



# **Human Milk Composition and Health Benefits**

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# OUTLINE

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- **Stages of lactation**
- **Macronutrients**
- **Micronutrients**
- **Bioactive components**
- **Health benefits**



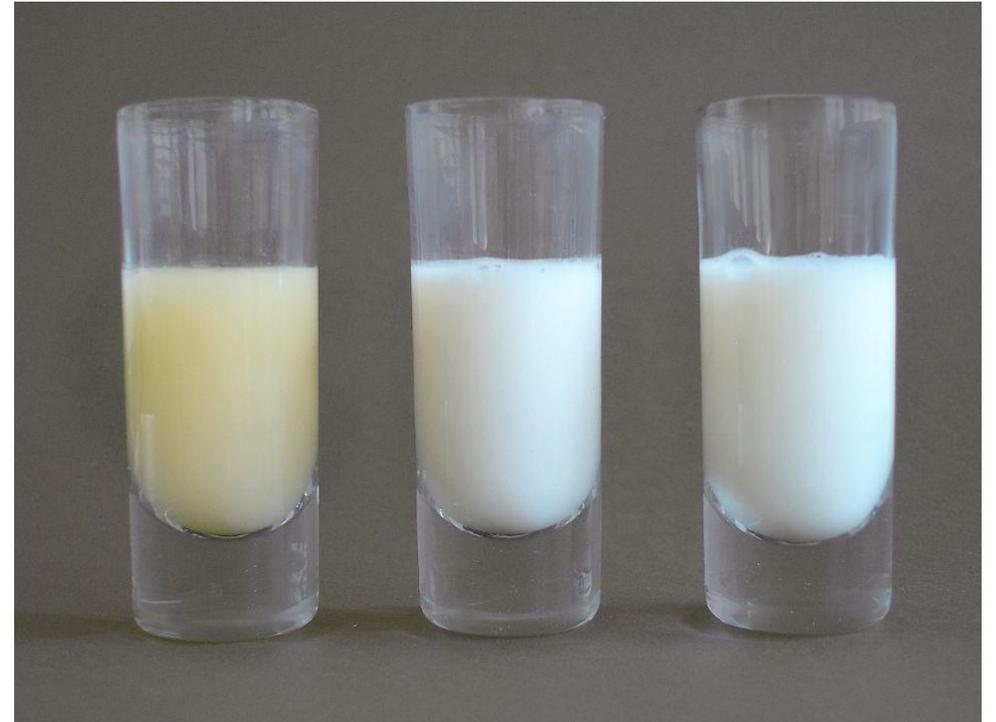
# STAGES OF LACTATION

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**Colostrum:** produced in low quantities in the first few days postpartum

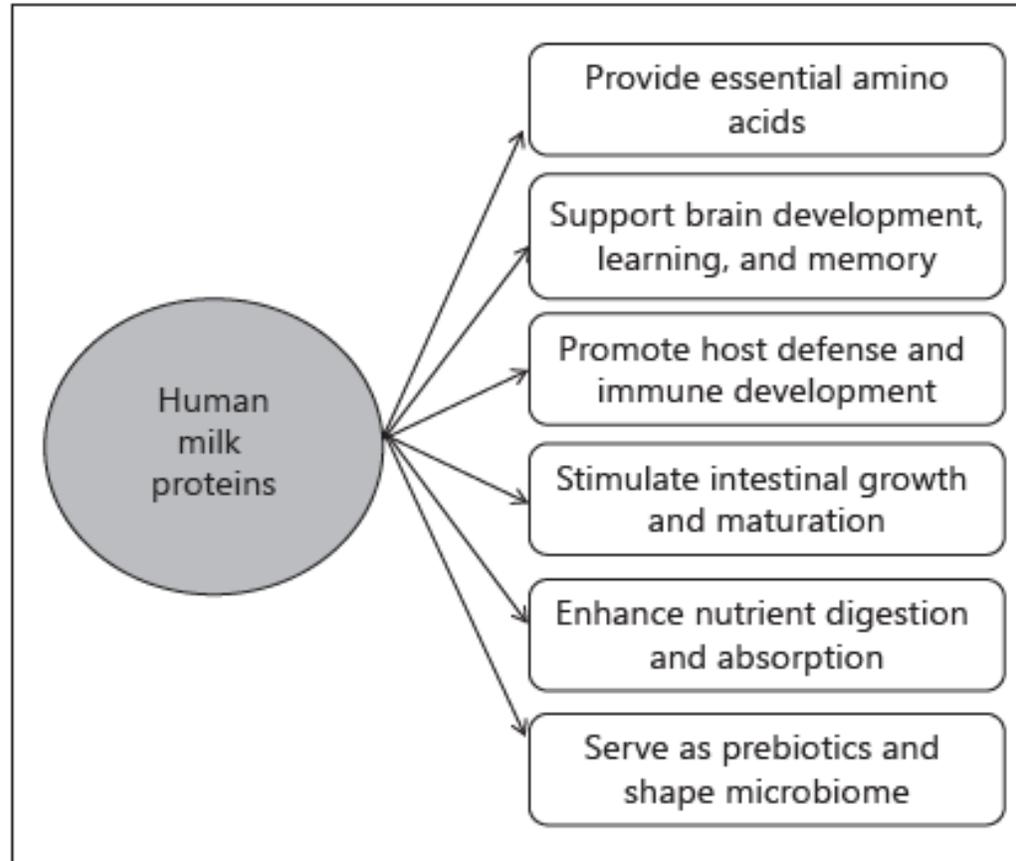
**Transitional milk:** occurs from 5 days to two weeks postpartum, after which milk is considered largely mature.

**Mature milk:** By four to six weeks postpartum, human milk is considered fully mature.



# Macronutrients--Protein

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Source: <https://www.nestlenutrition-institute.org/>

# Macronutrients--Protein

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Milk proteins are classified into three groups

- milk fat globule membrane (MFGM) proteins,
- caseins
- whey proteins.

# Macronutrients--Protein

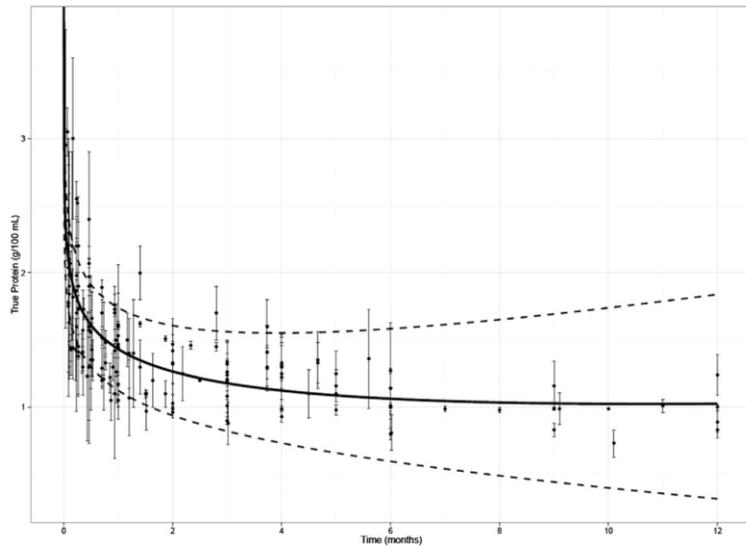


Fig. 1. Linear regression analysis (solid line) of the true protein dataset in g per 100 ml over the first year of lactation (lower and upper confidence bands are represented by the dashed lines). Data points correspond to mean values and error bars to  $\pm$  standard deviations.

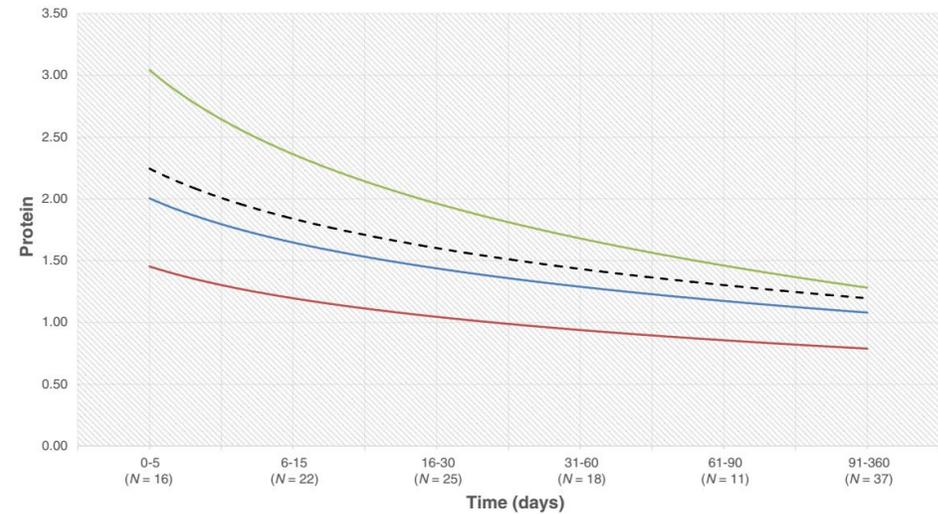
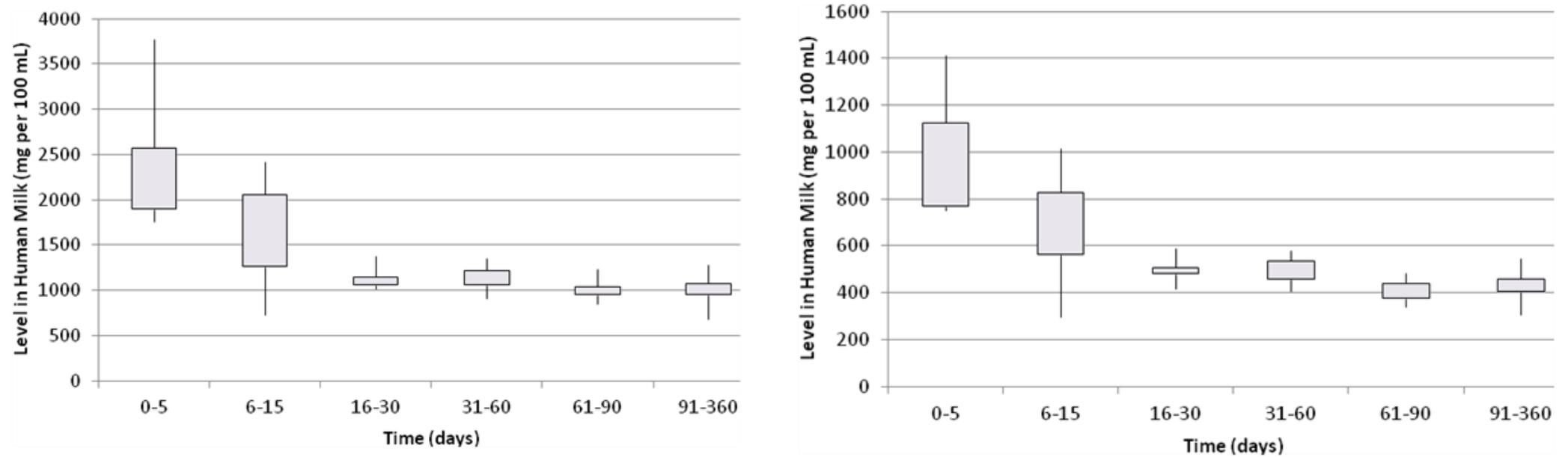


Fig. 2. Estimated evolution of infant protein requirements (in g per day and per kg of body weight; dashed black line) and true protein content in human milk (in g per 100 ml; minimum, solid red line; median solid light blue line and maximum solid green line). Logarithmic regressions were calculated from the human milk protein concentration dataset (present study) and from the dietary protein requirements dataset from Dewey *et al.*, 1996.

# Macronutrients--Protein



**Figure 3. Boxplots displaying the longitudinal evolution of (A) total amino acid and (B) essential amino acid content in human milk (mg per 100 mL).**

# Macronutrients--Protein

Human Milk



Total milk proteins:  
0.95 g/100ml

60% total protein	<b>WHEY PROTEINS</b>	<ul style="list-style-type: none"> <li><math>\beta</math>-lactoglobulin 0%</li> <li><math>\alpha</math>-lactalbumin 36%</li> <li>immunoglobulins (IgG, IgA, IgM) 17%</li> <li>serum albumin 6%</li> <li>lactoferrin 25%</li> <li>glycomacropeptide ND</li> <li>other 10%</li> </ul>
40% total protein	<b>CASEINS</b>	<ul style="list-style-type: none"> <li><math>\beta</math>-casein 68%</li> <li><math>\kappa</math>-casein 20%</li> <li><math>\alpha_{s1}</math>-casein 12%</li> <li><math>\alpha_{s2}</math>-casein 0%</li> </ul>

Bovine Milk



Total milk proteins:  
3.3 g/100ml

20% total protein	<b>WHEY PROTEINS</b>	<ul style="list-style-type: none"> <li><math>\beta</math>-lactoglobulin 52%</li> <li><math>\alpha</math>-lactalbumin 17%</li> <li>immunoglobulins (IgG, IgA, IgM) 10%</li> <li>serum albumin 5%</li> <li>lactoferrin 1.5%</li> <li>glycomacropeptide 12%</li> <li>other 2.5%</li> </ul>
80% total protein	<b>CASEINS</b>	<ul style="list-style-type: none"> <li><math>\beta</math>-casein 36%</li> <li><math>\kappa</math>-casein 14%</li> <li><math>\alpha_{s1}</math>-casein 40%</li> <li><math>\alpha_{s2}</math>-casein 10%</li> </ul>

Layman et al. Nutr Rev. 2018 Jun 1;76(6):444-460.

# Macronutrients--Protein

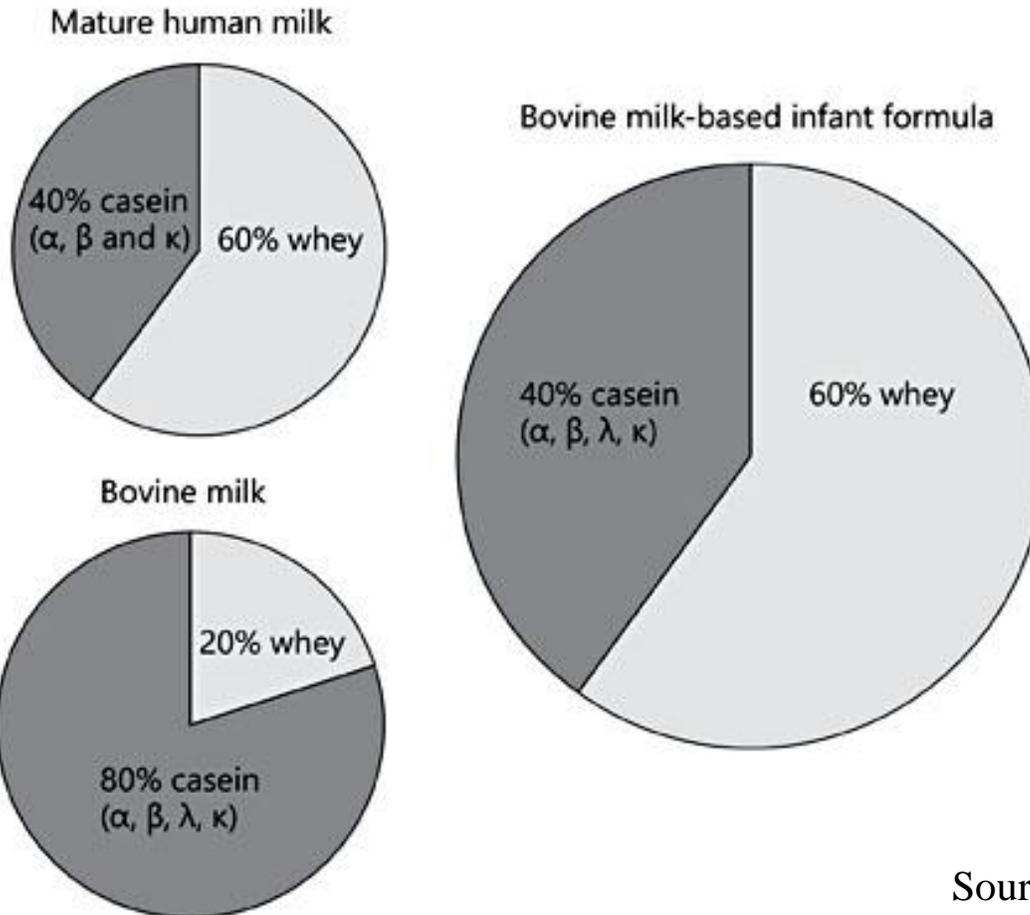
Median values of whey to casein ratio, lactoferrin,  $\alpha$ -lactalbumin, serum albumin, IgG, IgM, IgA and lysozyme in human milk (data in mg per ml)

Time (days)	Whey-to-casein ratio	Lactoferrin	$\alpha$ -Lactalbumin	Serum albumin	IgG	IgM	sIgA	Lysozyme
0-5	89:11	5.05	4.30	0.35	–*	–	5.45	0.32
6-15	65:35	3.30	4.20	0.62	0.05	0.12	1.50	0.30
16-30	59:41	2.31	3.30	0.67	0.05	0.05	1.10	0.28
31-60	61:39	1.95	3.10	0.69	–	–	1.00	1.10
61-90	61:39	1.89	2.84	0.45	0.03	0.03	1.30	0.85
91-360	60:40	1.44	2.62	0.37	0.04	0.03	–	–

\* Not reported.

# Macronutrients--Protein

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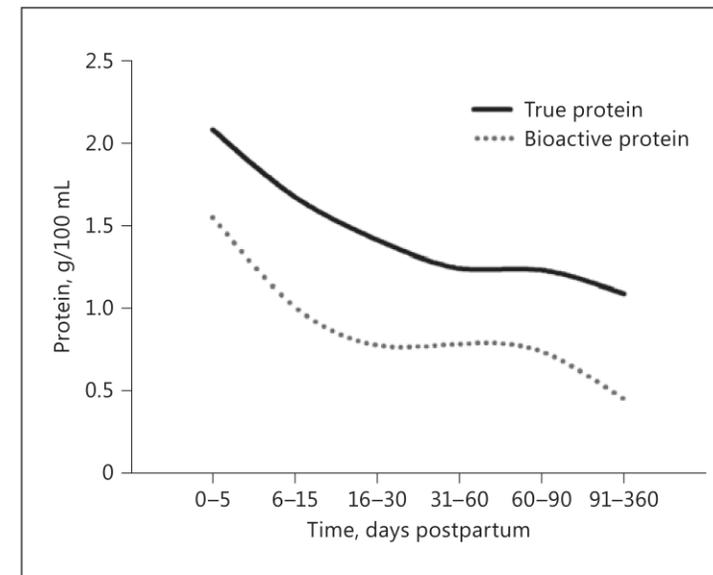


Source: <https://www.nestlenutrition-institute.org/>

# Macronutrients--Protein

**Table 1.** Bioactive functions of breast milk proteins

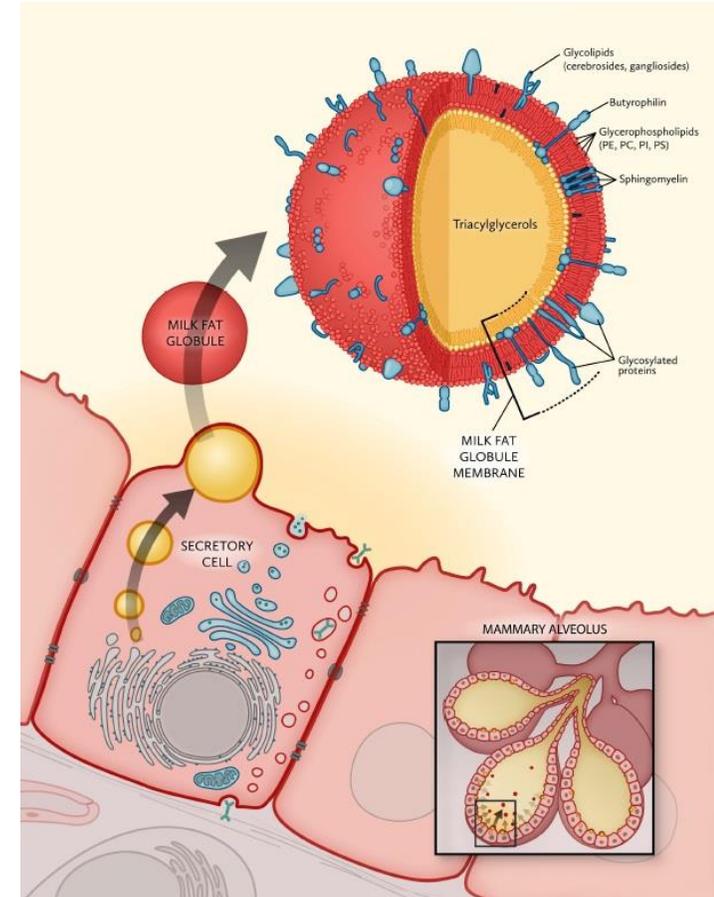
Function	Bioactivity	References
Immune modulation and antimicrobial activity	Lactoferrin	29, 30, 113
	Secretory IgA	36, 114
	Osteopontin	38, 43
	Cytokines	53, 54
	Lysozyme	57
	$\kappa$ -Casein	59
	Lactoperoxidase	61, 62
	Haptocorrin	64
	$\alpha$ -Lactalbumin	70
Digestive function	Bile salt-stimulated lipase	79
	Amylase	81
	$\alpha$ 1-antitrypsin	86
Gut development	Growth factors	91
	Lactoferrin	94
Carriers for other nutrients	Lactoferrin	96
	Haptocorrin	99
	Folate-binding protein	105, 106
	$\alpha$ -Lactalbumin	107
	$\beta$ -Casein	111, 112



**Fig. 2.** Evolution of true protein (solid line) and bioactive protein (dotted line; sum of lactoferrin,  $\alpha$ -lactalbumin, serum albumin, sIgA, IgG, IgM, lysozyme, well-characterized bioactive proteins) of breast milk within the first year of postpartum life. Based on data from Lönnerdal et al. [5].

# Macronutrients--Fat

- Human milk fat provides almost 50% of the energy intake of young infants, corresponding to intakes around 25 g/day for the age up to 6 months
- Milk can be characterized as an emulsion of milk fat globules in an aqueous liquid.
- Surrounding the TAG core is the milk fat globule membrane (MFGM), which is derived from the mammary gland epithelium



# Macronutrients--Fat

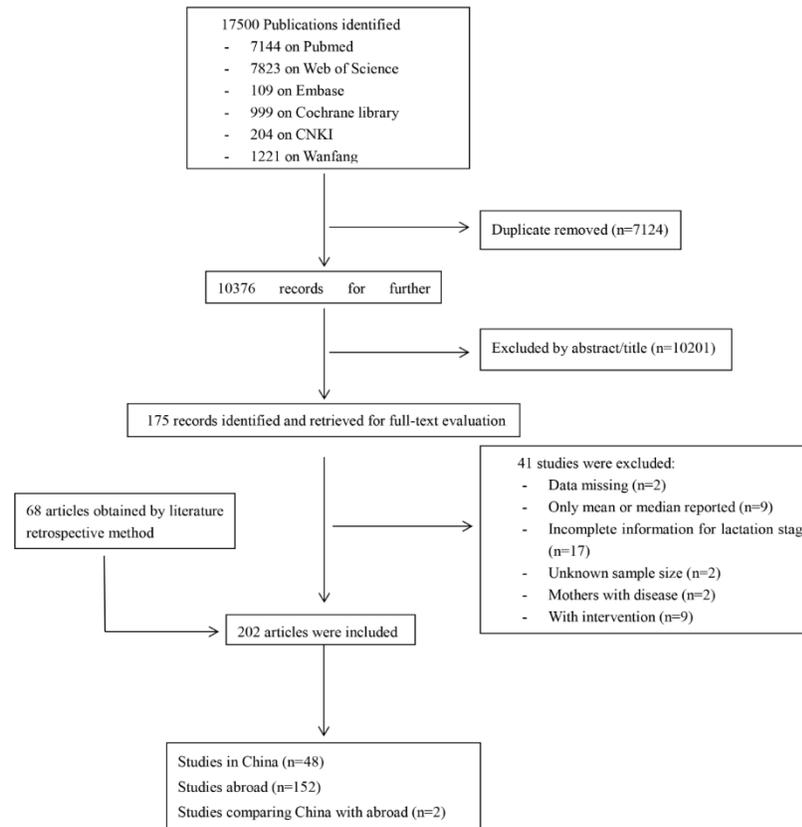


Figure 1 Flowchart of study selection

Source: Zheqing Zhang et al, unpublished



# Macronutrients--Fat

**Table 1 Concentration of total and subtypes of lipids in human milk.**

Variables	Worldwide				China			
	n	k	Mean	95%CI	n	k	Mean	95%CI
<b>Total lipid (g/100ml)</b>	<b>16</b>	<b>4129</b>	<b>3.13</b>	<b>2.87, 3.40</b>	<b>2</b>	<b>132</b>	<b>3.59</b>	<b>3.16, 4.03</b>
<b>Total fat (g/100ml)</b>	<b>35</b>	<b>18507</b>	<b>3.26</b>	<b>3.12, 3.41</b>	<b>9</b>	<b>2690</b>	<b>3.21</b>	<b>2.93, 3.49</b>
<b>Cholesterol (mg/100ml)</b>	<b>8</b>	<b>344</b>	<b>20.40</b>	<b>17.06, 23.75</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>
<b>Phospholipid (mg/100ml)</b>	<b>10</b>	<b>14256</b>	<b>38.65</b>	<b>35.83, 41.47</b>	<b>2</b>	<b>787</b>	<b>30.12</b>	<b>26.26, 33.98</b>

n: number of individual studies; k: sample size

Source: Zheqing Zhang et al, unpublished

# Macronutrients--Fat

**Table 2 Fatty acids composition in human milk (% of total fatty acids).**

Variables	Worldwide				China			
	n	k	Mean	95%CI	n	k	Mean	95%CI
SFA	80	12080	40.62	38.41, 42.83	25	7453	36.80	35.92, 37.69
MUFA	76	11276	36.65	35.54, 37.76	24	7352	34.84	32.94, 36.74
PUFA	48	7403	22.36	20.71, 24.01	19	5081	28.15	25.94, 30.35

n: number of individual studies; k: sample size

Source: Zheqing Zhang et al, unpublished

# Macronutrients--Fat

**Table 15 Saturated fatty acids composition in human milk (% of total fatty acids)**

Variables	Worldwide				China			
	n	k	Mean	95%CI	n	k	Mean	95%CI
<b>SFA</b>	<b>80</b>	<b>12080</b>	<b>40.62</b>	<b>38.41, 42.83</b>	<b>25</b>	<b>7352</b>	<b>36.80</b>	<b>35.92, 37.69</b>
<b>C10:0</b>	<b>78</b>	<b>11081</b>	<b>1.12</b>	<b>0.99, 1.25</b>	<b>27</b>	<b>6405</b>	<b>1.05</b>	<b>0.89, 1.21</b>
<b>C12:0</b>	<b>94</b>	<b>13286</b>	<b>4.92</b>	<b>4.59, 5.25</b>	<b>30</b>	<b>8045</b>	<b>3.92</b>	<b>3.58, 4.26</b>
<b>C14:0</b>	<b>101</b>	<b>13995</b>	<b>6.10</b>	<b>5.61, 6.59</b>	<b>30</b>	<b>8047</b>	<b>4.48</b>	<b>4.14, 4.82</b>
<b>C16:0</b>	<b>108</b>	<b>14070</b>	<b>21.81</b>	<b>20.10, 23.52</b>	<b>30</b>	<b>7778</b>	<b>20.41</b>	<b>19.77, 21.04</b>
<b>C18:0</b>	<b>107</b>	<b>14441</b>	<b>6.93</b>	<b>6.42, 7.43</b>	<b>30</b>	<b>7778</b>	<b>5.64</b>	<b>5.45, 5.84</b>

n: number of individual studies; k: sample size

Source: Zheqing Zhang et al, unpublished

# Macronutrients--Fat

**Table 16 Monounsaturated fatty acids composition in human milk(% of total fatty acids)**

Variables	Worldwide				China			
	n	k	Mean	95%CI	n	k	Mean	95%CI
MUFA	76	12080	36.65	35.54, 37.76	25	7453	34.84	32.94, 36.74
C16:1 n-7	37	7611	2.11	1.87, 2.34	17	5629	2.15	1.99, 2.32
C18:1 n-9	60	7735	32.36	29.67, 35.05	21	4420	30.10	25.55, 34.66
C22:1 n-9	34	7382	0.17	0.15, 0.19	15	5386	0.20	0.17, 0.23

n: number of individual studies; k: sample size

Source: Zheqing Zhang et al, unpublished

# Macronutrients--Fat

**Table 17 Polyunsaturated fatty acids composition in human milk(% of total fatty acids).**

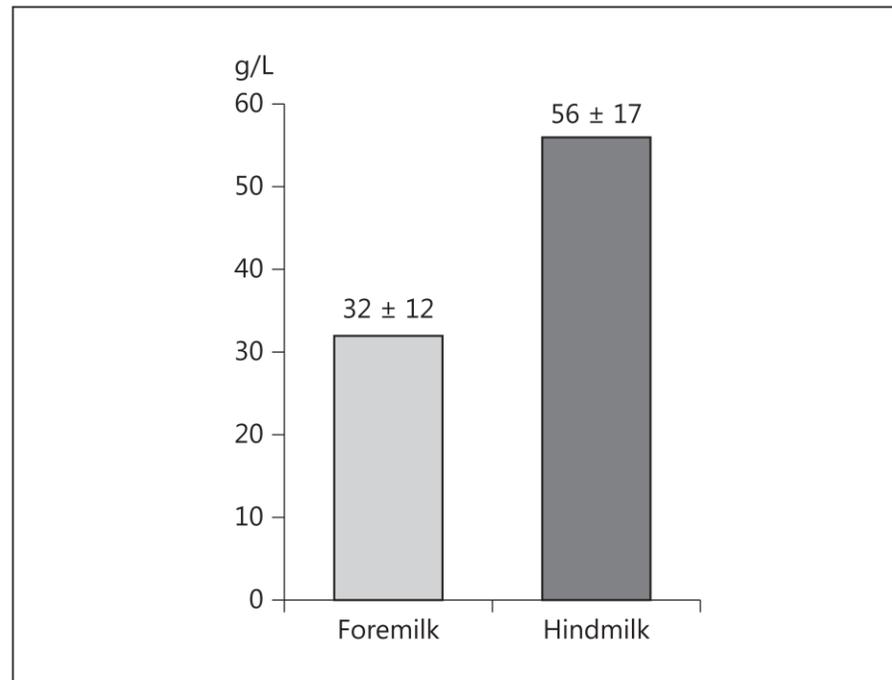
Variables	Worldwide				China			
	n	k	Mean	95%CI	n	k	Mean	95%CI
<b>PUFA</b>	<b>48</b>	<b>7403</b>	<b>22.36</b>	<b>20.71, 24.01</b>	<b>19</b>	<b>5081</b>	<b>28.15</b>	<b>25.94, 30.35</b>
<b>n-6 PUFA</b>	<b>67</b>	<b>9727</b>	<b>18.44</b>	<b>16.48, 20.40</b>	<b>20</b>	<b>5452</b>	<b>23.99</b>	<b>18.92, 29.05</b>
<b>C18:2 n-6</b>	<b>108</b>	<b>13463</b>	<b>15.91</b>	<b>14.79, 17.02</b>	<b>30</b>	<b>6653</b>	<b>21.58</b>	<b>20.09, 23.07</b>
<b>C20:4 n-6</b>	<b>111</b>	<b>15039</b>	<b>0.62</b>	<b>0.60, 0.64</b>	<b>28</b>	<b>7531</b>	<b>0.68</b>	<b>0.64, 0.73</b>
<b>n-3 PUFA</b>	<b>68</b>	<b>11306</b>	<b>1.88</b>	<b>1.73, 2.03</b>	<b>19</b>	<b>6754</b>	<b>2.14</b>	<b>1.79, 2.5</b>
<b>C18:3 n-3</b>	<b>111</b>	<b>14605</b>	<b>1.09</b>	<b>1.02, 1.15</b>	<b>29</b>	<b>7606</b>	<b>1.54</b>	<b>1.41, 1.68</b>
<b>C20:5 n-3</b>	<b>84</b>	<b>7298</b>	<b>0.14</b>	<b>0.12, 0.16</b>	<b>20</b>	<b>3842</b>	<b>0.22</b>	<b>0.14, 0.29</b>
<b>C22:6 n-3</b>	<b>107</b>	<b>15010</b>	<b>0.45</b>	<b>0.43, 0.48</b>	<b>25</b>	<b>7553</b>	<b>0.53</b>	<b>0.49, 0.58</b>

n: number of individual studies; k: sample size

Source: Zheqing Zhang et al, unpublished

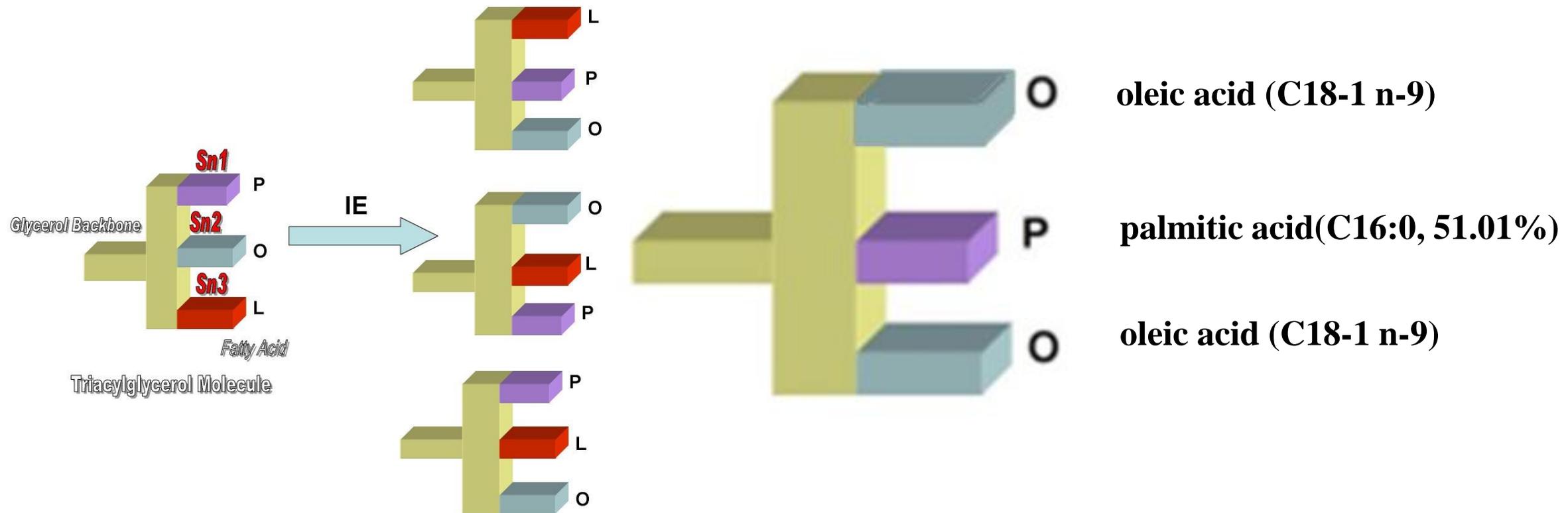
# Macronutrients--Fat

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**Fig. 2.** Milk fat concentration in fore- and hindmilk collected before and after breastfeeding of 15 term infants. Drawn from data of Khan et al. [79].

# Macronutrients--Fat



**“O-P-O” structure allows babies to absorb more palmitic acid and calcium**

Source: Zheqing Zhang et al, unpublished

# Macronutrients--Fat

**Table 11 Structured lipids in human milk (% of TAG).**

Variables	Worldwide				China			
	n	k	Mean	95%CI	n	k	Mean	95%CI
<b>OPO</b>	<b>9</b>	<b>751</b>	<b>17.44</b>	<b>14.18, 20.70</b>	<b>5</b>	<b>616</b>	<b>13.45</b>	<b>10.33, 16.57</b>
<b>OPL</b>	<b>8</b>	<b>573</b>	<b>16.45</b>	<b>13.02, 19.88</b>	<b>4</b>	<b>438</b>	<b>16.46</b>	<b>11.31, 21.60</b>
<b>LaPO</b>	<b>2</b>	<b>354</b>	<b>8.91</b>	<b>6.91, 10.92</b>	<b>1</b>	<b>309</b>	<b>7.57</b>	<b>7.05, 8.08</b>
<b>OLL</b>	<b>4</b>	<b>879</b>	<b>5.13</b>	<b>3.56, 6.70</b>	<b>3</b>	<b>839</b>	<b>5.57</b>	<b>3.98, 7.16</b>
<b>PPO</b>	<b>5</b>	<b>931</b>	<b>5.82</b>	<b>4.91, 6.73</b>	<b>3</b>	<b>839</b>	<b>5.46</b>	<b>4.38, 6.55</b>

n: number of individual studies; k: sample size; OPO: 1,3-olein-2-palmitin; OPL: 1(3)-olein-2-palmitin- 3(1)-linolein; LaPO: 1-laurin-2-palmitin-3- olein; OLL: 1-olein-2,3-linolein ; PPO: 1,2-dipalmitoyl-3-Oleoylglycerol.

Source: Zheqing Zhang et al, unpublished

# Macronutrients--Fat

**Table 13 Total fat concentration in human milk at different lactation stages (g/100ml)**

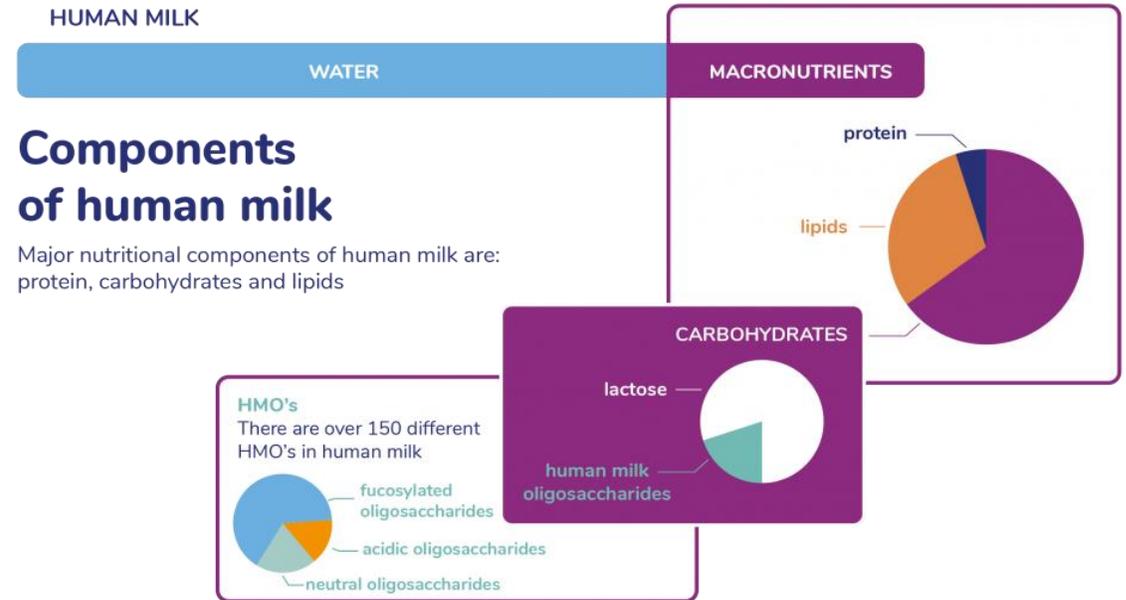
<b>Variables</b>	<b>Worldwide</b>			<b>China</b>		
	<b>n</b>	<b>k</b>	<b>Mean (95%CI)</b>	<b>n</b>	<b>k</b>	<b>Mean (95%CI)</b>
<b>Colostrum</b>	<b>14</b>	<b>1094</b>	<b>2.47(2.16, 2.79)</b>	<b>6</b>	<b>525</b>	<b>2.27(1.56, 2.98)</b>
<b>Transition</b>	<b>13</b>	<b>1220</b>	<b>3.44(3.26, 3.62)</b>	<b>6</b>	<b>721</b>	<b>3.53(3.19, 3.88)</b>
<b>Mature</b>	<b>31</b>	<b>15979</b>	<b>3.50(3.34, 3.65)</b>	<b>8</b>	<b>1324</b>	<b>3.60(3.35, 3.85)</b>
<b>P</b>			<b>&lt;0.01</b>			<b>&lt;0.01</b>

n: number of individual studies; k: sample size

Source: Zheqing Zhang et al, unpublished

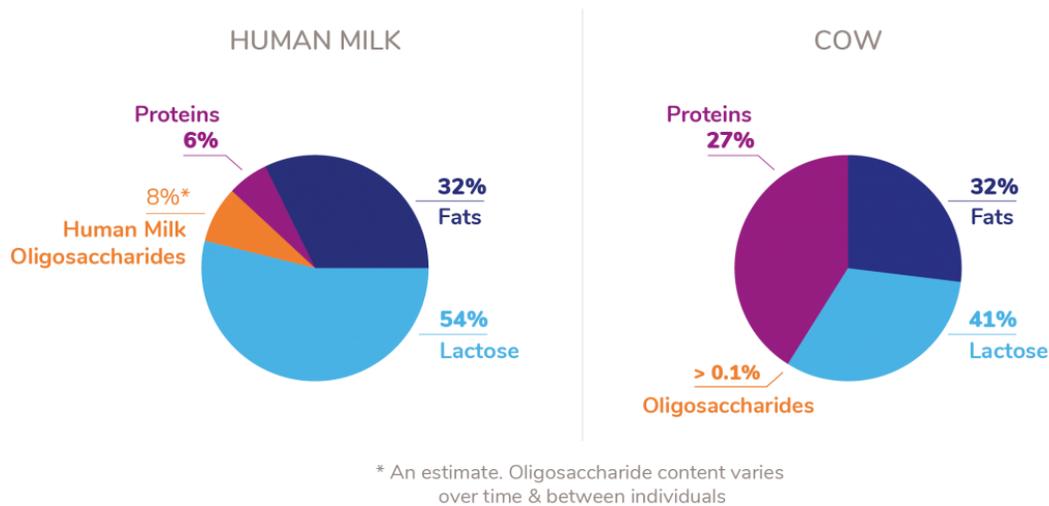
# Macronutrients--sugar

- The principal sugar of human milk is the disaccharide lactose
- Human milk oligosaccharides (HMOs) are the third most abundant component of breast milk, after lactose and lipids.



# Macronutrients--sugar

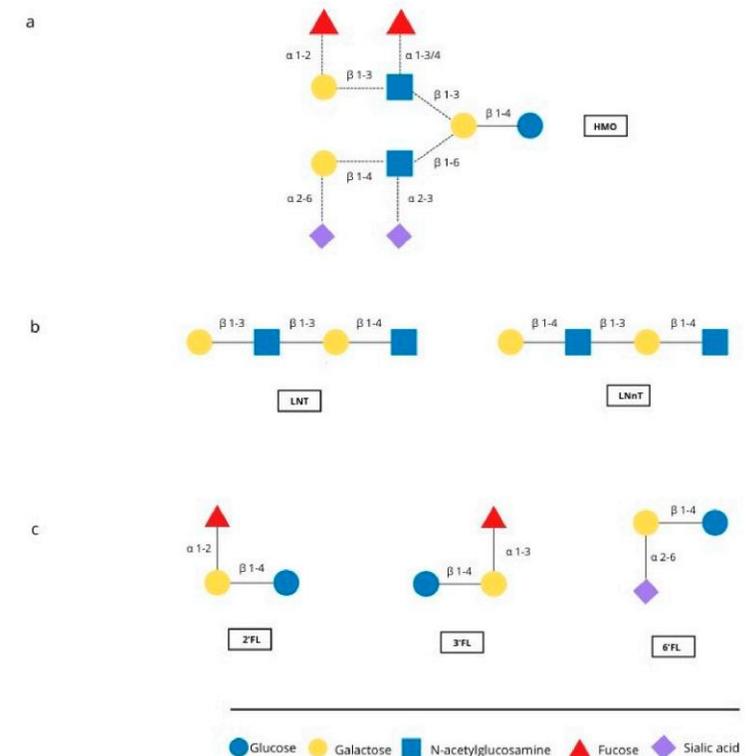
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**Breast milk vs. cow's milk oligosaccharides**  
Oligosaccharides are at least 20 times more abundant in human breast milk than of cow's milk.  
But also many of the oligosaccharide structures found in human milk are essentially absent or exist in only trace amounts in bovine milk.

# Macronutrients--sugar

**Human milk oligosaccharides (HMOs),**  
are made of five basic monosaccharides:  
glucose (Glc), galactose (Gal), N-  
ethylglucosamine (GlcNAc), fucose (Fuc) and  
sialic acid (SA)



**Figure 1.** Representative structure of HMO and the major oligosaccharides found in breast milk. (a) Possible linkages of HMO building blocks, (b) type 1 (LNT) and type 2 chains (LNnT) (c) structures of 2'FL, 3'FL and 6'FL.

Wiciński et al, Nutrients. 2020 Jan; 12(1): 266.

# Macronutrients--sugar

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## Health benefits of HMOs

- Prevention of Pathogen Adhesion
- Effects of HMOs on Microbiota Composition
- Antiviral Activity
- Immunity System Development

# Macronutrients--sugar

Meta-analysis results of preterm and term breast milk lactose and oligosaccharide content over time

LactoseKcal/dl	Preterm			Term			Preterm & term compared	
	mean	SD	n	mean	SD	n	% difference	p-value
d 1-3	5.1	0.7	95	5.6	0.6	59	-9	< 0.00001*
d 4-7	6.3	1.1	114	6.0	1.0	281	4	0.009
week 2	5.7	0.8	231	6.2	0.6	100	-8	< 0.00001*
week 3-4	6.0	0.5	225	6.7	0.7	193	-10	< 0.00001*
week 5-6	5.8	0.6	104	6.1	1.0	22	-6	0.06
week 7-9	6.3	0.4	123	6.5	0.5	646	-2	< 0.00001*
week 10-12	6.8	0.3	28	6.7	0.7	58	2	0.47

◆◆References: [6,11,12,19,21-23,121,123,129-131,135,140,143,146,147]

## Oligosaccharides (g/dL) ◆◆◆

Time frame:	mean	SD	n	mean	SD	n	% difference	p-value
d 1-3	-	-	-	1.6	0.2	9	-	-
days 4-7	2.1	0.4	89	1.9	0.4	93	12	0.0009
week 2 (days 7-14)	2.1	0.5	89	1.9	0.4	54	7	0.004
week 3-4 (days 15-30)	1.7	0.3	152	1.6	0.3	46	12	0.27
week 5-6	-	-	-	1.4	0.3	46	-	-
week 7-9	-	-	-	1.3	0.3	46	-	-
week 10-12	-	-	-	-	-	-	-	-

◆◆◆References: [140,141,143,147].

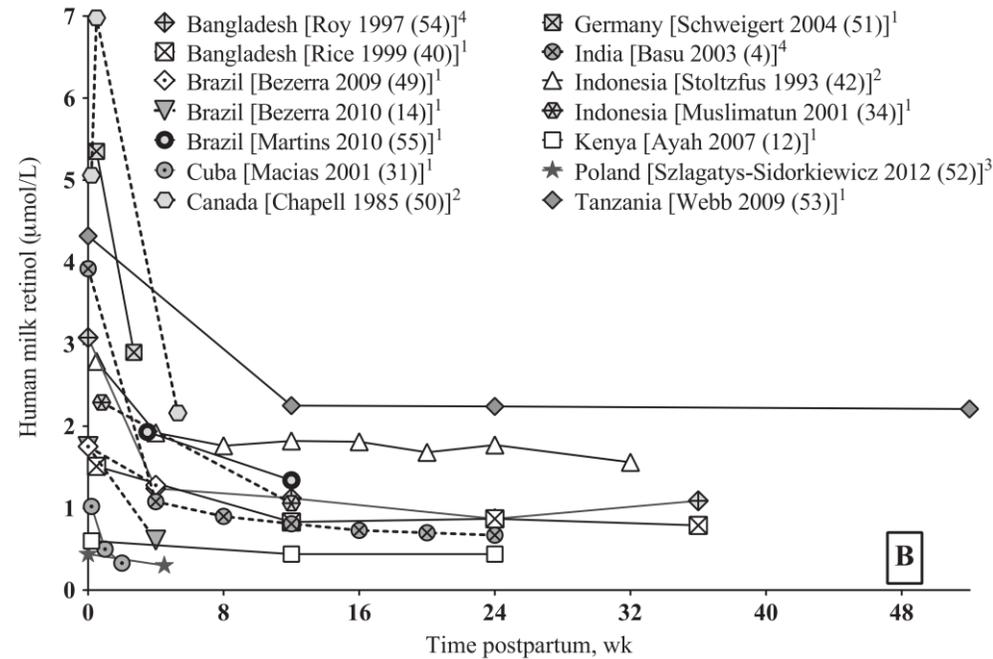
\*Statistically significant difference. In compensation for multiple comparisons, an approximate Bonferroni adjustment was made and the p-value for statistical significance was < 0.001.

# Micronutrients—vitamins

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- Many micronutrients vary in human milk depending on maternal diet and body, including vitamins A, B<sub>1</sub>, B<sub>2</sub>, B<sub>6</sub>, B<sub>12</sub>, D, and iodine.
- Regardless of maternal diet, Vitamin K is extremely low in human milk
- Vitamin D also occurs in low quantity in human milk, particularly with low maternal exposure to sunshine

# Micronutrients—vitamin A



**FIGURE 2** Human-milk retinol:fat (A) and retinol concentrations (B) in longitudinal studies (unsupplemented women). Analytical methods for measuring vitamin A are indicated by superscript numbers. Unless otherwise noted by an asterisk (\*), milk fat was measured by using the creatatocrit method (47). <sup>1</sup>HPLC after saponification to obtain free retinol from retinyl esters; <sup>2</sup>HPLC without saponification; <sup>3</sup>HPLC with the use of a commercial kit for sample preparation (validated for plasma but not milk); <sup>4</sup>colorimetry after saponification.

# Micronutrients—vitamin E

Subtypes of vitamin E concentration in human milk (mg/L).

Souces	Postpartum days	$\alpha$ -tocopherol	$\beta$ --tocopherol	$\gamma$ --tocopherol	$\delta$ --tocopherol
Lacomba et al, 2012	30~120	3.48 (1.04~5.40)	0.62 (0.19~1.29)	0.76 (0.21~1.39)	0.13 (0.06~0.24)
Tijerna-S áenz et al, 2009	30	2.32±0.11 (0.66~5.02)	--	0.46±0.03 (0.11~1.27)	0.11±0.01 (0.00~0.56)

# Micronutrients—vitamin D

**TABLE 4**

Seasonal variations in concentrations of vitamin D and 25-hydroxyvitamin D in foremilk, hindmilk, and maternal plasma<sup>1</sup>

	Winter ( <i>n</i> = 118 samples)	Summer ( <i>n</i> = 108 samples)	<i>P</i>
Vitamin D, nmol/L			
Foremilk	0.1 (0.1–0.4) <sup>2</sup>	0.4 (0.1–1.3)	<0.01
Hindmilk	0.3 (0.1–0.9)	0.9 (0.3–3.0)	<0.01
25-Hydroxyvitamin D, nmol/L			
Foremilk	0.8 (0.5–1.1)	0.9 (0.7–1.5)	<0.01
Hindmilk	1.2 (0.8–1.6)	1.6 (1.1–2.2)	<0.01
Maternal plasma	55.5 ± 22.9 <sup>3</sup>	73.6 ± 25.7	<0.01

<sup>1</sup>Samples with concentrations below the detection limit were assigned a value of 0.14 nmol/L (see Methods for explanations). Numbers of samples are minimum numbers (i.e., for some indexes measured, more samples were available for analyses). Statistical tests were performed with the use of the Mann-Whitney *U* test for nonparametric data or a 2-sample *t* test for data with a normal distribution. No adjustments were performed for repeated measures (i.e., that some individuals contributed with more than one sample).

<sup>2</sup>Median; IQR in parentheses (all such values).

<sup>3</sup>Mean ± SD (all such values).

**TABLE 5**

Concentrations of vitamin D and 25-hydroxyvitamin D in foremilk, hindmilk, and maternal plasma stratified by the use of vitamin D supplements<sup>1</sup>

	Use of vitamin D supplements		<i>P</i>
	Nonusers ( <i>n</i> = 63 samples)	Users ( <i>n</i> = 161 samples)	
Vitamin D, nmol/L			
Foremilk	0.1 (0.1–0.7) <sup>2</sup>	0.3 (0.1–0.8)	0.08
Hindmilk	0.3 (0.1–1.3)	0.6 (0.2–1.9)	0.02
25-Hydroxyvitamin D, nmol/L			
Foremilk	0.7 (0.5–0.9)	0.9 (0.7–1.3)	<0.01
Hindmilk	1.2 (0.7–1.8)	1.4 (1.0–1.9)	0.01
Maternal plasma	53.1 ± 22.1 <sup>3</sup>	69.2 ± 25.4	<0.01

<sup>1</sup>Samples with concentrations below the detection limit were assigned a value of 0.14 nmol/L (see Methods for explanations). Numbers of samples are minimum numbers (i.e., for some indexes measured, more samples were available for analyses). Statistical tests were performed with the use of the Mann-Whitney *U* test for nonparametric data or a 2-sample *t* test for data with a normal distribution. No adjustments were performed for repeated measures (i.e., that some individuals contributed with more than one sample).

<sup>2</sup>Median; IQR in parentheses (all such values).

<sup>3</sup>Mean ± SD (all such values).

Streym et al, Am J Clin Nutr. 2016 Jan;103(1):107-14.

# Micronutrients—vitamin K

**Vitamin K concentrations in human milk at different lactation stages (µg/L)**

Source	Colostrum	Transition	Mature
	Concentration	Concentration	Concentration
VonKries et al, 1987	1.8		1.2
Greer et al, 1991	0.64 ± 0.43		0.86 ± 0.52
Greer et al, 2001		1.18 ± 0.99	0.50 ± 0.70
Canfield et al, 1991	3.4 ± 2.6		3.2 ± 2.9 6.4 ± 5.3
Fournier et al, 1987	5.2 (3.1~10.8)	8.9 (6.4~15.7)	9.2 (4.8~12.8)
Haroon et al, 1982	2.3 (0.7~4.2)		2.5 (1.1~6.5)

# Micronutrients—water soluble vitamins

Vitamins	Concentration	Sources
Vitamin B <sub>1</sub> ( mg/L)	0.012~47.4	Yin et al, 1986
	0.007~0.036	Ford JZet al, 1983
	0.066~0.134	Sakurai Tet al, 2005
	0.002~0.221	Hampel Det al, 2012
	0.027	Bohm Vet al, 1997
Vitamin B <sub>2</sub> ( mg/L)	0.070~175	Yin et al, 1986
	0.12~0.73	Ford JZet al, 1983
	0.34~0.397	Sakurai Tet al, 2005
	0~0.845	Hampel Det al, 2012
	0.057	Bohm Vet al, 1997
Niacin ( mgNE/L)	0.21~16.8	Yin et al, 1986
	0.292~0.53	Sakurai Tet al, 2005
	0.002~3.179	Hampel Det al, 2012
Vitamin C (mg/L)	13~73.3	Daneel-Otterbech Set al, 2005
	6.26~69	Wang et al, 2009
	0.11~64	Shi et al, 2010
Vitamin B <sub>6</sub> (mg/L)	0.014~0.18	Ford JZet al, 1983
	0.46	Hamaker B, 1985
	0.019~0.119	Sakurai Tet al, 2005
	0.006~0.692	Hampel Det al, 2012
Folic acid (µg/L)	1~98	Ford JZet al, 1983
	52~150	Houghton LAet al, 2009
Vttamin B <sub>12</sub> (µg/L)	0.19~2.629	Greibe Eet al, 2013
	0.02~3.4	Ford JZet al, 1983
	0.33~3.2	Sandberg DPet al, 1981
	0.4~0.7	Sakurai Tet al, 2005
	0.24~3.3	Allen LHet al, 2004
	0.033~1.76	Hampel Det al, 2012
Biotin (µg/L)	0.02~12.0	Ford JZet al, 1983
	2.8~5.9	Sakurai Tet al, 2005
Pantothenic acid (mg/L)	0.36~6.4	Ford JZet al, 1983
	2.0~2.9	Sakurai Tet al, 2005

# Micronutrients--minerals

**Table 2. Summary of trace element concentrations.**

	<b>United States</b>	<b>Namibia</b>	<b>Poland</b>	<b>Argentina</b>	<b>Total</b>
<b>Trace Element</b>	<b>(n = 20)</b>	<b>(n = 6)</b>	<b>(n = 23)</b>	<b>(n = 21)</b>	<b>(N = 70)</b>
<b>Calcium (mg/L)</b>					
<i>M</i>	268.72	143.83	227.06	231.79	233.25
<i>SD</i>	59.34	64.67	36.72	37.62	56.45
Min	138.02	36.69	152.94	177.47	36.69
Max	374.95	205.21	293.71	304.47	374.95
<b>Iron (mg/L)</b>					
<i>M</i>	1.27	1.53	1	0.99	1.12
<i>SD</i>	0.26	0.86	0.15	0.21	0.35
Min	0.84	0.74	0.8	0.71	0.71
Max	1.85	2.97	1.38	1.51	1.38
<b>Zinc (mg/L)</b>					
<i>M</i>	0.67	1.34	0.75	0.93	0.83
<i>SD</i>	0.43	1.29	0.46	0.5	0.59
Min	0.15	0.03	0.2	0.25	0.03
Max	1.61	3.75	2.02	2.01	3.75
<b>Copper (µg/L)</b>					
<i>M</i>	169.52	130.94	186.87	211.04	184.4
<i>SD</i>	63.06	63.49	48.1	99.5	74.33
Min	71.48	55.6	82.95	89.52	55.6
Max	317.09	208.83	252.42	419.09	419.09
<b>Manganese (µg/L)</b>					
<i>M</i>	2.71	11.6	1.61	7.62	4.58
<i>SD</i>	1.12	9.78	0.89	3.76	4.76
Min	1.46	2.79	0.22	3.29	0.22
Max	5.86	30.27	4.32	20.24	30.27
<b>Arsenic (µg/L)</b>					
<i>M</i>	3.47	6.68	3.86	4.51	4.18
<i>SD</i>	0.84	2.46	1	1.34	1.5
Min	2.4	4.08	3.03	2.54	2.4
Max	6.02	11.2	7.9	9.08	11.2
<b>Lead (µg/L)</b>					
<i>M</i>	0.77	2.15	1.02	0.59	0.91
<i>SD</i>	0.45	0.24	0.26	0.4	0.55
Min	0.41	1.92	0.52	0.21	0.21
Max	2.1	2.48	1.44	1.69	2.48

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# The influence of maternal intake, status, supplementation, and other factors on human milk concentrations of each nutrient

**TABLE 1** Summary of BM nutrients<sup>1</sup>

	Infant reliance on BM	Concentrations trend	Affected by maternal status	Affected by maternal diet	Affected by maternal supplementation	Maternal factors influencing BM concentrations	Comments
Thiamin	+	Increases over first several months	–	+	+/– (+ in case of maternal dietary insufficiency)	Insufficient data	The body does not store thiamin so continuous supply is needed to mother and infant
Riboflavin	+	Decreases vs. stable	+/– (mixed evidence)	+	+	Insufficient data	Very limited infant reserves at birth
Vitamin B-6	+/–	Increases during first weeks postpartum, followed by gradual decline	+	+	+	Insufficient data	Gestational reserves help support infant vitamin B-6 needs through first months of lactation; after 6 mo, BM alone may be insufficient to meet infant needs (1)
Vitamin B-12	+	Decreases during first 3–4 mo of lactation	+	+	+/–	Veganism/ vegetarianism/ low consumption of animal source foods (–), pernicious anemia (–)	Limited infant reserves at birth
Folate	+	Peaks at 2–3 mo of lactation	–	–	–	Insufficient data	Supplemental folate may affect BM folate concentrations in undernourished women (2); more data are needed; only severe maternal deficiency compromises BM concentrations
Choline	+	Increases rapidly from 7 to 22 d postpartum and remains stable in mature milk	+	+	+	SNPs in MTHFR (–), preterm delivery (–), inflammation (+), hormones (+/–)	Gene polymorphisms may explain variation in BM choline concentrations in women with similar intakes (3)
Vitamin C	+	Highest in colostrum, decreases with progression of lactation	–	+/–	+/–	Preterm delivery (+), smoking (–), diabetes (–)	Greater effect of diet and supplementation in women with poor status; the body does not store vitamin C so continuous supply is needed to mother and infant
Vitamin A	+	Highest in colostrum, stabilizes in mature milk	– (unless maternal reserves are depleted)	+/– (+ if maternal reserves are inadequate)	+	Preterm delivery (–), adolescence (–), parity (+)	BM vitamin A derived from circulating as well as dietary retinol (4)
Vitamin D	+/– [vitamin D <sub>3</sub> but not active 25(OH)D]	Little 25(OH)D in BM	+/– (conflicting data)	+/– [diet may affect BM vitamin D <sub>3</sub> but not active 25(OH)D]	+	Season, sun exposure (+), obesity (–)	Primary form passed from maternal circulation to BM is vitamin D <sub>3</sub> , the biological precursor of 25(OH)D (5, 6)
Vitamin E	+	Decreases from colostrum to mature milk, then stable	–	–	+	Preterm delivery (–)	Limited infant reserves at birth; Greater increase in BM vitamin E concentrations with natural (RRR- $\alpha$ -tocopherol) vs. synthetic all-rac- $\alpha$ -tocopherol supplementation (7)

(Continued)

# The influence of maternal intake, status, supplementation, and other factors on human milk concentrations of each nutrient

**TABLE 1** (Continued)

	Infant reliance on BM	Concentrations trend	Affected by maternal status	Affected by maternal diet	Affected by maternal supplementation	Maternal factors influencing BM concentrations	Comments
Vitamin K	—	Low concentrations in BM	—	—	+	Insufficient data	—
Iron	—	Low concentrations in BM, declines through first year of lactation	—	—	—	No consistent evidence	Infants depend on hepatic reserves to meet iron needs (8)
Copper	—	Low concentrations in BM, declines as lactation progresses	—	—	—	BM selenium concentrations (+)	Hepatic reserves protect infants from deficiency in early infancy (9)
Zinc	+/- (+ in early lactation)	Sharp initial decrease followed by gradual decline	—	—	—	Age (-), parity (-), iron deficiency (-)	Infant zinc stores are limited (9)
Calcium	+	Increases in first week, subsequent gradual decline for duration of lactation	—	+/- (+ where habitual calcium intake is low)	—	Adolescence (-), iron deficiency anemia (-)	—
Phosphorus	+	Increases in first week, subsequent gradual decline for duration of lactation	+/- (+ only in case of genetic anomalies)	—	No data	Familial hypophosphatemia (-), hyperparathyroidism (-)	BM phosphorus is tightly regulated (10)
Magnesium	+	Stable during lactation	—	—	—	Adolescence (-)	—
Iodine	+	Initial decline, stable after 1 mo	—	+	+	Smoking (-)	Influenced by environment (soil iodine, salt iodization, etc.); infants are born with limited reserves
Selenium	+	Decreases throughout lactation	+/- (weak correlation, if present)	+	+	No consistent evidence	Influenced by environment (soil selenium); infants are born with limited reserves
Protein	+	Brief, sharp decrease, then stable from 2 to 6 mo until weaning	—	+/- (amino acid composition varies by maternal intake)	N/A	Milk volume (-)	Similar concentrations in BM of well-nourished and undernourished mothers
Lipids	+	Sharp increase in first week, then stable	+	+/- (FA composition varies by maternal intake)	N/A	%IBW (+), milk volume (-)	Large intraindividual CV
Carbohydrates	+	Lactose is lowest in colostrum, stabilizes as milk matures	—	—	N/A	BMI (-), milk volume (+), preterm delivery (-)	Non-nutritive HMOs decrease from colostrum to mature milk

<sup>1</sup> BM, breast milk; HMO, human-milk oligosaccharide; IBW, ideal body weight; MTHFR, methylenetetrahydrofolate reductase; N/A, Not available; SNP, single nucleotide polymorphism; 25(OH)D, 25-hydroxyvitamin D; +, Yes; -, No.

# Bioactive components--growth factors

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- **Intestinal maturation, and repair: Epidermal growth factor (EGF)**
- **Growth and development of the enteric nervous system: Neuronal growth factors**
- **Tissue growth: The insulin-like growth factor (IGF) superfamily**
- **Regulation of the vascular system: Vascular endothelial growth factor (VEGF)**
- **Intestinal development and prevention of anemia: Erythropoietin (Epo)**
- **Growth-regulating hormones: Calcitonin and somatostatin**
- **Regulating metabolism and body composition: Adiponectin and other hormones**

# **Bioactive components--Immunological factors**

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- Transfer of living protection and programming: Cells of human milk**
- Communication between cells: Cytokines and chemokines**
- Protection from infection: Acquired and innate factors**
- Selection for the growth of beneficial organisms: Oligosaccharides**

# Why is breastfeeding so important?

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## Health benefits for the babies

### Short-term health outcomes

- **88% reduction of mortality in comparison to infants that have never been breastfed during the first six months of life**
- **longer exposure to breastfeeding is associated with a relative risk of 0.69 (95% CI 0.58-0.82) for developing diarrhea within the first five years of age and a 72% reduction of hospital admissions**
- **Furthermore a 68% (CI 95% 60-75) reduction in the risk of malocclusion has been demonstrated if the infant is breastfed**

# Why is breastfeeding so important?

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## Health benefits for the babies

### Long-term health outcomes

- longer exposure to breastfeeding is associated with 35% (95% CI 14-51) reduction of the risk of developing diabetes type II
- a meta-analysis including 113 studies demonstrated an association between 26% reduction of the risk of developing overweight/obesity and longer breastfeeding.

# Why is breastfeeding so important?

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## Health benefits for the mother

- ❑ **Contribute to postpartum weight loss.**
- ❑ **Exclusive breastfeeding for the first 6 months postpartum, in the absence of menses, is 98 percent effective in preventing pregnancy.**
- ❑ **Women who lactate for a total of two or more years reduce their chances of developing breast cancer by 24 percent.**
- ❑ **A 30% reduction in the incidence of ovarian cancer has also been associated with longer periods of breastfeeding**
- ❑ **Women who nursed for at least 24 months over the course of their reproductive lifespan had a 23 percent lower risk of developing heart disease.**

# Why is breastfeeding so important?

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## Health benefits for the mother

- ❑ Nursing for a total of two years decreased the risk of Rheumatoid arthritis by 50 percent, while nursing for 12 to 23 months lowered risk by 20 percent.
- ❑ Breastfeeding appears to reduce the mother's risk of developing osteoporosis and its-related fracture in later years.
- ❑ Many mothers also get emotional benefits from breastfeeding because of the closeness of this interaction with the baby and from the satisfaction of helping to nourish their babies.

Thank you

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