast, the lipid content increased during the stages of lactation, being significantly higher in mature milk than in the colostral or transitional milk (p<0.001) (Table 2). The concentration of carbohydrates and lactose in the transitional milk was significantly higher than that in the mature milk, with the lactose concentration in colostrum being between that of transitional and mature milk (p<0.001).

Fatty acids composition of breast milk from Chinese women

The distribution of fatty acids composition in human milk is presented in Table 3. The level of DHA in human breast milk from Taiwan and Zhoushan was higher than that from the other regions (Table 3). The summary statistics of fatty acids during the three lactation stages are presented in Table 4. Saturated fatty acids (SFA) accounted for 34.92±5.21, 36.19±4.83 and 36.13±4.19% of the total fatty acids in colostral, transitional and mature milk, respectively. Colostral milk exhibited lower SFA concentrations than in the mature and transitional milk (p<0.001).The proportions of monounsaturated fatty acids (MUFA), 36.11±3.65, 35.81±3.53, and 35.75±4.08% in colostral, transitional and mature milk, respectively, were not significantly different. Polyunsaturated fatty acids (PUFA) accounted for 29.24±1.01 (colostral milk), 27.44±3.63 (transitional milk) and 26.84±4.66% (mature milk), respectively, of total fatty acids. The PUFA content decreased significantly from colostrum to mature milk (p<0.001). LA was the most abundant PUFA, accounting for 77.02 (colostral milk), 77.84 (transitional milk), and 80.70% (mature milk) of the total PUFA. Table 4 shows that the proportion of LA of the total fatty acids in colostrum was higher than that in transitional and mature milk, while that of ALA in colostrum was lower than that in transitional and mature milk (p<0.001). The amount of DHA and AA decreased over the three lactation stages.

Mineral composition of breast milk from Chinese women

The distribution of minerals is shown in Tables 5 and 6, with the summary statistics of mineral concentrations over the three lactation stages shown in Table 7. The K, Zn, and Cu concentrations decreased significantly over the three lactation stages (p<0.001), but the standard deviations were large. The Mg concentration showed significant differences across the three lactation stages (p<0.001), and the Mn concentration showed differences between transitional and mature milk (p=0.012). In colostral milk, the sodium (Na) concentration was higher than in the transitional and mature milk while the concentrations of calcium (Ca) and iron (Fe) were lower, but the standard deviations were also very great. The phosphorus (P) concentration remained stable throughout lactation except being slightly lower in the transitional milk.

DISCUSSION

This systematic review has summarised the available data on the nutritional composition of breast milk from Chinese women and found that it was greatly affected by the stage of lactation.

Macronutrients in breast milk

This review has suggested that the stage of lactation had a major impact on the concentrations of all macronutrients in breast milk. In colostral milk, the protein and lactose concentrations were significantly higher (p<0.001), while the lipid was significantly lower (p<0.001) than in the transitional and mature milk.

The higher concentration of protein in colostral milk was mainly caused by secretory immunoglobulin (IgA), which is not nutritionally available because it is probably not absorbed by the gut. However, it has been supposed to have a function in protecting the gut from infection.[14] The protein content decreased as lactation progressed,

Table 1. Macronutrients in breast milk among Chinese women

Sample source	Stages of lactation	Detection method	NO.	Protein (g/dL)	Lipid (g/dL)	Carbohydrates (g/dL)	Lactose (g/dL)
				x̄±s	x̄±s	x̄±s	x̄±s
Shijiazhuang (urban)[42]	Colostrum	HMA	78	2.12±0.35	2.60±0.83		6.90±0.25
Shijiazhuang (rural)[42]	Colostrum	HMA	40	1.84±0.45	3.31±0.89		6.86±0.32
Hebei (urban)[43]	Colostrum	HMA	78	2.04±0.41	2.63±0.69		6.73±0.37
Hebei (rural)[43]	Colostrum	HMA	66	1.90±0.38	2.96±0.95		6.63±0.35
Suzhou[44]	Colostrum	HMA	37	1.30±0.1	2.62±1.41		8.10±0.62
Kunshan[45]	Colostrum	HMA	231	1.20±0.11	1.77±1.17		7.48±0.70
Inner Mongolia[46]	Colostrum	IDF	7	1.33±0.07	3.45±0.85		6.79±1.01
HongKong [47]	Colostrum		25	2.5±1.13			4.42±0.75
Suzhou[44]	Transitional milk (8-10 d)	HMA	32	1.23±0.08	4.14±1.47		7.64±0.47
Kunshan[45]	Transitional milk	HMA	231	1.18±0.10	3.12±1.33		7.30±0.59
Shijiazhuang (urban)[42]	Transitional milk	HMA	32	1.72±0.41	2.88±0.76		6.99±0.39
Shanghai (urban)[48]	Transitional milk (8-10 d)	GB	90	1.98±0.37	2.97±0.43	7.91±1.06	
Shanghai (suburban)[48]	Transitional milk (8-10 d)	GB	30	1.22±0.09	2.33±0.49	8.28±0.68	
Inner Mongolia[46]	Transitional milk	IDF	7	1.28±0.22	3.29±0.75		6.65±1.02
Hebei (urban)[43]	Mature milk (1 month)	HMA	75	1.53±0.34	3.67±0.98		7.03±0.20
Hebei (rural)[43]	Mature milk (1 month)	HMA	41	1.50±0.30	2.71±1.03		6.99±0.30
Shijiazhuang (urban)[42]	Mature milk (1 month)	HMA	64	1.52±0.27	3.11±1.13		7.03±0.19
Shijiazhuang (rural)[42]	Mature milk (1 month)	HMA	26	1.28±0.31	3.06±0.90		7.06±0.11
Nanning [49]	Mature milk (1 month)	GB	18	1.95±0.54	4.10±0.45	8.09±0.90	
Sanjiang Dong[49]	Mature milk (1 month)	GB	17	1.78±0.48	4.08±0.43	8.16±0.89	
Jinan[50]	Mature milk (42 d)	HMA	240	3.78±0.29	3.58±0.75		5.44±0.41
Shijiazhuang (urban)[42]	Mature milk (2 month)	HMA	20	1.31±0.34	2.53±1.17		7.06±0.30
Nanning[49]	Mature milk (2 month)	GB	21	1.57±0.46	4.07±0.46	8.20±0.69	
Sanjiang Dong[49]	Mature milk (2 month)	GB	21	1.15±0.42	3.92±0.36		
Hebei (urban)[43]	Mature milk (3 month)	HMA	57	1.17±0.36	2.16±0.97		
Hebei (rural)[43]	Mature milk (3 month)	HMA	19	1.11±0.35	2.38±0.99		
Shijiazhuang (urban)[42]	Mature milk (3 month)	HMA	50	1.06±0.28	2.06±0.92		
Shijiazhuang (rural)[42]	Mature milk (3 month)	HMA	9	1.26±0.26	2.01±0.66		
Nanning[49]	Mature milk (3 month)	GB	19	1.50±0.49	3.90±0.54		
Sanjiang Dong [49]	Mature milk (3 month)	GB	21	1.09±0.30	3.90±0.37		
Shunyi in Beijing[51]	Mature milk (1-3 month)	HMA	39	1.07±0.15	4.07±1.54		
Shunyi in Beijing[51]	Mature milk (4 month)	HMA	52	1.09±0.19	4.36±1.51		
Shijiazhuang (urban)[42]	Mature milk (4 month)	HMA	18	1.03±0.32	1.47±0.74		7.07±0.35
Nanning [49]	Mature milk (4 month)	GB	20	1.46±0.58	3.87±0.36	8.13±0.47	
Sanjiang Dong[49]	Mature milk (4 month)	GB	21	1.07±0.37	3.87±0.43	8.02±0.49	
Nanning[49]	Mature milk (5 month)	GB	21	1.45±0.47	3.84±0.29	8.28±0.66	
Sanjiang Dong[49]	Mature milk (5 month)	GB	20	1.04±0.46	3.84±0.29	8.13±0.60	
Hebei (urban)[43]	Mature milk (6 month)	HMA	39	1.00±0.25	1.81±0.82		7.08±0.26
Hebei (rural)[43]	Mature milk (6 month)	HMA	9	0.90±0.35	1.53±1.00		6.93±0.24
Nanning[49]	Mature milk (6 month)	GB	21	1.36±0.39	3.90±0.49	7.88±0.55	
Sanjiang Dong[49]	Mature milk (6 month)	GB	21	1.04±0.34	3.83±0.37	7.92±0.56	

Table 1. Macronutrients in breast milk among Chinese women (cont.)

Sample source	Stages of lactation	Detection method	NO.	Protein (g/dL)	Lipid (g/dL)	Carbohydrates (g/dL)	Lactose (g/dL)
				x̄±s	x̄±s	x̄±s	x̄±s
Suzhou[44]	Mature milk	HMA	161	1.13±0.08	4.47±0.17		7.02±0.21
Kunshan[45]	Mature milk	HMA	231	1.10±0.06	3.11±1.61		6.81±0.35
Inner Mongolia[46]	Mature milk	IDF	66	1.20±0.28	3.04±0.85		6.97±1.22
HongKong[47]	Mature milk		11	1.01±0.14			6.66±0.55

Table 2. Summary statistics for macronutrients (g/dL) in breast milk among Chinese women

Stages of lactation	Protein	Lipid	Carbohydrates	Lactose
Colostrum	1.64±0.57 (n=562)	2.36±1.17 (n=537)		7.05±0.88 (n=562)
Transitional milk	1.40±0.4 (n=422)	3.09±1.17 (n=422)	8.04±0.99 (n=120)	7.29±0.58 (n=302)
Mature milk	1.22±0.35 (n=1228)	3.39±1.24 (n=1457)	7.61±0.97 (n=332)	6.65±0.71 (n=1136)
p-value	P_{ANOVA} <0.001	P_{ANOVA} <0.001	$P_{t\text{-}test}$ <0.001	P_{ANOVA} <0.001
S-N-K test	C>T>M	M>T>C		T>C>M

C: colostrum; T: traditional milk; M: mature milk.

Table 3. Fatty acid composition of the breast milk (% of total FA) among Chinese women

Sample source	Stages of lactation	No.	Total SFA	Total MUFA	Total PUFA	C18:2n-6 (LA)	C18:3n-3 (ALA)	C20:4n-6 (AA)	C22:6n3 (DHA)
Hohhot[52]	Colostrum	38	38.21±4.75	36.84±3.46	24.96±4.12	20.11±3.8	1.85±1.38	0.85±0.15	0.38±0.13
Changchun[52]	Colostrum	25	36.83±4.21	35.34±2.78	27.93±3.95	23.64±3.89	1.09±0.37	0.93±0.18	0.52±0.19
Chongqing[52]	Colostrum	31	36.12±4.89	44.23±3.41	19.65±0.04	15.66±3.33	1.10±0.58	0.82±0.18	0.50±0.17
Shanghai[52]	Colostrum	31	36.63±4.95	34.23±3.89	29.14±0.05	24.40±4.61	1.23±0.62	0.88±0.29	0.67±0.29
Guangzhou[52]	Colostrum	31	37.44±3.81	40.78±3.43	21.78±3.57	17.56±3.34	0.56±0.31	1.05±0.42	0.6±0.22
Shanghai[53]	Colostrum	45	37.05±5.62	33.82±2.79	29.13±5.51	24.99±5.11	1.35±0.40	0.56±0.14	0.33±0.17
Shanghai[54]	Colostrum	216	36.63±4.95	34.23±3.87	29.14±4.70	24.40±4.61	1.23±0.62	0.88±0.29	0.67±0.29
Inner Mongolia[46]	Colostrum	7	38.36	34.62	24.87	18.88±5.19	5.27±4.19		
Taiwan[55]	Colostrum	63	36.7±3.17	34.68±2.47	28.52±2.66	19.16±1.27	1.29±0.11	0.86±0.04	1.47±0.44
Wenzhou[22]	Colostrum	20	42.9±4.88	35.55±3.45	21.54±3.68	17.3±3.41	0.76±0.20	0.65±0.16	0.61±0.46
Changzhou[22]	Colostrum	82	36.63±5.35	33.64±3.27	29.73±5.27	25.42±4.84	1.44±0.50	0.59±0.14	0.38±0.23
Zhoushan[56]	Colostrum	20				15.6±2.3	1.8±0.5	0.76±0.16	0.78±0.26
Hangzhou[57]	Colostrum	202	28.43±3.52	36.17±0.26	35.69±3.68	26.28±9.54	1.34±0.82	0.55±0.40	0.64±0.50
Beijing[57]	Colostrum	133	34.18±2.35	36.39±3.25	29.40±0.25	21.57±3.94	1.22±0.69	0.98±0.30	0.57±0.24
Lanzhou[57]	Colostrum	142	36.06±0.25	39.10±0.54	26.56±0.47	18.73±3.43	2.74±1.60	0.81±0.17	0.46±0.13
Inner Mongolia[46]	Transitional milk	7	39.48	37.21	20.47	16.51±5.51	3.39±0.68		
Guangzhou[58]	Transitional milk	25	42.25	34.35	19.78	15.71	0.9	0.55	0.41
Shanghai[58]	Transitional milk	25	41.48	30.77	24.57	19.15	1.43	0.61	0.47
Nanchang[58]	Transitional milk	25	35.18	37.71	21.79	17.05	1.25	0.68	0.39
Harbin[58]	Transitional milk	11	37.89	31.65	29.51	23.27	2.17	0.76	0.53
Hohhot[58]	Transitional milk	11	41.05	33.73	21.73	16.37	2.22	0.61	0.4

Table 3. Fatty acid composition of the breast milk (% of total FA) among Chinese women (cont.)

Sample source	Stages of lactation	No.	Total SFA	Total MUFA	Total PUFA	C18:2n-6 (LA)	C18:3n-3 (ALA)	C20:4n-6 (AA)	C22:6n3 (DHA)
Shanghai[54]	Transitional milk	62	35.74±5.18	35.71±4.13	28.56±5.65	24.77±5.40	1.42±0.66	0.65±0.16	0.52±0.23
Jurong in Jangsu[59]	Transitional milk	42	36.82 ±4.64	36.77 ±4.34	26.41±2.25	16.71±2.19	1.53±0.44	0.74±0.13	0.46±0.20
Laishui in Hebei[59]	Transitional milk	41	41.88 ±4.54	30.60 ±3.32	27.52 ±3.58	19.36±3.73	0.87±0.36	0.71±0.14	0.29±0.09
Hangzhou[57]	Transitional milk	166	35.64±6.15	34.86±0.57	29.49±0.21	24.43±0.59	1.50±0.19	0.68±0.03	0.55±0.02
Beijing[57]	Transitional milk	93	32.04±0.02	37.10±2.35	30.86±0.36	24.56±5.72	1.65±0.90	0.73±0.26	0.56±0.42
Lanzhou[57]	Transitional milk	126	35.31±0.25	38.89±3.25	25.92±1.25	18.42±3.46	4.25±1.13	0.68±0.14	0.36±0.12
Hohhot[52]	Mature milk	38	37.43±4.28	37.42±4.35	25.15±5.24	21.09±4.9	1.99±1.3	0.52±0.11	0.19±0.08
Changchun[52]	Mature milk	25	32.8±4.88	32.57±4.05	34.63±6.53	30.82±6.35	2.12±0.76	0.58±0.15	0.28±0.13
Chongqing[52]	Mature milk	31	33.91±3.79	44.03±3.44	22.05±3.80	18.43±3.58	1.88±0.58	0.53±0.11	0.29±0.20
Shanghai[52]	Mature milk	31	33.14±4.80	35.85±3.74	31.01±6.25	27.62±6.21	1.42±0.63	0.53±0.10	0.41±0.17
Guangzhou[52]	Mature milk	31	37.17±5.01	39.22±3.98	23.61±3.2	20.82±3.12	0.79±0.5	0.61±0.1	0.41±0.19
Kinmen[60]	Mature milk	42	34.88±9.28	37.15±4.2	28.06±7.14	22.8±4.70	1.46±0.54	0.93±0.46	0.98±0.55
Inner Mongolia[46]	Mature milk	66	40.35	34.65	21.71	16.97±4.6	3.29±2.23		
Hebei (rural)[61]	Mature milk	52	35.92±7.34	32.59±7.21	19.97±4.85	17.73±4.24	1.03±0.19	0.3±0.15	0.19±0.08
Taiwan[55]	Mature milk	181	36.46±2.9	33.52±1.55	29.97±2.83	23.08±1.56	1.76±0.26	0.58±0.09	0.94±0.24
Guangzhou[58]	Mature milk	25	40.85	34.97	21.27	16.58	0.94	0.54	0.39
Shanghai[58]	Mature milk	25	41.04	30.71	24.68	19.82	1.48	0.56	0.42
Nanchang[58]	Mature milk	25	37.55	36.14	22.5	17.58	1.38	0.63	0.35
Harbin[58]	Mature milk	11	38.25	30.73	29.46	23.7	2.18	0.73	0.51
Hohhot[58]	Mature milk	11	40.15	34.85	22.71	16.79	2.68	0.54	0.29
Laishui in Hebei[62]	Mature milk	30				15.3±4.8	0.92±0.5		0.24±0.14
Zhoushan[56]	Mature milk	15				20±3.1	2.5±0.6	0.56±0.11	0.67±0.21
Beijing[9]	Mature milk	23	34.66±0.83	39.32±0.81	26.02±1.11	22.69±1.05	1.19±0.11	0.51±0.02	0.18±0.02
Shanghai[54]	Mature milk	31	33.14±4.80	35.85±3.74	31.01±6.25	27.62±6.21	1.42±0.63	0.55±0.10	0.41±0.17
Miyun[63]	Mature milk	18	36.59±1.02	38.03±0.84	25.38±1.39	21.47±1.21	1.29±0.17	0.63±0.03	0.33±0.05
Shanghai[53]	Mature milk	45	37.09±3.90	33.62±3.86	29.29±4.51	25.80±4.25	1.76±0.55	0.49±0.12	0.27±0.14
Miyun[63]	Mature milk	23	34.66±0.83	39.32±0.81	26.02±1.11	22.69±1.05	1.19±0.11	0.51±0.02	0.18±0.02
Hangzhou[57]	Mature milk	150	34.69±3.25	38.1±3.54	27.12±2.11	22.56±6.02	1.85±0.75	0.64±0.17	0.49±0.38
Beijing[57]	Mature milk	106	37.53±0.35	33.63±0.58	28.13±0.58	22.94±7.70	1.67±0.79	0.67±0.22	0.35±0.32
Lanzhou[57]	Mature milk	116	33.74±0.96	37.35±3.17	27.15±1.47	19.74±3.57	4.52±1.05	0.57±0.15	0.28±0.11

Table 4. Summary statistics for fatty acid composition (% of total FA) in breast milk among Chinese women

Stages of lactation	Total SFA	Total MUFA	Total PUFA	C18:2n-6(LA)	C18:3n-3(ALA)	C20:4n-6(AA)	C22:6n3(DHA)
Colostrum	34.92±5.21 (n=1066)	36.11±3.65 (n=1066)	29.24±1.01 (n=1066)	22.52±6.39 (n=1086)	1.49±1.10 (n=1086)	0.78±0.32 (n=1079)	0.62±0.40 (n=1079)
Transitional milk	36.19±4.83 (n=634)	35.81±3.53 (n=634)	27.44±3.63 (n=634)	21.36±4.81 (n=634)	2.03±1.33 (n=634)	0.68±0.14 (n=627)	0.50±0.21 (n=627)
Mature milk	36.13±4.19 (n=1106)	35.75±4.08 (n=1106)	26.84±4.66 (n=1106)	21.66±5.53 (n=1151)	2.00±1.29 (n=1151)	0.59±0.19 (n=1055)	0.47±0.36 (n=1085)
p-value	$P_{ANOVA} <0.001$	$P_{ANOVA}=0.07$	$P_{ANOVA} <0.001$	$P_{ANOVA} <0.001$	$P_{ANOVA} <0.001$	$P_{ANOVA} <0.001$	$P_{ANOVA} <0.001$
S-N-K test	T>C, M >C		C>T>M	C>T, C>M	T>C, M >C	C>T>M	C>T, C>M

C: colostrum; T: traditional milk; M: mature milk.

Table 5. Mineral contents (K, Na, P, Mg) of human milk (mg/100 g) among Chinese women

Sample source	Stages of lactation	Detection method	No.	K	Na	P	Mg
				x̄±s	x̄±s	x̄±s	x̄±s
Hebei (urban)[43]	Colostrum	ICP-MS	78	61.20±6.95			2.03±0.30
Hebei (rural)[43]	Colostrum	ICP-MS	66	61.25±10.03			2.00±0.37
Shijiazhuang (urban)[42]	Colostrum	ICP-MS	78	60.42±7.03			2.09±0.37
Shijiazhuang (rural)[42]	Colostrum	ICP-MS	40	64.32±12.55			2.13±0.44
Tangshan in Hebei[64]	Colostrum	GB	31			19.3±6.5	
Inner Mongolia [46]	Colostrum	IDF	7	46.0±11.1	11.0±3.3	14.1±1.7	3.5±0.6
Lanzhou[65]	Colostrum	GB	352	67.2±15.52	81.5±41.5		3.88±0.67
Inner Mongolia [46]	Transitional milk	IDF	7	46.3±13.9	16.3±8.7	15.0±2.5	3.6±0.8
Shijiazhuang (urban)[42]	Transitional milk	ICP-MS	32	61.23±8.13	24.54±5.00		1.95±0.33
Shanghai (urban)[48]	Transitional milk	GB	90	62.08±7.58	26.88±8.96	16.05±1.79	
Shanghai (suburban)[48]	Transitional milk	GB	30	45.95±3.15	12.21±3.8	13.00±1.25	
Hebei (urban)[43]	Mature milk (1 month)	ICP-MS	75	53.27±7.38			2.07±0.37
Hebei (rural)[43]	Mature milk (1 month)	ICP-MS	41	58.22±10.58			2.17±0.47
Shijiazhuang (urban)[42]	Mature milk (1 month)	ICP-MS	64	56.46±7.69			2.08±0.43
Shijiazhuang (rural)[42]	Mature milk (1 month)	ICP-MS	40	54.4±8.92			2.18±0.51
Laishui in Hebei[66]	Mature milk (≤30 d)	GB	39	28.19±1.65	18.40±0.92	32.59±5.17	2.81±0.31
Laishui in Hebei[66]	Mature milk (>30 d)	GB	39	28.49±1.02	14.31±0.39	19.37±4.01	2.75±0.14
Hangzhou[67]	Mature milk	GB	12	50.00	12.5	8.02	3.1
Jinan[50]	Mature milk (42 d)	GB	240				2.72±0.51
Hebei (urban)[43]	Mature milk (3 month)	ICP-MS	57	48.27±9.79			2.23±0.39
Hebei (rural)[43]	Mature milk (3 month)	ICP-MS	19	48.52±8.59			2.56±0.64
Shijiazhuang (urban)[42]	Mature milk (3 month)	ICP-MS	50	46.43±7.53			2.43±0.66
Shijiazhuang (rural)[42]	Mature milk (3 month)	ICP-MS	9	51.81±11.04			2.16±0.36
Jinan[68]	Mature milk	GB	56				3.5
Shangxi (urban)[69]	Mature milk	GB	44				2.56±1.36
Shangxi (rural)[69]	Mature milk	GB	55				2.3±1.16
Hebei (urban)[43]	Mature milk (6 month)	ICP-MS	9	42.57±0.40			2.55±0.70
Hebei (rural)[43]	Mature milk (6 month)	ICP-MS	39	37.28±0.68			2.21±0.38
Tangshan in Hebei[64]	Mature milk	GB	31			15.1±3.0	
Hunan (urban)[70]	Mature milk	ICP-MS	62				
Hunan (rural)[70]	Mature milk	ICP-MS	61				3.48±1.793.43±0.57
Shenzhen[71]	Mature milk	ICP-MS	60	48.4±3.06	18.31±11.55		2.75±0.61
Nanning[37]	Mature milk	GB	50				3.31±0.58
Inner Mongolia[46]	Mature milk	IDF	66	50.4±14.6	13.8±5.6	16.7±2.9	3.7±1.0
Lanzhou[65]	Mature milk	GB	352	51.87±12.5	26.28±21.66		2.93±0.48

Table 6. Mineral contents (Ca, Zn, Fe, Mn, Cu) of human milk (mg/100 g) among Chinese women

Sample source	Stages of lactation	Detection method	No.	Ca	Zn	Fe (ug/100 g)	Mn (ug/100 g)	Cu (ug/100 g)
				x̄±s	x̄±s	x̄±s	x̄±s	x̄±s
Hebei (urban)[43]	Colostrum	ICP-MS	78	16.37±2.92	0.31±0.09	32.00±8.60		
Hebei (rural)[43]	Colostrum	ICP-MS	66	15.92±2.96	0.34±0.13	32.07±12.77		
Shijiazhuang (urban)[42]	Colostrum	ICP-MS	78	16.59±3.22	0.34±0.12	30.81±9.96		51.67±13.15
Shijiazhuang (rural)[42]	Colostrum	ICP-MS	40	16.50±3.87	0.32±0.12	38.08±17.13		58.23±15.95
Tanshan in hebei[64]	Colostrum	GB	31	31.4± 8.1				
Lanzhou[65]	Colostrum	GB	352	24.39±3.73	0.91±0.34			83.57±24.98
Inner Mongolia[46]	Colostrum	IDF	7	28.5 ± 3.6	0.3±0.2	50±20		61.3±82.7
Inner Mongolia[46]	Transitional milk	IDF	7	28.0 ±4.3	0.3±0.2	50±20		59.0±48.3
Shijiazhuang (urban)[42]	Transitional milk	ICP-MS	32	16.42 ±3.46	0.29 ±0.06	35.01 ±8.51		54.79 ±8.42
Shanghai (urban)[48]	Transitional milk	GB	90	28.80±2.00	0.41±0.12	65.00±5.00	1.83±0.29	46.60±9.63
Shanghai (suburban)[48]	Transitional milk	GB	30	26.80±3.00	0.16±0.03	40.00±3.15	1.00±0.88	29.25±8.4
Hebei (urban)[43]	Mature milk (1 month)	ICP-MS	75	19.35±3.73	0.20±0.06	37.57±11.84		
Hebei (rural)[43]	Mature milk (1 month)	ICP-MS	41	18.96±2.75	0.19±0.06	40.33±15.23		
Shijiazhuang (urban)[42]	Mature milk (1 month)	ICP-MS	64	19.24±3.56	0.19±0.06	38.20±12.47		41.44±8.27
Shijiazhuang (rural)[42]	Mature milk (1 month)	ICP-MS	40	16.93±5.71	0.17±0.06	41.69±15.33		40.22±8.68
Laishui in Hebei [66]	Mature milk (≤30 d)	GB	39	20.93±3.28	0.31±0.13	29.63±3.65	8.05±0.99	80.2±10.7
Laishui in Hebei [66]	Mature milk (>30 d)	GB	39	12.90±1.93	0.14±0.10	29.11±4.95	5.06±0.46	60.4±7.7
Nanning[49]	Mature milk (1 month)	GB	18	27.81±1.38	0.34±0.16	26.18±8.45	1.47±0.38	39.12±10.23
Sanjiang Dong[49]	Mature milk (1 month)	GB	17	27.21±1.36	0.34±0.15	29.13±3.79	0.35±0.21	17.83±3.43
Beijing[72]	Mature milk (1 month)		18		0.32±0.02			
Nanning[49]	Mature milk (2 month)	GB	21	24.63±2.31	0.32±0.12	25.42±6.32	1.56±0.46	38.24±8.56
Sanjiang Dong[49]	Mature milk (2 month)	GB	21	23.52±2.12	0.31±0.10	25.42±6.12	0.37±0.22	17.93±3.49
Jinan[50]	Mature milk (42 d)	GB	240	35.93±7.37	0.26±0.18	39.19±9.37		41.34±16.68
Inner Mongolia[73]	Mature milk (21-69 d)	GB	37		0.26±0.002	48.12±1.57		39.58±1.45
Inner Mongolia[73]	Mature milk (61-120 d)	GB	37		0.13±0.02	30.44±1.59		31.98±1.65
Inner Mongolia[73]	Mature milk (121-180 d)	GB	36		0.11±0.002	31.76±1.64		19.74±1.35
Beijing[72]	Mature milk (3 month)		23		0.19±0.02			
Nanning[49]	Mature milk (3 month)	GB	19	23.8±1.96	0.29±0.16	25.02±7.42	1.23±0.53	41.23±9.43
Sanjiang Dong[49]	Mature milk (3 month)	GB	21	21.80±2.21	0.28±0.22	24.02±6.32	0.36±0.25	18.60±4.15
Nanning[37]	Mature milk	GB	50		0.21±0.06			34±12
Shijiazhuang (rural)[42]	Mature milk (3 month)	ICP-MS	9	23.00±4.73	0.13±0.02	31.82±12.87		26.05±7.13
Hebei (urban)[43]	Mature milk (3 month)	ICP-MS	57	20.46±3.89	0.11±0.04	25.96±11.42		
Hebei (rural)[43]	Mature milk (3 month)	ICP-MS	19	17.95±2.11	0.14±0.06	27.50±12.25		
Nanning[49]	Mature milk (4 month)	GB	20	24.7±2.14	0.31±0.09	25.23±8.23	1.59±0.39	43.62±8.42
Sanjiang Dong[49]	Mature milk (4 month)	GB	21	22.71±2.16	0.27±0.11	22.23±7.26	0.39±0.43	19.13±4.98
Nanning[49]	Mature milk (5 month)	GB	21	24.47±2.54	0.29±0.14	26.08±7.65	1.46±0.47	38.79±6.79
Sanjiang Dong[49]	Mature milk (5 month)	GB	20	23.4±2.46	0.29±0.12	23.08±6.84	0.38±0.37	17.80±3.47

Table 6. Mineral contents (Ca, Zn, Fe, Mn, Cu) of human milk (mg/100 g) among Chinese women (cont.)

Sample source	Stages of lactation	Detection method	No.	Ca	Zn	Fe (ug/100 g)	Mn (ug/100 g)	Cu (ug/100 g)
				x̄ ± s	x̄ ± s	x̄ ± s	x̄ ± s	x̄ ± s
Hebei (urban)[43]	Mature milk (6 month)	ICP-MS	9	16.39±0.26	0.07±0.02	14.65±5.46		
Hebei (rural)[43]	Mature milk (6 month)	ICP-MS	39	16.50±0.35	0.06±0.01	13.97±7.41		
Nanning[49]	Mature milk (6 month)	ICP-MS	21	23.83±1.56	0.32±0.17	25.21±7.46	1.52±0.36	34.56±8.57
Sanjiang Dong[49]	Mature milk (6 month)	ICP-MS	21	22.89±1.53	0.28±0.15	21.21±7.32	0.42±0.52	22.04±4.56
Jinan[68]	Mature milk		56	37.9	0.21	131	1.75	32
Inner Mongolia[46]	Mature milk	IDF	66	33.4± 7.0	0.2±0.1	50±20		36.7±19.8
Shangxi (urban)[69]	Mature milk	GB	44	19.54±9.8	0.15±0.08	73±216		42.18±35.34
Shangxi (rural)[69]	Mature milk	GB	55	17.61±9.6	0.15±0.17	56±98		35.37±26.69
Hangzhou[67]	Mature milk	GB	12	28.9	0.14	23	1	24
Tangshan in Hebei[64]	Mature milk	GB	31	28.8± 4.9				
Hunan (urban)[70]	Mature milk	ICP-MS	62	29.1±3.9	0.14±0.06	145±38		35±13
Hunan (rural)[70]	Mature milk	ICP-MS	61	30.5±17.8	0.13±0.08	180±107		30±15
Shenzhen[71]	Mature milk	ICP-MS	60	27.45±4.7	0.22±0.08	34.85±16		32.93±8.25
Lanzhou[65]	Mature milk	GB	352	23.8±2.7	0.27±0.13			38.77±27.34

Table 7. Summary statistics for mineral contents of human milk (mg/100 g) in breast milk among Chinese women

Mineral element	Colostrum	Transitional milk	Mature milk	*p*-value	S-N-K test
	x̄±s	x̄±s	x̄±s		
K	64.54±13.55 (n=621)	58.17±10.06 (n=159)	49.20±12.36 (n=971)	P_{ANOVA} <0.001	C>T>M
Na	80.12±42.24 (n=359)	23.18±9.46 (n=159)	22.33±18.33 (n=568)	P_{ANOVA} <0.001	C>T, C>M
P	18.34±6.25 (n=38)	15.27±2.15 (n=127)	19.75±7.97 (n=187)	P_{ANOVA} <0.001	C>T, M> T
Mg	3.11±1.06 (n=621)	2.25±0.60 (n=39)	2.77±0.82 (n=1539)	P_{ANOVA} <0.001	C> M> T
Ca	21.53±5.94 (n=652)	25.90±5.51 (n=159)	25.42±8.69 (n=1711)	P_{ANOVA} <0.001	T>C, M>C
Zn	0.66±0.39 (n=621)	0.33±0.14 (n=159)	0.22±0.13 (n=1881)	P_{ANOVA} <0.001	C>T>M
Fe (ug/100 g)	33.04±12.55 (n=269)	53.59±15.06 (n=159)	50.44±63.95 (n=1438)	P_{ANOVA} <0.001	T>C, M>C
Mn (ug/100 g)		1.62±0.62 (n=120)	2.18±2.40 (n=387)	$P_{t\text{-}test}$ =0.012	M> T
Cu (ug/100 g)	75.90±27.91 (n=477)	45.52±16.08 (n=159)	37.42±20.56 (n=1600)	P_{ANOVA} <0.001	C>T>M

C: colostrum; T: traditional milk; M: mature milk.

which agreed with previous studies.[15-17] Fat, the main source of energy in breast milk, is influenced by the maternal dietary intake and its content seems to vary the most of the macronutrients. The fat in human milk is better absorbed by the infant than that in other animals' milk.[14] As the results of the present review, fat content has been shown to increase throughout lactation,[11,18] but conflicting results have also been found in other studies.[19]

The concentration of lactose, the main carbohydrate in human milk, increased with the stages of lactation. The positive association between lactose concentration and the duration of lactation has been documented,[15] although some studies have reported otherwise.[16] Human milk also contains a small amount of glucose, galactose, and amines, with a larger amount of oligosaccharides. Oligosaccharides are important bioactive substances for promoting the healthy growth and development of infants by preventing gastrointestinal and respiratory infections.[20] Therefore, it is very important to further characterise these numerous oligosaccharides in breast milk.

Fatty acids in breast milk

The long-chain polyunsaturated fatty acids (LC-PUFAs) in human milk help to develop the nervous system in early life. In particular, AA and DHA are essential for developing the brains and retinas of infants during the early phase of growth.[21] Human milk also contains LA and ALA which are essential fatty acids for satisfying the neonates' high requirements for LC-PUFAs during the first postnatal weeks.[22]

This review has covered studies on the fatty acid composition of human milk from mothers in many geographical regions. It has been well documented that the maternal dietary habits influence the fatty acid composition of human milk.[23,24] Dietary differences between different countries or between locations in the same country have also been documented as influencing the composition of human milk.[25-29]

The essential fatty acid, LA, was most abundant in the breast milk (21.36 22.52%) (Table 4). Chinese human milk was significantly richer in LA than Saudi,[30] Nepalese,[31] German,[32] Australian,[33] and Spanish,[34] human milk (8.7, 9.05, 10.6, 11, and 12.3%, respectively). The content of LA in our review was higher than that found in milk from women living in Europe, probably because Chinese women, unlike European women, consume a considerable amount of vegetable oil in their diet. In colostral milk, the ratio of LA to ALA was 15.1:1, which was close to the recommendation of the European Society for Paediatric Gastroenterology and Nutrition (between 5:1 and 15:1).[35] And in the transitional and mature milk, the ratio was 10.5:1 and 10.8:1, which was in the range of 5:1 to 15:1.

Mothers can increase the level of DHA in their milk significantly by eating fish.[36] In this review, the level of DHA in human milk from Taiwan and Zhoushan was higher than that from other regions (Table 3). It was also similar to that milk from Japan[12] and Penang Island, Malaysia.[27] It was indicated that the higher DHA concentrations in human milk were found primarily in coastal or island populations and were associated with the consumption of fish and marine food.

Minerals in breast milk

This review suggests that the mean concentrations of K, Na, Mg, Fe, Zn, Mn, and Cu in breast milk exhibited a wide range of standard deviations. It is supposed that the concentration of minerals in breast milk may result from geographic locations and different foods consumed by the mothers. It has been reported that the maternal diet affected the Zn concentration in breast milk,[37] but it had little influence on the concentrations of Ca, Cu and Mg in breast milk.[14,37-39] We can recommend that Zinc intake during lactation may be marginal and require optimization.

Our review has also indicated that the mineral content of human milk varies between individuals and between lactation stages. It has been reported that Zn concentration in breast milk decreased rapidly as the stage of lactation progressed,[40,41] a result consistent with this review. The present review has also indicated that the Ca content in the breast milk of Chinese mothers is relatively low compared with reported values from other populations.[10,11] It may relate to the genetic differences between Chinese and foreign mothers, which needs further investigation. The review also showed that concentrations of Ca and P in human milk were lower than those in cow's milk. However, the ratio of Ca to P in breast milk led to the higher absorption of Ca from breast milk than from cow's milk. The Cu concentration in breast milk was also higher than that in cow's milk. Ca is necessary for the growth of bone, and Cu for the formation of myelin sheaths in the nervous systems, therefore, breastfeeding is better for the infant's health.

Changes continue to be made to infant formula milk to make these products closer to those of human milk regarding composition and function. This review provides a scientific basis for the production of Chinese infant formulas and emphasises that the lactation period is a crucial factor affecting variation in the composition of human milk.

However, this review was limited to some extent by the lack of relevant information on vitamins and selenium (Se) because there were few Chinese studies in this area, even though these micronutrients are significant for infants. In addition, neither amino acids nor bioactive components were discussed in this review, a topic we hope to cover in the future.

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AUTHOR DISCLOSURES

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