Annexe D. Composition of breast milk review

Rachel White and Rachel Allen, Department of Health

Table of contents

List of tables

List of figures

List of addenda

A literature review of the nutrient composition of human breast milk

D.1. Introduction

The Diet and Nutrition Survey of Infants and Young Children (DNSIYC) is due to collect data on the volume of breast milk consumed by breastfed infants (through the use of isotopically labelled water), for infants attending the clinic component of the survey. In order to calculate the nutrient intakes of breastfed infants from these consumption data, accurate data on the nutrient composition of breast milk are required. The purpose of this review was to ensure that the Food Standards Agency (FSA), The Department of Health (DH) and the Scientific Advisory Committee on Nutrition's Subgroup on Maternal and Child Nutrition (SMCN) were confident that the nutrient composition data for human breast milk are up-to-date and the resulting estimates of nutrient intakes from DNSIYC are therefore as reliable as possible.

In the UK, data for the nutrient composition of human breast milk are currently published within McCance and Widdowson's *The Composition of Foods, Milk Products and Eggs* (1989) and *Fatty Acids* (1998) supplements. These data are taken from an analytical report published by the Department of Health and Social Security (DHSS) in 1977[1]; with fatty acid data from the Institute of Human Nutrition and Brain Research (IHNBR) (publication date unknown)[2], collectively referred to as DHSS and IHNBR values respectively from here on. As diets are likely to have changed over the last 30 years, it was considered advisable to review these data for use in DNSIYC.

It was decided that carrying out further chemical analysis of breast milk composition would be unlikely to add value to the results of the survey, as the variability likely to be experienced during sampling (for example, due to incomplete expression of the breast or not collecting a full 24-hour sample) would provide results no more reliable than that found within existing literature. As much research on this topic has already been published it was proposed that the FSA carry out a review of the published literature.

D.2. Methodology

Stage 1: Identifying relevant papers

This review included review papers only, published in English, containing data for one or more nutritional component(s) of human breast milk from mothers in Western countries (defined for the purposes of this review as the UK, Europe, the USA, Canada, Australia and New Zealand). Since the current data were published by DHSS in 1977 (the publication date for the IHNBR data is unknown), the search boundaries were set to include those papers published between 1974 and 2009.

Papers were identified through searching the MEDLINE database in July 2009 using the following key words and Medical Search Heading (MeSH) terms:

("Milk, Human"[Mesh] OR "Breast Feeding"[Mesh] OR "Lactation"[Mesh] OR "Milk Banks"[Mesh] OR breastmilk[tiab] OR breast milk[tiab] OR breast-fe*[tiab] OR breastfe*[tiab] OR lactat*[tiab] OR ((mother*[tiab] OR maternal[tiab]) AND milk[tiab])) AND (("1974"[PDAT]: "2009"[PDAT]) AND "humans"[MeSH Terms] AND English[lang] AND (Meta-Analysis[ptyp] OR Review[ptyp]))

Additional resources were identified by consulting food composition data and dietary reference values for infants used in the USA and Australia/New Zealand. The process of identifying papers was guided by the Chair of SMCN and colleagues in FSA and DH with expert knowledge in infant feeding and formula milk legislation.

Papers were excluded if:

- They provided data for donor milk or formula milk only.
- The only data provided within the review were duplicated within another paper.
- The only data within the review were published prior to 1974.
- They were narrative reviews found not to contain numerical data for the nutrient composition of breast milk.
- They only included one reference for a quoted value for a particular nutrient. These papers were kept for information.

Stage 2: Allocation of values to each nutrient

Data were extracted from each of the included review papers and collated for each nutrient. Where there were a number of studies reported separately within a review paper, further restrictions were applied:

- Values from individual studies published prior to 1974 were excluded;
- For those studies providing data from different countries, values from non-Western countries were excluded. If this comprised a number of studies providing UK data, then only UK data was transcribed. Where only one reference

was available for the UK, then this was supplemented with values for other Western countries.

- Where there were a number of studies in a review paper providing data from mothers with babies of different gestational ages or varying stages of lactation, values for breast milk from mothers of pre-term babies or less than 14 days post-partum were excluded where possible.
- Values from studies that indicate supplement use by the mother during lactation were also excluded.

In total, data from 37 papers was used in the final review (Figure 1).

Units and Conversion factors

To allow ease of comparison, volumes were converted into weights where necessary. This involved applying a factor of 1.03g/ml for the specific gravity of milk (MAFF, 1993[3]). If a study provided values using more than one type of unit, preference was given to metric rather than molar units, for ease of conversion and comparison. A factor of 0.945 was applied to values of total milk lipid in order to calculate total fatty acids (Paul & Southgate, 1978[4]).

Nutrients

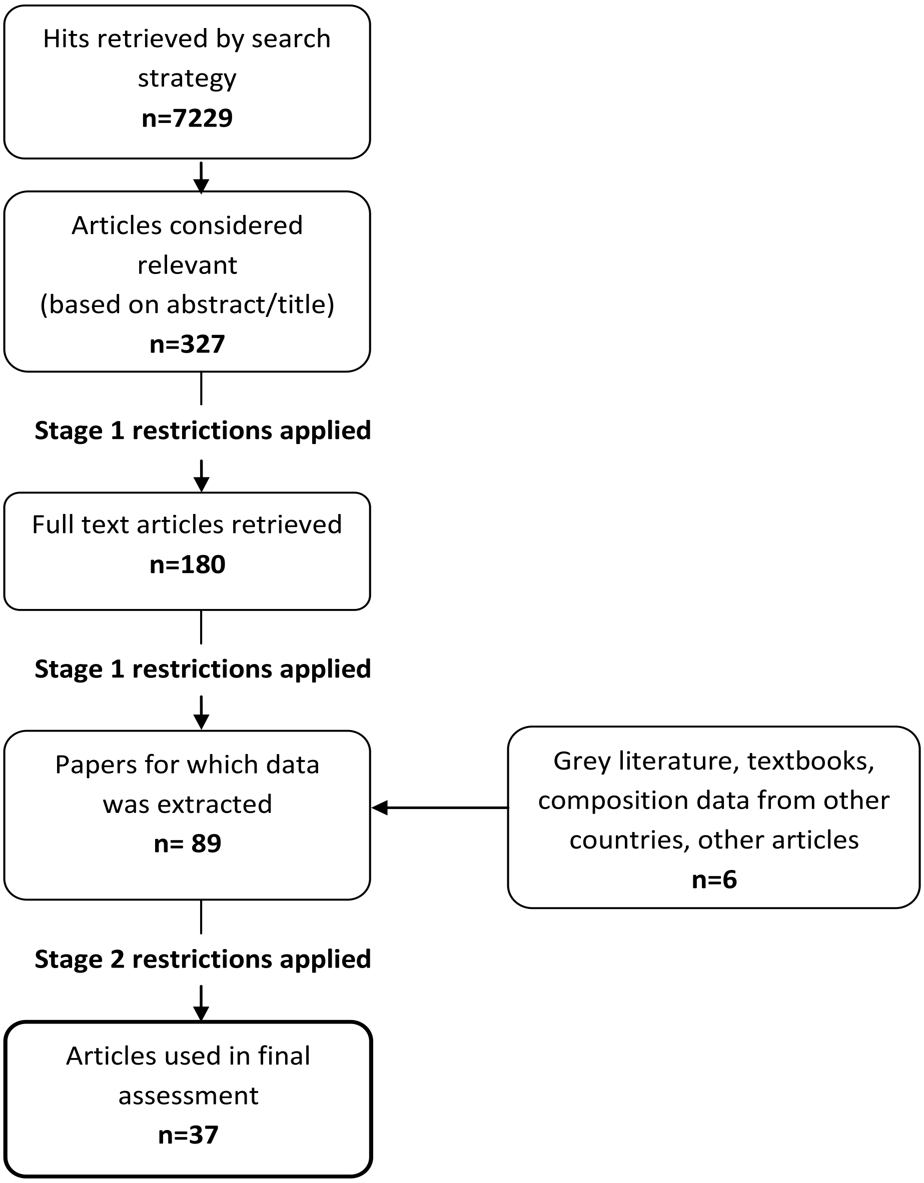
This review looked at all nutrients included within McCance & Widdowson's *The Composition of Foods* series (including the *Fatty Acid* supplement):

- **Macronutrients:** energy, protein, lactose, total fat, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, linoleic acid (18:2 n-6), alpha-linolenic acid (18:3 n-3), arachidonic acid (20:4 n-6), docosahexaenoic acid (22:6 n-3), *trans* fatty acids

- **Vitamins:** retinol/carotene, D, E, C, thiamin, riboflavin, niacin, B_6, B_{12}, folate, pantothenate, biotin

- **Minerals:** calcium, phosphorus, magnesium, sodium, potassium, chloride, copper, iron, zinc, manganese, selenium, iodine

Figure D.1. Flow diagram indicating numbers of included and excluded review articles. See Addendum 1 for a list of all articles included in the review.



D.3. Results

Table 1 categorises nutrients by whether the DHSS/IHNBR values are consistent with the reviewed literature and whether nutrient concentrations in human breast milk are likely to have changed over the last 30 years, based on interpretations from both the numerical and narrative data obtained during the literature search.

For the purposes of interpreting the data, an arbitrary threshold was used. The DHSS/IHNBR value was considered inconsistent if it 'agreed' with none or only one of the values provided in the reviewed literature. The DHSS/IHNBR value was considered consistent if it 'agreed' with two or more of the values provided from the reviewed literature. Cases where there was insufficient data to do this are noted in Table 1. To 'agree' the values either matched exactly, the DHSS/IHNBR value fell within the range provided in the literature, or the literature value could be rounded up to the DHSS/IHNBR value exactly.

Using these thresholds, the DHSS/IHNBR values for potassium, protein, *trans* fatty acids, vitamin B_{12}, niacin and carotene fell outside the range of values found within the reviewed literature. Although the DHSS value for protein fell within the range provided in one review, it sat close to, but just outside the ranges provided in three reviews (only when the upper values in the range were rounded up). As the remaining 13 review values were consistently lower than the DHSS value, it was considered inconsistent with the reviewed literature.

Table D.1. Categorisation of nutrients by whether DHSS/IHNBR values were consistent with the reviewed literature and whether human breast milk concentration is likely to have changed over the last 30 years.

Breast milk concentration in 2010/11 compared to 1977.	**Nutrients for which DHSS/IHNBR values are inconsistent with reviewed literature**	**Nutrients for which DHSS/IHNBR values are consistent with reviewed literature**
Nutrients known to be present at generally stable concentrations within breast milk and unlikely to have changed.	Potassium Protein*	Energy Total fat SFA Carbohydrate (lactose) Sodium Calcium Magnesium

		Phosphorus Iron Copper Zinc Chloride Manganese Selenium
Nutrients that may have changed due to a change in dietary intakes at a population level, but for which current inter-individual dietary variation would be likely to have a greater impact on the variation of breast milk composition.	Trans FA** Vitamin B_{12} Niacin Carotene	PUFA (LA, ALA, AA, DHA) MUFA** Vitamin A/Retinol Vitamin D Vitamin E Thiamin Riboflavin Vitamin B_6 Folate Pantothenate Biotin Vitamin C Iodine
Nutrients for which values presented within the literature may have changed due to a change in analytical techniques/calculations.		Energy Vitamin D

* The DHSS report calculated protein from total amino acid nitrogen (i.e. free amino acids plus those derived by hydrolysis of milk protein) multiplied by the factor 6.38. This is the conversion factor for milk and milk products as stated in McCance &Widdowson's *The Composition of Foods, Sixth Summary edition* (Table 3, page 7).
** Nutrients for which there are limited data available for comparison

D.4. Discussion and interpretation

Generally the DHSS/IHNBR macronutrient values fell within the range of values found within the reviewed literature, although some did appear to deviate.

The literature search concentrated on review papers only. This meant that the information available for each of the primary studies, from which the nutrient values were derived, was limited. Having sought statistical advice it was advised that without knowing the methodological quality of the primary studies and therefore the quality of each review, it was not possible to judge whether the DHSS/IHNBR values identified as differing from the ranges of values provided in the reviewed literature, differed enough to warrant revision. It was therefore decided to look at the nutrients on a case by case basis.

D.4.1. Macronutrients

The accuracy of macronutrient data was believed to be of greatest priority for ensuring the data is fit for purpose in estimating nutrient intakes of breastfed infants sampled in DNSIYC. The literature suggests that the macronutrient content of breast milk is generally stable across the population and it is unlikely to have changed over the last 30 years. The slight difference in values for protein between DHSS and the reviewed literature may have been due to differences in sampling or analytical methodologies of the studies included in the review articles. It was therefore agreed that the literature review did not provide justification to update existing macronutrient data.

As the types of fats consumed in the diet may have changed over the last 30 years, it was acknowledged that the proportions of fatty acids in human milk may have changed since the DHSS/IHNBR analyses were carried out. The reviewed literature indicated that the proportion of saturated fatty acids in human milk is fairly stable and so is unlikely to have changed since the publication of the DHSS report. However, the review provided insufficient data to make a reliable judgement on the *trans* and monounsaturated fatty acid content of breast milk. The IHNBR values were consistent with the literature for polyunsaturated fatty acids. However, the reviewed literature indicated that the fatty acid composition of breast milk is influenced by short and long term dietary intakes of fatty acids. This suggests that inter-individual dietary variation is a more important factor in determining the fatty acid composition of breast milk than any dietary changes since the publication of the DHSS report in 1977. It was therefore agreed that the literature review did not provide sufficient evidence to update the existing fatty acid data.

D.4.2. Energy

Since the DHSS report was published potential limitations in the calculations used for estimating the energy content of breast milk have been identified. Although the DHSS value for energy is generally consistent with the reviewed literature, it is possible that many of the primary studies included in the reviews used different approaches to calculating the energy content of breast milk.

The DHSS report provides an estimate of metabolisable energy for breast milk using modified Atwater factors, which are estimated based on the metabolism foods and drinks in adults. In the absence of a reliable published correction factor for the metabolisable energy content of breast milk in infants, it was agreed that the gross energy figure of 0.67 kcal/g (2.80kj/g) (Butte and King, 2005[5]), as quoted in the draft SACN energy report (2010)[6], should be used as an estimate for energy available to infants from breast milk within DNSIYC.

It is acknowledged that this is an estimate of gross energy and therefore does not take into consideration a small proportion (3-7%) of energy not available to the infant. However given the variability of the energy content of breast milk among lactating women and the inaccuracies of estimating the volume of breast milk consumed, as well as the general inaccuracies of estimating food consumption in this age group, this slight over estimation is unlikely to be significant within DNSIYC.

Although this energy figure is not consistent with the DHSS macronutrient values it only differs from the DHSS energy figure of 0.68kcal/g (2.84kj/g) by 0.01kcal/g (0.04kj/g). As there is insufficient evidence to justify revising the macronutrient values these should remain unchanged.

D.4.3. Micronutrients

Generally the DHSS micronutrient values fell within the range of values found within the reviewed literature, with inconsistent values for potassium, vitamin B_{12}, niacin and carotene only. For the reasons outlined in paragraph 15, it was not possible to know whether the values differed significantly from the reviewed literature to warrant revision. It is likely that current inter-individual variation in diet is likely to have a greater influence on breast milk composition for these nutrients than any population changes in diet over the last 30 years.

The vitamin D values reported by the DHSS were based on the analysis of vitamin D sulphate. It is now known that this method is erroneous (as this form of the vitamin, if present in human milk at all, is probably not biologically active), and that the predominant species of vitamin D in milk are 25-hydroxyvitamin D and parent vitamin

D (cholecalciferol and ergocalciferol). The analytical techniques used to measure vitamin D in the DHSS report are therefore not consistent with modern methods. There have been very few published studies on the vitamin D activity or the vitamin D (plus metabolites) concentration of human breast milk. However, it is known that the vitamin D content of breast milk is relatively low and therefore the amount transferred in breast milk to the infant per day is small.

The UK has a policy to ensure breastfed infants receive adequate vitamin D, by recommending vitamin D supplements for infants and pregnant and lactating women. Furthermore, the SACN Position Statement *Update on Vitamin D* (2007) states that '*Under normal circumstances, the sunshine exposure of breastfed infants is the major factor affecting their vitamin D status'*, suggesting that updating the DHSS value for the vitamin D content of breast milk would not improve the assessment of vitamin D status and so not add value to DNSIYC.

The Chair of SMCN has advised that the vitamin D content of UK breast milk is uncertain and attribution of any value would introduce an element of spurious precision to measures of intake. It is proposed that for reporting purposes in DNSIYC, vitamin D intake from breast milk is disregarded and is instead assessed from intake by diet (if complementary fed) or supplement use. Therefore, a zero or 'blank' should be considered for the purposes of assigning a value for vitamin D in the Nutrient Databank.

It was assumed that other recent changes in analytical methods used to quantify nutrients (e.g. folate) would only have a marginal impact on the nutrient composition values for breast milk, and therefore could be discounted for the purposes of DNSIYC.

It was therefore agreed that all DHSS micronutrient values are adequate for use within DNSIYC, other than vitamin D. As discussed above, vitamin D should be omitted from the nutrient profile for breast milk for the purposes of assessing nutrient intakes in DNSIYC[7].

D.5. Caveat associated with use of DHSS data

It should be noted that DNSIYC will sample infants from the age of four to eighteen months with the aim of assessing the diets of infants and young children at, and following, the stage at which solid foods are first introduced into their diets (i.e. from four to six months). The stage of lactation when milk samples were collected for analysis in the DHSS report was approximately four to six weeks after birth. The volume produced and the nutrient composition of breast milk is known to differ at early stages of lactation compared to later stages. Therefore combining breast milk volumes measured in DNSIYC with the DHSS composition values may not reflect the true contribution of breast milk to nutrient intakes for breast fed infants within the DNSIYC sample. However, the use of the DHSS values in DNSIYC is justified in the absence of detailed reliable UK breast milk composition data analysed at later stages of lactation. In addition, recent breastfeeding incidence figures (Bolling, 2005[8]) projected for the DNSIYC age group, suggest that only 16% of the survey population are likely to be breastfeeding during the survey period and <1% are likely to be exclusively breastfeeding, so any misrepresentation of the contribution of breast milk to nutrient intakes within the DNSIYC sample is unlikely to significantly distort the DNSIYC results.

D.6. Conclusions

It was agreed that the current values for the nutrient composition of breast milk published within McCance and Widdowson's *The Composition of Foods*, supplements *Milk Products and Eggs* (1989) and *Fatty Acids* (1998), are adequate for use within DNSIYC. This is subject to the omission of vitamin D from the micronutrient profile, and a minor adjustment to the energy value from the DHSS value of **0.68kcal/g (2.84kj/g)** to the value used by SACN in the draft energy report **0.67kcal/g (2.80kj/g)**.

However, it is important to stress that there remains a need for a detailed and robust analysis of breast milk composition using modern methods and appropriate sampling techniques.

Caveats relating to the differences in stage of lactation between the DNSIYC sample and the DHSS sample (both relating to the nutrient composition and the volume of breast milk produced) ought to be included in publications and written communications arising from DNSIYC to guard against over-reliance on estimated intakes from breast milk. DNSIYC will require careful reporting so as not to imply that the micronutrient intakes of breastfed babies are somehow inadequate as a consequence of comparison between breast milk and fortified infant formula. Therefore, comparative statements about breastfed and formula fed babies ought to be avoided.

Department of Health
Nutrition Science & Delivery Branch
December 2010

References and endnotes

[1] Department of Health and Social Security (1977). *The Composition of Mature Human Milk*. Report on Health and Social Subjects No. 12. Referenced in: Holland, B., Unwin, I.D., and Buss, D.H. (1989) *Milk Products and Eggs*. Fourth supplement to *McCance and Widdowson's The Composition of Foods*, Royal Society of Chemistry, Cambridge

[2] Institute of Human Nutrition and Brain Research. Referenced in: *Fatty Acids*. Seventh supplement to 5th edition of *McCance and Widdowson's The Composition of Foods*. Ministry of Agriculture, Fisheries and Food. (1998) The Royal Society of Chemistry, Cambridge

[3] Ministry of Agriculture, Fisheries and Food (1993). *Food Portion Sizes*: Second edition. HMSO, London

[4] Paul & Southgate (1978). McCance & Widdowson's *The Composition of Foods*. MRC Special Report 297. HMSO, London

[5] Butte NF, King JC (2005). Energy requirements during pregnancy and lactation. *Public Health Nutrition*: **8**(7A): 1010-1027

[6] Scientific Advisory Committee on Nutrition. (2010) *SACN Energy Requirements Working Group Draft Report*. Available online at: http://www.sacn.gov.uk/pdfs/5nov_sacn_energy_drafting_group_draft.pdf

[7] Since this paper was agreed by SACN, a study was published of a sample of 108 European women (2 to 3 weeks postpartum) reporting median values for the vitamin D content of human breast milk of 2.2µg/L (interquartile range of 1.6 g/L to 4.4 g/L). This study however included mothers of infants younger than the DNSIYC sample aged 4 to 18 months and therefore the vitamin D content of breast milk may differ for the older DNSIYC age group. Zhang JY, Lucey AJ, Galvin K, Nolan L, Cashman KD, Higgins JR and Kiely M (2012). Vitamin D content of human milk and associations with milk fat content and maternal serum 25-hydroxyvitamin D concentrations. *Proceedings of the Nutrition Society*. **71** (OCE2), E54.

[8] Bolling K, Grant C, Hamlyn B, Thornton A. (2007) *Infant Feeding Survey* 2005. The NHS Information Centre

Addendum 1. List of references included in the review

Ailhaud G & Guesnet P (2004). Fatty acid composition of fats is an early determinant of childhood obesity: a short review and an opinion. *Obesity Reviews* **5**: 21-26

Bates CJ & Prentice A (1994). Breast milk as a source of vitamins essential minerals and trace elements. *Pharmac. Ther*. **62**: 193-220

Blanc B (1981). Biochemical aspects of human milk - comparisons with bovine milk. *Wld Rev. Nutr. Diet* **36**: 1-89

Bokor S, Koletzko B & Decsi T (2007). Systematic review of fatty acid composition of human milk from mothers of preterm compared to full-term infants. *Annals of Nutrition Metabolism* **51**: 550-556

Brenna JT, Varamini B, Jensen RG, Diersen-Schade DA, Boettcher JA & Arterburn LM (2007). Docosahexaenoic and arachidonic acid concentrations in human breast milk worldwide. *American Journal of Clinical Nutrition* **85**: 1457-64

British Medical Association Board of Science (2009). *Early Life Nutrition and Lifelong Health*. Appendix 6: Comparison of the nutrient composition of mature human breast milk and formula.

Brown KH, Engle-Stone R, Krebs, NF & Peerson JM (2009). Dietary intervention strategies to enhance zinc nutrition: promotion and support of breastfeeding for infants and young children. *Food and Nutrition Bulletin* **30**: S144-S171

Butte NF & King JC (2005). Energy requirements during pregnancy and lactation. *Public Health Nutrition* **8**(7A): 1010-1027

Australia/New Zealand Department of Health & Ageing, National Health & Medical Research Council (2005). Nutrient Reference Values for Australia and New Zealand. Commonwealth of Australia.
http://www.nhmrc.gov.au/_files_nhmrc/file/publications/synopses/n35.pdf

Dorea JG (2000a). Zinc in human milk. *Nutrition Research* **20**: 1645-1687

Dorea JG (2000b). Magnesium in human milk. *Journal of the American College of Nutrition* **19**: 210-219

Dorea JG (2000c). Iron and copper in human milk. *Nutrition* **16**: 209-220

Dorea JG (2002a). Iodine nutrition and breast feeding. *Journal of Trace Elements in Medicine and Biology* **16**: 207-220

Dorea JG (2002b). Selenium and breast-feeding. *British Journal of Nutrition* **88**: 443-461

Hartmann PE, Rattigan S, Saint L & Supriyana O (1985). Variation in the yield and composition of human milk. *Oxf Rev Reprod Biol.* **7**: 118-67

Innis SM (1993). Essential fatty acid requirements in human nutrition. *Canadian Journal of Pharmacology* **71**: 699-706

Innis SM (2004). Polyunsaturated fatty acids in human milk. An essential role in infant development. *Adv Exp Med Biol*. **554**: 27-43

Jenness R (1979). The Composition of Human Milk. *Seminars in Perinatology* **3**: 225-239

Jensen RG (1995). *Handbook of Milk Composition*. California: Academic Press Inc.

Jensen (1992). Effect of dietary intake of n-6 and n-3 fatty acids on the fatty acid composition of human milk in North America. *The Journal of Pediatrics* **120**: S87-92

Jensen RG, Ferris AM, Lammi-Keefe CJ, Henderson RA (1990). Lipids of bovine and human milks: a comparison. *Journal of Dairy Science* **73**: 223-240

Jensen RG (1999). Lipids in human milk. *Lipids* **34**: 1243-1271

Koletzko B, Thiel I & Abdiodun PO (1992). The fatty acid composition of human milk in Europe and Africa. *The Journal of Pediatrics* **120**: S62-S70

Kumpulainen JT (1992). Chromium content of foods and diets. *Biological Trace Element Research* **32**: 9-18

Lammi-Keefe CJ & Jensen RG (1984). Fat-soluble vitamins in human milk. *Nutrition Reviews* **42**: 365-371

Lawrence RA & Lawrence RM (2005). *Breastfeeding: A Guide for the Medical Profession*. Chapter 4: Biochemistry of Human Milk. Elsevier Science.

Levander OA (1989). Upper limit of selenium in infant formulas. *The Journal of Nutrition* **119**: 1869-1873

Lonnerdal B (1997). Effects of milk and milk components on calcium, magnesium, and trace element absorption during infancy. *Physiological Reviews* **77**: 643-669

Mojska H (2003). Influence of trans fatty acids on infant and fetus development. *Acta Microbiologica Polonica* **52**:67-74

Nayman R, Thomson ME, Scriver CR & Clow CL (1979). Observations on the composition of milk substitute products for treatment of inborn errors of amino acid metabolism. Comparisons with human milk. *The American Journal of Clinical Nutrition* **32**: 1279-1289

Nettleton JA (1993). Are n-3 fatty acids essential nutrients for fetal and infant development? *Journal of the American Dietetic Association* **93**: 58-64

Pierse P, Van Aerde J & Clandinin MT (1988). Nutritional value of human milk. *Progress in Food and Nutrition Science* **12**: 421-447

Prentice A (1996). Constituents of human milk. *Food and Nutrition Bulletin* **17**: 1-12

Reilly, Ashworth & Wells (2005). Metabolisable energy consumption in the exclusively breast-fed infant aged 3-6 months from the developed world: a systematic review. *British Journal of Nutrition* **94**: 56-63

Rodriguez-Palmero M, Koletzko B, Kunz C & Jensen R (1999). Nutritional and biochemical properties of human milk: II Lipids, micronutrients, and bioactive factors. C*linical Aspects of Human Milk and Lactation* **26**: 335-359

Roekens E, Deelstra H & Robberecht H (1985). Trace elements in human milk, selenium a case study. *The Science of Total Environment* **42**: 91-108

Saini AS, Harbans Lal, Agarwal SK & Kaur J (1990). Human milk in Infant nutrition. *Indian Pediatrics* **27**: 681-702