Breast milk: An evolving nutritional solution
Current guidelines from international health experts recommend exclusive breast-feeding of infants during the first 6 months of life (IOM 2011, WHO 2013, ESPGHAN 2009). Breast milk is recognized as the ideal form of nutrition for infants because it is best adapted to their needs and is well-known as having unique advantages:

- Supports healthy growth and development
- Provides the infant with effective protection against infection and disease
- Contributes to mother-infant bonding

Nevertheless, there still remains so much to learn from this fascinating source of nutrition. Research in recent years has revealed just how dynamic breast milk is as a substance, with a composition that not only varies within single feeds but more gradually over days and months, adapting to perfectly match the changing nutritional needs of developing babies.

In addition, within the past decade, the long-term impact of breast-feeding has started to emerge with research suggesting that breast-feeding’s benefits could continue into adulthood. Scientific studies show that breast-fed babies are at a lower risk than formula-fed babies of obesity, as well as other cardiometabolic disorders in later life. Breast milk’s nutritional profile, and potentially its unique evolving composition, could have an effect on early metabolic programming.

The Nestlé Nutrition Institute presents the latest scientific research on breast-feeding.
1. The evolving composition of breast milk

It is now clearly established that breast milk composition is not constant, but rather evolves throughout lactation in response to the changing nutritional requirements of the neonate. Nearly every macronutrient in breast milk evolves in some way during the course of lactation, with perhaps the most striking changes occurring with proteins, lipids and energy. These variations are believed to respond to specific infant needs and have beneficial effects on growth and development both during infancy and later in life.

Evolving energy requirements and breast milk consumption

Total energy expenditure among infants increases very rapidly, doubling during the first year of life. This fast evolution mirrors the infants’ increasing energy requirements and is needed to support healthy growth and development.

The increase in energy required by infants to support growth and physical activity is mirrored by a corresponding increase in breast milk consumption. A recent study estimating human milk intake using an isotope tracer in infants aged 0-24 months found that the volume consumed by infants increases during the first 4 months then plateaus (da Costa et al. 2010).

Important changes in energy density in breast milk also take place during the lactation period. It is generally accepted that the energy content of breast milk is 67 kcal/100mL; however, several studies have demonstrated that caloric density varies during breast-feeding and that it is below this standard value (Lucas et al. 1987; de Bruin et al. 1998; Reilly et al. 2005). Some studies have even estimated the caloric density of breast milk at 57 kcal/100mL (Lucas et al. 1987), questioning the widely used standards.

Evolving energy requirements and breast milk consumption

Total energy expenditure in girls and boys in the first year of life

Ref: FAO/WHO/UNU, 2004

Breast milk intake in the first 12 months

Ref: Adapted from da Costa et al 2010

Evolution in energy content of breast milk

Ref: Adapted from Lucas et al. 1987; Hospi et al. 2005; Saarela et al. 2005; Nielsen et al. 2008; Thakkur et al. 2013
As a result of this decline, breast-fed infants have a relatively low protein intake. Growth velocity rapidly slows in the first 6 months of life and this coincides with a reduction in protein intake. Both parameters decrease by about half during the first year of lactation (Van’t Hof 2000).

The protein profile of breast milk also evolves to fulfill the nutritional needs of the infant for its growth and development. The ratio of the two major milk fractions, whey and casein, vary considerably over the lactation period. In early lactation, the protein fraction consists mainly of whey and casein is not synthesized or detectable. As milk production increases, whey proteins decrease relative to the casein proportion that increases. In early lactation it is as high as 90:10, yet this ratio falls to about 60:40 at full lactation and as low as 50:50 in late lactation (Kunz & Lönnerdal 1990, 1992).

The protein content of breast milk varies at each stage of lactation. The milk secreted in the first few days after birth, colostrum, contains very high concentrations of protein, ranging from 20 to 30 g/L (Lönnerdal 2008). The very high protein content of colostrum can be explained in part by the low volumes of milk produced, but it is mainly due to the hormonal regulation of protein content. Other studies have shown that the protein content of breast milk decreases significantly after several months of breast-feeding, reaching 7 to 8 g/L after six months of breast-feeding (Lönnerdal 2004).

The energy content of breast milk is not the only value to have been over-estimated; infant energy requirements were also over estimated by 15-30% (Butte, 2005). Based on these findings, the FAO published new values for daily energy needs in 2004. The daily caloric needs in relation to the infant’s weight (kcal/kg/day) decrease during the first year of life. This trend is similar for girls and boys.

<table>
<thead>
<tr>
<th>Estimated daily caloric needs</th>
<th>1st Month</th>
<th>12th Month</th>
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<tbody>
<tr>
<td>Boys</td>
<td>113 kcal/kg/day</td>
<td>81 kcal/kg/day</td>
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<tr>
<td>Girls</td>
<td>107 kcal/kg/day</td>
<td>79 kcal/kg/day</td>
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Ref: Butte 2005, Butte 2006

Evolving protein composition matching growth velocity

Ref: Lönnerdal 2004

Ref: Van’t Hof 2000

Ref: Van’t Hof 2000

Ref: Van’t Hof 2000
The evolution of lipids and carbohydrates

Beyond protein and energy, lipids and carbohydrate concentrations in breast milk have also been shown to change over time. Lipid concentrations vary following birth with one study showing an increase from 1.8 to 3.0 g/100ml during the first four weeks postpartum (Anderson et al. 1981). Triglycerides are the main lipid class found in human milk and represent about 98% of total lipids (Jensen 1996). Significant longitudinal variations in phospholipid/triglycerides and cholesterol/triglycerides ratios in human milk have also been reported (Harzer et al. 1986).

Lactose is the predominant digestible carbohydrate in human milk. It partly escapes digestion and absorption, and is thus available for fermentation by colonic microbiota, potentially favoring a microbiota predominant in lactobacilli and bifidobacteria (Bullen et al. 1977; Francavilla et al. 2012). Very recent results suggest an additional function of lactose in innate immunity that may lead to protection of the neonatal gut against pathogens and regulation of the infant’s microbiota (Cederlund et al. 2013).

Human milk oligosaccharides represent the third most abundant group of milk components, in concentrations ranging from 10 to 20 g/L (Egge et al. 1983; Kunz et al. 2000; Thurl et al. 2010; Urashima et al. 2011). They have been suggested to promote the establishment of a normal gut microbiota, to prevent pathogen adherence to the intestinal epithelium and to influence gut maturation processes (Bode et al. 2004; Newburg et al. 2005; Kuntz et al. 2008; Kuntz et al. 2009).
2. Breast-feeding and metabolic programming

Several studies have found that the prevalence of overweight and obesity has become epidemic in many parts of the world. In the United States, for example, in the past three decades the prevalence of obesity among children and adolescents has tripled (Ogden 2010).

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<tr>
<td>2-5</td>
<td>5.0</td>
<td>10.3</td>
<td>13.9</td>
<td>10.4</td>
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<tr>
<td>6-11</td>
<td>6.5</td>
<td>15.1</td>
<td>18.8</td>
<td>19.6</td>
</tr>
<tr>
<td>12-19</td>
<td>5.0</td>
<td>14.8</td>
<td>174</td>
<td>18.1</td>
</tr>
<tr>
<td>Total</td>
<td>5.5</td>
<td>13.9</td>
<td>171</td>
<td>16.9</td>
</tr>
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Obesity: BMI values at or above the 95th percentile of the sex-specific BMI growth charts
Ref: Ogden 2010

What impact could infant nutrition have on obesity in childhood and even adulthood? It has been clear for some time now that breast-fed and formula-fed babies experience different patterns of weight gain in early life. The possible consequences of these different growth patterns has, up until recently, been undefined. Now longer-term studies suggest that breast-fed babies have a much lower risk of obesity, as well as other associated cardiometabolic disorders, than formula-fed babies in childhood and even in adulthood.

Protein intake in children and obesity in adulthood

The difference in protein concentration between breast milk and infant formula could result in lower weight gain over the first 2 years of life. This theory is called the "early protein hypothesis". In 1988, Axelson et al. reported that increased protein ingestion resulted in increased levels of insulin-releasing amino acids (Axelson et al. 1988). In 2005, Koletzko et al. established this hypothesis:

The hypothesis suggests that high protein intake calibrates an infant’s metabolism, predisposing it to weight gain. It has been estimated that nearly 13% of cases of childhood obesity can be explained by high protein intake in infants fed with conventional formula (Haschke, 2010).

Reducing protein intake in early infancy

The potential negative effects of infant formula with high concentrations of protein have lead researchers to investigate the implications of lower protein infant formula. A European project by Koletzko et al. indicated that low protein infant formula is associated with lower weight in infants up to two years of age, which suggests that lower protein intake in infancy may decrease the risk of overweight and obesity later in life (Koletzko et al. 2009).
The benefits of low protein formula extend to babies of overweight mothers. A study of infants of overweight mothers compared the differences of weight gain between infants fed standard or low protein formula. The low protein formula resulted in lower weight gain and BMI during the first year of life (Inostroza et al. 2012).

Role of breast milk lipid profile in programming

The importance of the type of lipids in the diet on a potential early metabolic programming has also become a prominent issue. Breast milk contains a unique lipid profile that differs from that of other mammals: its concentration of total cholesterol is significantly higher (Uauy & Dangour 2009). Epidemiological data (17 studies and 17,498 subjects) has highlighted the fact that once adulthood was reached, total cholesterol of breast-fed infants was lower than formula-fed infants (Owen 2008). This result suggests that cholesterol metabolism is programmed from an early age. The mechanism behind this phenomenon has yet to be identified. However, it is possible that it may occur through regulation of hepatic hydroxymethylglutaryl coenzyme A (HMG-CoA) reductase, or through low-density lipoprotein (LDL)-receptor activity. More study is required to better understand the role cholesterol may play.


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