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ORIGINAL CONTRIBUTION

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# The fatty acid composition of human colostrum

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**Summary** We reviewed 15 studies reporting on the fatty acid composition of colostrum lipids from 16 geographic regions: 11 European studies and one study each from Central America, the Caribbean, Australia and Asia. The contents of essential fatty acids, saturates and polyunsaturates were similar in the southern European countries Spain, Slovenia and France. Colostrum of St. Lucian women was high in saturates and low in oleic acid, reflecting a high-carbohydrate, low-fat diet. Abundant fish intake was reflected in high contents of docosahexaenoic acid and total n–3 long-chain polyunsaturated fatty acids in St. Lucia. Two French studies published with an interval of two years showed a very similar colostrum fatty acid composition, whereas two German studies obtained with an interval of 14 years showed higher docosahexaenoic acid and arachidonic acid contents in the later study, with an unchanged n–6/n–3 long-chain polyunsaturated fatty acid ratio. Studies from Spain reported a decline of α-linolenic acid in colostrum over a time period of 13 years. Colostrum of Australian women contained the lowest polyunsaturated/saturated and n–6/n–3 long-chain polyunsaturated fatty acids ratios (0.28 and 1.58) and the lowest contents of linoleic and α-linolenic acids (7.8 and 0.4 wt. %). In contrast, the contents of docosahexaenoic acid, eicosapentaenoic acid and total n–3 long-chain polyunsaturated fatty acids (0.6, 0.4 and 1.4 wt.%) were higher in Australian than in European samples. Fatty acid composition of human colostrum appears to be markedly influenced by geographic differences in maternal dietary composition.

**Key words** Capillary gas chromatography – diet – fat extraction – human milk – maternal nutrition

## Introduction

The fat content and fatty acid composition of human milk are variable. Milk fatty acid composition is influenced by diet, duration of pregnancy, stage of lactation, maternal parity, some diseases such as maternal diabetes, and possibly other individual and genetic factors [1]. Maternal diet appears to be the most important variable determining milk fatty acid composition, and differences observed in various geographic regions are primarily attributed to dietary differences.

Several studies have analysed the fatty acid composition of colostrum, transitional and mature human milk. The literature on fatty acid composition of mature human milk has been reviewed [1,2]. Since colostrum is the first food for the newborn infant and determines the initial postnatal substrate supply to the exclusively breastfed infant, it deserves a closer examination. This paper reviews the published information on fatty acid composition of colostrum lipids in different countries.

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## Methods

We performed an electronic literature search for data on colostrum fatty acid composition published during the last 16 years (1983 to 1999). Included were studies reporting data on colostrum defined as human milk samples collected between day 0 and 5 post-partum. We detected 15 studies reporting data from 16 geographic regions in 12 different countries, among them 11 studies in Europe, one each in central America and the Caribbean, one in Australia and one in Asia (Table 1). The Chinese study [3] includes data on fatty acid composition of women from two different areas, with very different dietary habits, which are presented separately.

Fatty acids data are presented as weight percentages (wt. %), which allows direct comparison of fatty acid values found in different studies [2, 4]. No attempts were made to distinguish relative variation of the data in the various studies since both the methodology used and the presentation of the data differed considerably. Metabolites of linoleic and alpha-linolenic acids, respectively, with 2 to 6 double bonds and 20 or 22 carbon atoms were grouped as long-chain polyunsaturated fatty acids (LCP) of the n–3 and n–6 series, respectively.

## Results

All women whose colostrum was analysed gave birth to full term babies, except three women in the Norwegian study [17] who gave birth prematurely, and one subgroup examined in Germany [13] that was not included in the evaluation. The number of subjects in the cited studies varies from only 6 to up to 89 (Table 1). We also noted the methodology of milk collection if stated in the publication (Table 1). In all cited studies, the fatty acid composition of total lipids has been determined, with the exception of Martin et al. [5] who determined the fatty acid composition of milk triglycerides.

### Fatty acid composition of colostrum lipids

Total saturates were calculated from the sum of between 5 and 14 fatty acids. They were the lowest in Spain [6] and Slovenia [7] (37.2 and 37.7 wt.%) and highest in St. Lucia (49.6 wt. %). [8] The high amount in St. Lucia in colostrum lipids was due to higher content of all saturated fatty acids. The content of medium-chain fatty acids (C6-C12) was reported to increase in transitional and mature human milk, which is typical for the diet rich in carbohydrates and low in fat [1]. Similar high values of saturated fatty acids (more than 50 wt.%), also due to intermediate-chain fatty acids, have been reported in mature human milk from African women who consume high carbohydrate diets, since high carbohydrate diets enhance *de novo* fatty acid synthesis [2].

The average content of total saturated fatty acids in colostrum lipids of women from most other European countries and Australia was in a very small range from 41 to 45 wt.%, which is within the range that has been reported for mature human milk in European countries [2]. The distribution of saturated fatty acids in colostrum lipids was very similar in all studies, palmitic (C16:0) acid being represented in the greatest amounts, followed by stearic (C18:0) and myristic acid (C14:0).

Total monounsaturates were calculated as the sum of two to eight fatty acids. They were the lowest in St. Lucia [8] and Panama [9] (about 35 wt. %) and highest in Italy [10] (about 45 wt.%). Most other total monounsaturated values were within the range of 39 to 44 wt. %. [3–6, 11–15] The very low amount of monounsaturates in colostrum lipids of women from St. Lucia and Panama is due to a low content of oleic acid [8]. Very high amounts of monounsaturates in Italy reflect dietary habits in Mediterranean countries with high intakes of monounsaturated and low intakes of saturated fatty acids [10].

Total polyunsaturates calculated as the sum of between nine and fifteen fatty acids were lowest in Australia [16] and Sweden [11] (12.2 and 12.4 wt. %) and highest in Panama [9] (24.4 wt. %). The polyunsaturated/saturated (P/S) ratio (Table 2) was very high in Panama (0.64) [9], as well as in Slovenia [7], China (Hong Kong) [3] and Spain [6], (0.58 to 0.55), whereas in most other countries it was in the range from 0.26 (in Sweden) [11] to 0.38 (in Chongquing, China) [3].

The mean content of linoleic acid (Table 2) in colostrum lipids was very different between countries, from as low as about 8 wt. % in Australia [4], Sweden [11] and Poland [15], to as high as about 15 wt.% in Spain [6] and Slovenia [7] or even 18.3 wt.% in Panama [9], i. e. more than twofold higher than the Australic, Swedish and Polish values. In the other studies from St. Lucia [8], Italy [10], Germany [13, 14], Norway [17] and France [5, 12] mean linoleic acid contents from 8 to 12 wt. % have been reported.

The $\alpha$-linolenic acid content was the lowest in Italy [10], Australia [4], Spain in 1998 [9] and St. Lucia [8] (near 0.4 wt.%), and the highest in Panama [9] and China (Hong Kong) [3] (near 1.3 wt.%). The linoleic/$\alpha$-linolenic acid ratio in colostrum lipids was in the range from 7.9 in Sweden [11] to over 27.4 in Italy [10] and Spain [9]. Lower mean ratios were reported for mature milk of women from European countries (9.2–13.7), whereas for mature milk of women from African countries ratios in a very wide range from 9.3 to even 157 have been reported [2].

The content of long-chain polyunsaturated (LCP) in human milk lipids is highest in colostrum and decreases with the maturation of milk, as cleary documented in several studies [3, 6, 8–11, 13, 14, 18]. The major LCP in colostrum lipids are docosahexaenoic acid (C22:6n–3, DHA), docosapentaenoic (C22:5n–3) and eicosapentaenoic acid (C20:5n–3) of the n–3 series and arachidonic acid (C20:4n–6), eicosatrienoic (C20:3n–6) and eicosa-

**Table 1** Saturated and monounsaturated fatty acids (mean wt. %) in colostrum samples from different countries

| Reference | Martin *et al.*, (5) 1991 | Guesnet *et al.*, (12) 1993 | Harzer *et al.*, (14) 1983 | Genzel-Borovi-czeny *et al.*,(13) 1997 | Serra *et al.*, (10) 1997 | Ronne-berg and Skara, (17) 1992 | Okolska *et al.*, (15) 1983 | Fidler, (7) 1997 | Pita et al,(6) 1985 | Rueda *et al.*, (9)1998 | Yu *et al.*, (11) 1998 | Gibson and Knee-bone (4) 1981 | Chen *et al.*, (3) 1997 | Chen *et al.*, (3) 1997 | Rueda *et al.*, (9) 1998 | Boersma *et al.*,(8) 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | France | France | Ger-many | Ger-many | Italy | Nor way$^{med}$ | Poland | Slovenia | Spain | Spain | Sweden | Aus-tralia | China, Chong-quing | China, Hong Kong | Panama | St. Lucia |
| Number of women | 69 | 41 | 13 | 38 | 20 | 11 | 10 | 41 | 28 | 11 | 17 | 89 | 33 | 51 | 6 | 13 |
| Milk collection | electri-cal pump | Hand | mechani-cal pump | hand | not stated | electri-cal pump | not stated | hand | electri-cal pump | not stated | not stated | hand | hand | hand | not stated | hand |
| Days post-partum | 5, before lunch | 2–5, morning | 3, 5-fold/ day | 5, morning | 1 9 a. m. and 3 p. m. | 2–4 | 3 | 3, before breakfast | 2–4 | 1–5 | 2–4, morning | 3–5 | 1–3 | 1–3 | 1–5 | 0–4 |
| GLC column | capillary | Capillary | capillary | capillary | capillary | capillary | packed | capillary | capillary | capillary | capillary | packed | capillary | capillary | capillary | capillary |
| Fatty acid | | | | | | | | | | | | | | | | |
| 6:0 | | | | | | | | | | | | 1.08 | | | | 0.03 |
| 8:0 | | 0.10 | | | | | | | | | | 0.04 | | | | 0.07 |
| 10:0 | | 0.60 | 0.26 | 0.50$^{med}$ | | 0 | 0.09 | | 0.83 | 0.73 | 0.74 | 0.40 | 0.69 | 0.33 | 0 | 0.73 |
| 12:0 | | 3.83 | 2.25 | 3.42$^{med}$ | | 0.59 | 1.20 | | 3.72 | 3.61 | 4.41 | 2.41 | 4.85 | 3.01 | 1.85 | 3.76 |
| 13:0 | | | tr. | | | | 0.01 | 0.00 | | | | 0.03 | | | | |
| 14:0 | | 6.79 | 5.34 | 5.86$^{med}$ | 6.59 | 2.97 | 4.68 | 6.72 | 6.15 | 7.42 | 7.62 | 5.11 | 5.22 | 5.35 | 5.07 | 6.52 |
| 15:0 | | 0.46 | | | | | 0.04 | 0.79 | | | 0.39 | 0.58 | 0.18 | 0.32 | | |
| 16:0 | 24.38 | 26.11 | 26.01 | 24.97 | 30.89 | 24.25 | 25.96 | 23.06 | 21.03 | 22.39 | 25.4 | 24.61 | 23.25 | 22.64 | 25.13 | 28.43 |
| 17:0 | | 0.43 | 0.79 | | | | 0.20 | 0.36 | | 0.35 | 0.85 | 1.08 | 0.28 | 0.33 | 0.41 | |
| 18:0 | 7.10 | 6.65 | 8.30 | 7.07 | 5.11 | 9.04 | 6.76 | 6.13 | 5.51 | 6.04 | 7.03 | 8.24 | 7.02 | 5.98 | 6.38 | 8.66 |
| 19:0 | | | | | | | | 0.01 | | | | | | | | |
| 20:0 | 0.2–6 | | | | | 0.36 | 3.06 | 0.28 | | | 0.26 | 0.71 | 0.19 | 0.18 | | 0.54 |
| 21:0 | | | | | | 0.26 | | | | | | 0.24 | | | | |
| 22:0 | | | tr. | | | 0 | 0.26 | 0.32 | | | 0.18 | 0.31 | | | | 0.43 |
| 24:0 | | | 0.29 | | | | | | | 0.18 | | | | | 0.33 | 0.43 |
| Total saturated | 42.00 (10) | 45.27 (9) | 43.24 (14) | 43.65 | 42.59 (3) | 40.45 | 42.52 (11) | 37.68 (9) | 37.24 (5) | 40.10 (7) | 46.88 (9) | 43.84 (13) | 41.35 (8) | 37.94 (8) | 38.74 (7) | 49.60 (10) |
| 18:1n–9 | 35.90 | 30.13 | 37.76 | 32.16 | 42.68 | | 39.01 | 35.52 | 38.29 | 36.05 | 33.4 | 37.18 | 36.27 | 34.60 | 28.71 | 26.78 |
| Total mono-un-saturated | 40.16 (6) | 39.11 (5) | 44.64 (7) | 42.64 | 45.19 (2) | | 44.02 (7) | 40.49 (8) | 41.46 (2) | 42.00 (6) | 40.80 (6) | 43.64 (8) | 43.10 (8) | 40.83 (8) | 35.42 (6) | 35.30 (7) |

$^{med}$median, tr. = traces, number of fatty acids that contributed to the sum is given in parenthesis.

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dienoic acids (C20:2n–6) of the n–6 series. This pattern of predominant LCP fatty acids is similar to that of mature human milk, although at an about twofold higher LCP percentage content in colostrum as compared to mature milk [2]. The content of DHA in colostrum lipids was reported to be as low as 0.2 wt. % in Italy [10] and Germany in 1983 [14], and to be near 0.6 wt.% in Norway [17], Panama [9], China (Hong Kong and Chongquing) [3], France [12] and Australia [4]. The highest DHA content in colostrum lipids was reported to be 1.1 wt.% in St. Lucia [8], a value more than 5-fold higher than the lowest reported contents [10, 14] (Table 2 and Fig. 1). The high content of DHA and total n–3 LCP in colostrum lipids from women living in St. Lucia, a Caribbean island, is most probably the consequence of high maternal intake of sea fish [8]. Several studies that examined the effect of a high DHA intake on human milk composition reported the DHA content of human milk to be directly related to maternal intake [19, 20]. The very low amount of DHA in colostrum lipids reported for women from Genoa, Italy is unexpected since it is generally assumed that the Italian or mediterranean diet includes a generous sea fish intake. However, the actual dietary habits of the Italian women participating in the study were not described [10]. Arachidonic acid in colostrum lipids was reported to be in a wide range, from a low of 0.6 wt.% in Germany in 1983 [14] and France in 1991 [5] to 1.6 and 2.1 wt. % in St. Lucia [8] and Poland [15]. The content of total n–3 LCP as well as total n–6 LCP fatty acids was as well the highest in St. Lucia (1.5 and 4.2 wt. %) [8] and the lowest in Italy (0.6 and 1.3 wt.%) [10]. The n–6 LCP/n–3 LCP ratio ranged from 1.6 to 3.8.

Fatty acid composition in colostrum lipids in different studies from the same countries

Two studies each reported fatty acid composition of colostrum lipids studied at different times from France [5, 12], Germany [13, 14] and Spain [6, 9]. The two French studies were published with a time interval of only two years and reported remarkably similar contents of all fatty acids. The Spanish studies were reported with an interval of 13 years. The only marked difference was a considerably lower content of α-linolenic acid in the later study (0.5 wt. % in 1998 vs. 1.1 wt.% in 1985), accompanied by a remarkable increase of the 18:2n–6/18:3n–3 ratio, from 19.1 in 1985 to 27.5 in 1998, the latter being higher than reported in any of the other studies reviewed here. The two German studies were published 14 years apart. The first study [14] was obtained in a smaller population (10 vs. 32 women in the later study). The contents of saturates, monounsaturates and polyunsaturates as well as P/S ratios were very similar in the two studies, as were the contents of linoleic and α-linolenic acid and their ratio (Tables 1 and 2). Remarkably different were contents of some n–3 LCPs, specially eicosapentaenoic acid (0.43 in 1983 vs. 0.04 wt. % in 1997) and DHA (0.21 in 1983 vs. 0.45 wt. % in 1997, Table 2 and Fig. 1). For the sum of n–3 and n–6 LCP fatty acids, there was a trend towards higher values in 1997, whereas the n–6/n–3 LCP ratio of 2.6 remained unchanged.

Fatty acid composition in colostrum lipids in two different regions of China

Very different dietary habits have been reported from two different parts of China, Hong Kong and Chongquing, which are reflected in several differences in fatty acid composition in colostrum lipids as well as in mature milk (at 2, 4 and 6 weeks post-partum) [3].

## Discussion

The initial substrate supply of the exclusively breast fed neonate is provided by colostrum; thus its content of essential and conditionally essential nutrients may be of considerable biological importance. The results reviewed here show that colostrum lipids have high percentages of LCP that tend to be at least twice as high as typically found in mature milk. This high percentage content of LCP compensates for the lower average fat content of colostrum, which contains between 20 and 30 g fat/l [3,17] and hence clearly less than the mean fat content of mature milk near 40 g/l [1]. Thus, the high LCP content of colostrum can supply the breastfed neonate with significant amounts of preformed LCP during the first few days after birth in spite of the still limited total milk intake. This LCP provision may be of biological importance in view of the strong bioactive effects of LCP on cell growth and function, the formation of eicosanoids and the regulation of cardiovascular, immune and many other physiological functions [1].

There are some limitations in the conclusions that can be drawn from the published data discussed here. The different studies have been carried out in groups of women which may or may not be representative of the populations from which they were recruited, and they were studied at different times during which dietary habits might have changed, which could have influenced the results on milk fatty acid composition obtained. The number of subjects investigated in the various studies differ. A limited subject number may be more problematic in studies on early lactation since the fatty acid composition of mature milk was reported to be less varaible than the composition of colostrum or transitional milk, although some degree of intraindividual variation is also observed for the fatty acid composition of mature milk [3, 6, 22].

With time, analytical methods have changed and tended to improve considerably. In two early studies, gas chromatography with packed analytical columns ware used for fatty acid determination [4, 15], which provides only limited resolution and precision and introduces errors particu-

**Table 2** Polyunsaturated fatty acids (mean wt. %) in colostrum samples from different countries

| Reference | Martin *et al.*, (5) 1991 | Guesnet *et al.*, (12) 1993 | Harzer *et al.*, (14) 1983 | Genzel-Borovi-czeny *et al.*,(13) 1997 | Serra *et al.*, (10) 1997 | Ronne-berg and Skara, (17) 1992 | Okolska *et al.*, (15) 1983 | Fidler, (7) 1997 | Pita et al,(6) 1985 | Rueda *et al.*, (9)1998 | Yu *et al.*, (11) 1998 | Gibson and Knee-bone (4) 1981 | Chen *et al.*, (3) 1997 | Chen *et al.*, (3) 1997 | Rueda *et al.*, (9) 1998 | Boersma *et al.*,(8) 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | France | France | Ger-many | Ger-many | Italy | Nor-way$^{med}$ | Poland | Slovenia | Spain | Spain | Sweden | Aus-tralia | China, Chong-quing | China, Hong Kong | Panama | St. Lucia |
| Fatty acid | | | | | | | | | | | | | | | | |
| 18:2n–6 | 11.74 | 11.56 | 10.30 | 9.44 | 9.60 | 11.49 | 8.44 | 15.25 | 15.30$^{f}$ | 12.39 | 7.86 | 7.82 | 10.30 | 14.85 | 18.25 | 8.84 |
| 18:3n–6 | 0.05 | 0.08 | 0.67 | 0.31 | 0.36 | | 0.16 | 0.08 | | 0.17 | 0.06 | 0.34 | 0.11 | 0.09 | 0.23 | n. i. |
| 20:2n–6 | 0.63 | 0.63 | 0.65 | 0.57$^{med}$ | | 0.59 | 0.21 | 1.24 | 0.70 f | 0.85 | 0.75 | 0.65 | 0.51 | 0.95 | 1.25 | 0.80 |
| 20:3n–6 | 0.46 | 0.55 | 0.35 | 0.59 | 0.35 | 0.53 | 0.63 | 0.86 | 0.75 f | 0.63 | 0.57 | 0.49 | 0.48 | 0.50 | 0.77 | 0.81 |
| 20:4n–6 | 0.58 | 0.75 | 0.55 | 0.72 | 0.70 | 0.72 | 2.06 | 1.03 | 1.25 f | 0.72 | 0.75 | 0.71 | 0.84 | 0.71 | 0.86 | 1.60 |
| 22:2n–6 | 0.09 | | 0.17 | | | | | 0.27 | | | | | | | | |
| 22:4n–6 | 0.22 | 0.22 | 0.15 | 0.23$^{med}$ | 0.27 | | 0.10 | 0.69 | 0.64 f | 0.34 | 0.28 | 0.40 | 0.23 | 0.39 | 0.40 | 0.77 |
| 22:5n–6 | 0.06 | | 0.10 | | | | | | | 0 | 0.05 | 0.12 | 0.11 | 0 | 0.22 | |
| Total n–6 | 13.81$^{(8)}$ | 13.84$^{(6)}$ | 12.94$^{(8)}$ | 12.09 | 11.28$^{(5)}$ | | 11.60$^{(7)}$ | 19.42$^{(7)}$ | 18.64$^{(5)}$ | 15.67$^{(7)}$ | 10.32$^{(7)}$ | 10.41$^{(6)}$ | 12.58 (7) | 17.59$^{(7)}$ | 21.66$^{(7)}$ | 13.04$^{(7)}$ |
| Total n–6 LCP | 2.04$^{(6)}$ | 2.20$^{(4)}$ | 1.97$^{(6)}$ | 2.23 | 1.32 | | 3.00$^{(4)}$ | 4.07$^{(5)}$ | 2.82$^{(4)}$ | 3.01 | 2.40 | 2.25$^{(4)}$ | 2.18 | 2.65 | 3.22 | 4.20$^{(5)}$ |
| 18:3n–3 | 0.71 | 0.61 | 0.70 | 0.66 | 0.35 | 0.77 | 0.67 | 0.91 | 1.09 f | 0.45 | 0.99 | 0.41 | 0.85 | 1.27 | 1.32 | 0.45 |
| 18:4n–3 | 0.28 | 0.29 | | | | | | 0.26 | | 0.11 | | | | | 0.18 | |
| 20:3n–3 | 0.05 | | | 0.08 | 0.25 | | | 0.13 | | | | | | | | |
| 20:5n–3 | 0.05 | | 0.43 | 0.04$^{med}$ | | 0 | 0.36 | 0.10 | 0.04$^{f}$ | 0.14 | 0.06 | 0.43 | 0.01 | 0.07 | 0.20 | 0.03 |
| 22:3n–3 | | | | | | | | 0.22 | | | | | | | | |
| 22:5n–3 | 0.21 | 0.27 | 0.13 | 0.22$^{med}$ | 0.18 | 0.26 | 0.31 | 0.37 | 0.11$^{f}$ | 0.37 | 0.27 | 0.35 | 0.23 | 0.28 | 0.75 | 0.44 |
| 22:6n–3 | 0.51 | 0.61 | 0.21 | 0.45 | 0.17 | 0.58 | 0.27 | 0.43 | 0.41 f | 0.46 | 0.54 | 0.64 | 0.64 | 0.60 | 0.58 | 1.10 |
| Total n–3 | 1.87$^{(7)}$ | 1.78$^{(4)}$ | 1.47$^{(4)}$ | 1.62 | 0.95$^{(4)}$ | | 1.61$^{(4)}$ | 2.42$^{(7)}$ | 1.67$^{(4)}$ | 1.24$^{(5)}$ | 2.03$^{(5)}$ | 1.83$^{(4)}$ | 1.87$^{(4)}$ | 2.33$^{(4)}$ | 2.72$^{(5)}$ | 2.02$^{(4)}$ |
| Total n–3 LCP | 0.88$^{(5)}$ | 0.89$^{(2)}$ | 0.77$^{(3)}$ | 0.87 | 0.60 | | 0.94$^{(3)}$ | 1.25$^{(5)}$ | 0.99$^{(3)}$ | 0.87 | 1.03 | 1.42$^{(2)}$ | 1.02 | 1.07 | 1.25 | 1.57$^{(3)}$ |
| Total polyun-saturated | 15.67$^{(15)}$ | 15.62$^{(10)}$ | 14.41$^{(12)}$ | 13.71 | 12.23 | 15.06 | 13.46$^{(11)}$ | 21.82$^{(15)}$ | 20.31$^{(9)}$ | 16.91$^{(12)}$ | 12.35$^{(12)}$ | 12.24$^{(10)}$ | 15.55 | 21.23 | 24.38$^{(12)}$ | 15.10$^{(12)}$ |
| Ratios | | | | | | | | | | | | | | | | |
| 18:2n–6/ 18:3n–3 | 16.67 | 19.08 | 14.71 | 14.30 | 27.43 | 14.92 | 12.60 | 16.76 | 14.10 | 27.53 | 7.93 | 19.07 | 12.11 | 11.69 | 13.83 | 20.10 |
| P/S | 0.37 | 0.35 | 0.33 | 0.31 | 0.28 | 0.42 | 0.32 | 0.58 | 0.55 | 0.42 | 0.26 | 0.28 | 0.38 | 0.56 | 0.64 | 0.31 |
| n–6/n–3 | 7.14 | 7.77 | 8.80 | 7.46 | 13.42 | 6.12 | 7.20 | 8.00 | 11.11 | 14.54 | 5.08 | 5.69 | 6.72 | 7.55 | 8.76 | 7.0 |
| n–6 LCP/ n–3LCP | 2.27 | 2.47 | 2.56 | 2.56r | 2.23 | 3.19 | 3.25 | 2.85 | 3.81 | 2.33 | 1.58 | 2.14 | 2.48 | 2.11 | 2.80 | |

$^{f}$ values were read from the figure, $^{r}$ calculated value, P/S = polyunsaturated/saturated fatty acids, $^{med}$mediane. Number of fatty acids that contributed to the sum is given in parenthesis.

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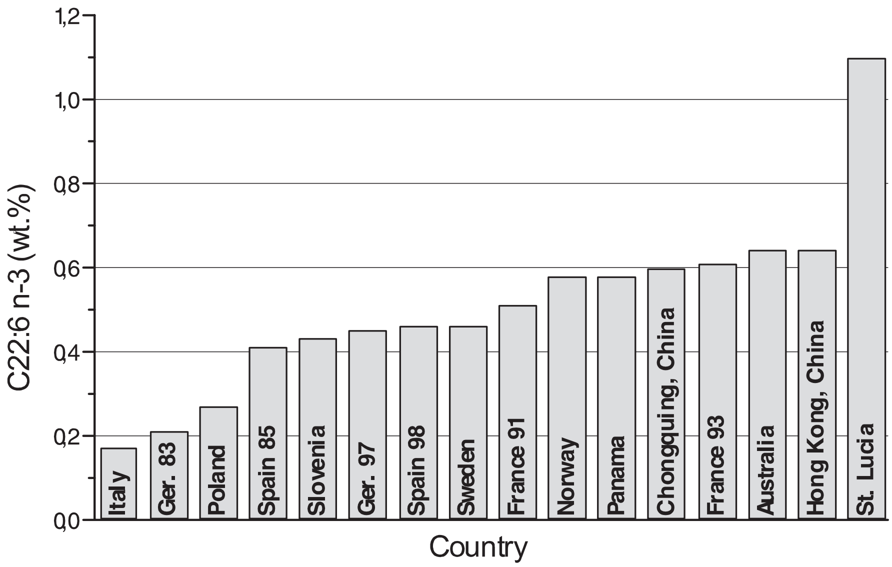


**Fig. 1** Comparison of DHA content (wt. %) in the colostrum lipids of women from different countries as well as from the same countries in different studies

larly with respect to determination of LCP fatty acids. In all later studies, more accurate methodologies with capillary analytical columns were used (Tables 1 and 2), which are about ten times more sensitive and can identify a larger number of fatty acids [23].

While most studies reported on the fatty acid composition of total lipids, Martin et al. [5] published the colostrum triglyceride fatty acid composition. Since triglycerides represent 98 to 99 % of total milk lipids, the fatty acid composition of triglyceride fraction is practically identical to the fatty acid composition of total milk lipids [24, 25].

Although potential influences of differences in methodology cannot be excluded, the increase of the 18:2n–6/18:3n–3 ratio over time found in Spain [9,11] appears to reflect a secular increase of dietary consumption of linoleic acid with vegetable oils, i. e., a change from the classical mediterranean diet rich on monounsaturated fats towards a more Western diet with higher intakes of n–6 fatty acid rich seed oils. The ratio of linoleic to α-linolenic acids is of importance, because both fatty acids compete for the same enzymes for LCP fatty acids biosynthesis of their respective series. Therefore, the precursor ratio affects the n–6/n–3 LCP ratio [21, 26]. The changes over time reported from Germany, with an increasing colostral content of LCP fatty acids [13, 14], might reflect changes in dietary habits in Germany such as a raised consumption of meat and fish products, or differences in the analytical methods used with a higher sensitivity for LCP measurement with the more recent methodology [13]. There was a considerable variation of both the reported AA and DHA contents between and within the various studies. It has been suggested that breast milk AA may be less sensitive to maternal dietary intakes than that of other fatty acids including DHA [3, 21], but the data reviewed here do not allow to draw final conclusions on the relative variation of AA versus DHA. In fact, the measurement of whole body oxidation of a $^{13}C$-labelled oil rich in DHA by lactating women was recently shown to be identical to the oxidation of a $^{13}C$-labelled dietary linoleic acid, which appears to question differential metabolic handling of different essential fatty acids during lactation [27]. In any case, the variation in the fatty acid and LCP content of human colostrum appears to be modulated by maternal dietary composition and to reflect differences in dietary habits between countries and within the same countries over time. Recent studies with stable isotope labelled essential fatty acids have shown that only about 30 % of human milk essential fatty acids are derived directly from the maternal diet, irrespective of the stage of lactation, while the major part of milk fatty acids are derived from maternal body stores [28]. Thus, we consider the observed differences in colostrum composition to reflect to a great part long-term dietary habits of the women studied.

Human milk composition is generally used as the model for designing infant formula unless other evidence is available [26, 29]. However, the composition of mature human milk is usually considered as the gold standard for definition of an adequate dietary substrate intake of the human infant. This might not be adequate under all conditions during the first days of life when infantile endogenous LCP synthesis is very limited [30], but infants already grow and deposit LCP in newly formed tissues and membrane lipids, a process that has been related to neural development [31]. Hence, the definition of adequate levels of LCP intakes in artificially fed neonates during the first week of life might require further consideration.

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