ORIGINAL ARTICLE

Fatty Acid Composition of Taiwanese Human Milk

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Background: The purpose of this study was to analyze quantitatively the fatty acid composition of the milk of Taiwanese women.

Methods: Two hundred and sixty-nine human milk specimens were obtained from 240 Taiwanese mothers, aged 19–41 years, and subjected to chromatographic analysis.

Results: Milk specimens were pooled by the mothers' districts of residence and lactation stages, at 0–11 days, 22–45 days, 46–65 days and 66–297 days after delivery. The fatty acid composition was expressed as weight percentage of all fatty acids detected with C8–C24 chain length. More than 80% of the fatty acids were composed of lauric, myristic, palmitic, stearic, oleic and linoleic acids. The amount of saturated fatty acid was 36.7%. With regard to essential fatty acids, the amount of linoleic acid (LA) was 22% and that of linolenic acid (ALA) was 1.8%, both levels being higher than in human milk from Western countries. However, the ratio of LA/ALA remained at 13:1 for the whole duration of lactation. It has been reported that mothers with high fish consumption have a high content of docosahexaenoic acid and eicosapentaenoic acid in their milk, and we found this phenomenon occurring in our study. The percentage of docosahexaenoic acid and eicosapentaenoic acid in Taiwanese human milk was 0.79% and 0.17%, respectively.

Conclusion: Fatty acid composition in human milk varies during lactation. With regard to essential fatty acids, the amount of LA was 22% and that of ALA was 1.8%, both levels being higher than in human milk from Western and other Asian countries. [*J Chin Med Assoc* 2010;73(11):581–588]

Key Words: docosahexaenoic acid, fatty acid, human milk, polyunsaturated fatty acid

Introduction

During the first 4–6 months of life, breast milk is recommended as the first choice of food for infants.[1] Breast milk is considered the ideal food for healthy infants born at term because it meets the nutritional necessities for babies at this time. During this crucial period, an infant accumulates up to 1,500–1,600 g of lipid,[2] which represents about 90% of all energy retained in the growing tissue. This lipid accumulation not only serves as an exchangeable energy store in adipose tissue, but also has a structural function in all tissues.[3] The biological significance of fatty acid composition of human milk for newborns and their development has led to widespread investigation. Recently, the role of long-chain polyunsaturated fatty acids (LCPUFAs) has drawn special attention because of the potential source of anatomic and functional development of the central nervous system in early life.[4] Linoleic acid (LA; C18:2 n-6) and linolenic acid (ALA; C18:3 n-3), for instance, are converted to LCPUFAs. These metabolites of the n-6 and n-3 series of fatty acids have been shown to affect the biophysical state of the cell membrane,[5,6] and to be an important precursor of prostaglandins.[7]

Although there have been many studies on fatty acid composition of human milk from Western countries, there is little information about that in the Taiwanese population. The nutritional status, cultural traditions, geographic region, socioeconomic status, and dietary habits of Taiwan are completely different from those found in Western countries. These differences might affect the fatty acid composition of human milk. In this study, we analyzed the fatty acid composition of Taiwanese human milk.

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Methods

Three hundred and three human milk specimens were obtained from 240 mothers aged between 19 and 41 years, who were living in Taipei, northern Taiwan and Kaohsiung, southern Taiwan. The predetermined conditions were as follows: (1) the milk specimens were collected between 10:00 hours and 18:00 hours to avoid circadian changes; (2) delivery was normal, and the baby was not born with a low birth weight; (3) the baby was healthy and growing well; and (4) the mother was healthy and had a balanced diet. We selected 264 milk specimens because 39 specimens did not meet all the standards above. We prepared 32 pooled milk samples according to lactation periods and the districts where the mothers lived. There were no statistical differences among the groups, except for lactation days (Table 1). Informed consent was obtained from the participants, and our study was approved by the Taipei Veterans General Hospital Institution Review Board.

Total lipids were extracted from 3-mL human milk samples with 20 mL methanol/chloroform (1:2 vol/vol). Fatty acid methyl esters were prepared with addition of 1 mL 2N KOH/methanol to the lipid fraction, and dissolved in *n*-hexane. Chromatographic analysis was performed with a Hewlett Packard type HP5890 chromatograph (Hewlett Packard, Wilmington, DE, USA), equipped with a fused silica DB-WAX capillary column (0.25 mm × 30 mm; J and W Scientific, Folsom, CA, USA) and Flame Ionization Detector (Hewlett Packard), under the following conditions: the column temperature was programmed at 140–230°C at an increasing rate of 2°C per minute; helium was used as a carrier gas at 1 mL/min flow rate; the injection temperature was 250°C; and the split ratio was 70:1.

Independent samples *t* test was used for statistical analysis. A p value < 0.05 was considered to be statistically significant.

Results

Our method allowed for sensitive analysis of 48 fatty acids by gas chromatography. The distribution and variation of fatty acids during lactation is shown in Table 2. The results were similar to the normal distribution for major fatty acids. More than 80% of the total fatty acids were composed of C12:0 (lauric acid), C14:0 (myristic acid), C16:0 (palmitic acid), C18:0 (stearic acid), C18:1n-9 (oleic acid) and C18:2n-6 (LA). Among the saturated fatty acids, we noted increases in the proportion of C10:0, C12:0 and C18:0, and decreases in C14:0 and C16:0 during lactation days 46–65 (Figure 1). The major saturated fatty acid, palmitic acid (C16:0), constantly accounted for 20% of total fatty acids. For the unsaturated fatty acids, the proportions of C18:2n-6, C18:3n-6, C18:3n-3 (ALA) were increased, and C20:3n-6, C20:4n-6 (arachidonic acid; AA), C22:4n-6 and C22:6n-3 (docosahexaenoic acid; DHA) were decreased from lactation days 0–7 to 46–65 (Figure 2). The proportion of C18:1n-9 (oleic acid) was 28% of the unsaturated fatty acids. Fluctuation of the proportion of C20:5n-3 (eicosapentaenoic acid; EPA) from lactation days 0–7 to 46–65 was found and remained stable thereafter. It comprised approximately 0.2% of the total fatty acids. Most of the other proportions of minor fatty acids were higher at lactation days 0–7. With regard to essential fatty acids, our data showed high proportions of LA and ALA, and the ratio of LA to ALA was higher in the 1^{st} week of lactation. The total ratio of n-6 series LCPUFAs increased, while the ratio of the n-3 series was decreased throughout lactation.

When comparing the breast milk of women living in Taipei with those living in Kaohsiung, the proportions of EPA and DHA were significantly higher in women living in Kaohsiung than in those living in Taipei (Figure 3). However, there was no difference in the other fatty acids, including LA.

Discussion

Studies on the fatty acid composition of human milk from mothers in a variety of geographical locations have been reported. It is well documented that the fatty acid composition of human milk is affected by dietary habits.[8–10] Dietary differences between different

Table 1. Basic information of the mothers and infants

Lactation period (d)	Specimens (*n*)	Age of mothers (yr)	Birth weight (g)	Order of birth
0–11	63	30.0	3,280	1.6
22–45	76	31.6	3,231	1.7
46–65	36	31.6	3,236	1.6
66–297	69	31.8	3,261	1.6

Table 2. Fatty acid composition of Taiwanese human milk (weight percentage)

Fatty acid	Lactation period			
	0–7 d	22–45 d	46–65 d	66–297 d
C8:0	0.08 ± 0.02	0.124 ± 0.05	0.12 ± 0.05	0.13 ± 0.04
C10:0	0.63 ± 0.18	1.08 ± 0.19	1.02 ± 0.17	1.00 ± 0.18
C12:0	3.45 ± 0.72	3.27 ± 0.68	3.71 ± 0.70	4.03 ± 0.91
C13:0	0.03 ± 0.00	0.02 ± 0.01	0.02 ± 0.00	0.02 ± 0.00
C14:0	5.27 ± 0.90	4.19 ± 0.90	3.98 ± 0.62	4.44 ± 0.75
C14:1	0.06 ± 0.16	0.09 ± 0.02	0.10 ± 0.02	0.09 ± 0.01
isoC15:0	0.02 ± 0.02	0.04 ± 0.12	0.05 ± 0.01	0.34 ± 0.01
anteisoC15:0	0.03 ± 0.02	0.04 ± 0.01	0.05 ± 0.01	0.04 ± 0.01
C15:0	0.19 ± 0.03	0.20 ± 0.03	0.21 ± 0.02	0.19 ± 0.02
isoC16:0	0.03 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01
C16:0	20.09 ± 0.98	19.46 ± 0.81	20.01 ± 0.43	19.30 ± 0.48
C16:1 n-9	0.45 ± 0.02	0.38 ± 0.02	0.37 ± 0.02	0.39 ± 0.03
C16:1 n-7	1.62 ± 0.13	2.03 ± 0.15	2.07 ± 0.18	1.94 ± 0.25
C16:1	0.07 ± 0.01	0.08 ± 0.02	0.07 ± 0.01	0.06 ± 0.01
isoC17:0	0.08 ± 0.02	0.10 ± 0.02	0.10 ± 0.02	0.09 ± 0.01
anteisoC17:0	0.08 ± 0.02	0.09 ± 0.02	0.10 ± 0.01	0.09 ± 0.02
C17:0	0.32 ± 0.02	0.32 ± 0.03	0.32 ± 0.01	0.31 ± 0.02
C17:1	0.13 ± 0.06	0.18 ± 0.01	0.18 ± 0.01	0.18 ± 0.02
C18:0	5.95 ± 0.20	6.53 ± 0.35	6.76 ± 0.51	6.45 ± 0.36
C18:1 n-9	28.39 ± 1.79	27.99 ± 0.86	27.45 ± 1.06	27.76 ± 0.70
C18:1 n-7	2.51 ± 0.12	2.26 ± 0.08	2.18 ± 0.13	2.19 ± 0.13
C18:2 n-6	19.16 ± 1.27	22.41 ± 2.03	23.20 ± 1.12	23.62 ± 1.52
C18:3 n-6	0.06 ± 0.01	0.13 ± 0.02	0.13 ± 0.02	0.12 ± 0.03
C18:3 n-3	1.29 ± 0.11	1.63 ± 0.32	1.82 ± 0.16	1.83 ± 0.29
C18:3	0.09 ± 0.02	0.11 ± 0.03	0.13 ± 0.02	0.14 ± 0.05
C18:2	0.15 ± 0.03	0.22 ± 0.05	0.24 ± 0.01	0.21 ± 0.03
C20:0	0.22 ± 0.01	0.20 ± 0.02	0.20 ± 0.01	0.19 ± 0.01
C20:1 n-11	0.12 ± 0.05	0.13 ± 0.07	0.12 ± 0.07	0.08 ± 0.03
C20:1 n-9	0.76 ± 0.05	0.48 ± 0.08	0.51 ± 0.20	0.44 ± 0.09
C20:1 n-7	0.10 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.05 ± 0.01
C20:2	0.07 ± 0.02	0.05 ± 0.02	0.03 ± 0.01	0.03 ± 0.01
C20:2 n-6	1.26 ± 0.12	0.58 ± 0.05	0.51 ± 0.03	0.49 ± 0.03
C20:3 n-6	0.67 ± 0.06	0.39 ± 0.04	0.34 ± 0.03	0.34 ± 0.07
C20:4 n-6	0.86 ± 0.04	0.70 ± 0.11	0.54 ± 0.06	0.49 ± 0.10
C20:3 n-3	0.19 ± 0.01	0.09 ± 0.01	0.08 ± 0.01	0.07 ± 0.03
C20:4 n-3	0.15 ± 0.04	0.11 ± 0.02	0.10 ± 0.02	0.09 ± 0.04
C20:5 n-3	0.19 ± 0.06	0.23 ± 0.10	0.17 ± 0.05	0.17 ± 0.12
C22:0	0.09 ± 0.01	0.07 ± 0.01	0.06 ± 0.00	0.06 ± 0.01
C22:1 n-11	0.04 ± 0.02	0.06 ± 0.06	0.12 ± 0.14	0.04 ± 0.05
C22:1 n-9	0.20 ± 0.02	0.09 ± 0.01	0.09 ± 0.03	0.08 ± 0.02
C22:2	0.26 ± 0.02	0.09 ± 0.02	0.07 ± 0.01	0.05 ± 0.01
C22:4 n-6	0.46 ± 0.05	0.15 ± 0.03	0.11 ± 0.02	0.11 ± 0.02
C22:5	0.10 ± 0.03	0.08 ± 0.02	0.06 ± 0.02	0.05 ± 0.02
C22:5 n-3	0.48 ± 0.17	0.39 ± 0.10	0.31 ± 0.04	0.30 ± 0.13
C24:0	0.14 ± 0.01	0.05 ± 0.02	0.04 ± 0.00	0.04 ± 0.01
C22:6 n-3	1.47 ± 0.44	1.13 ± 0.28	0.91 ± 0.15	0.79 ± 0.30
C24:1 n-9	0.23 ± 0.03	0.05 ± 0.01	0.04 ± 0.01	0.03 ± 0.01
Others	1.61 ± 0.16	1.23 ± 0.19	1.27 ± 0.20	1.27 ± 0.26
n-6	22.46 ± 1.33	24.37 ± 1.98	24.86 ± 1.15	25.54 ± 1.28
n-3	3.89 ± 0.62	3.57 ± 0.65	3.39 ± 0.27	3.26 ± 0.40

(*Contd*)

Table 2. (*Contd*)

Fatty acid	Lactation period			
	0–7 d	22–45 d	46–65 d	66–297 d
n-6/n-3	5.90 ± 1.03	7.01 ± 1.23	7.35 ± 0.47	7.82 ± 0.99
n-6 (long)*	3.31 ± 0.16	2.00 ± 0.04	1.64 ± 0.11	1.54 ± 0.19
n-3 (long)†	2.61 ± 0.66	1.94 ± 0.48	1.28 ± 0.30	1.49 ± 0.56
n-6/n-3 (long)	1.33 ± 0.31	1.09 ± 0.20	1.12 ± 0.21	1.16 ± 0.25

**n-6 (long) = all n-6 excluding linoleic acid; †n-3 (long) = all n-3 excluding linolenic acid.*

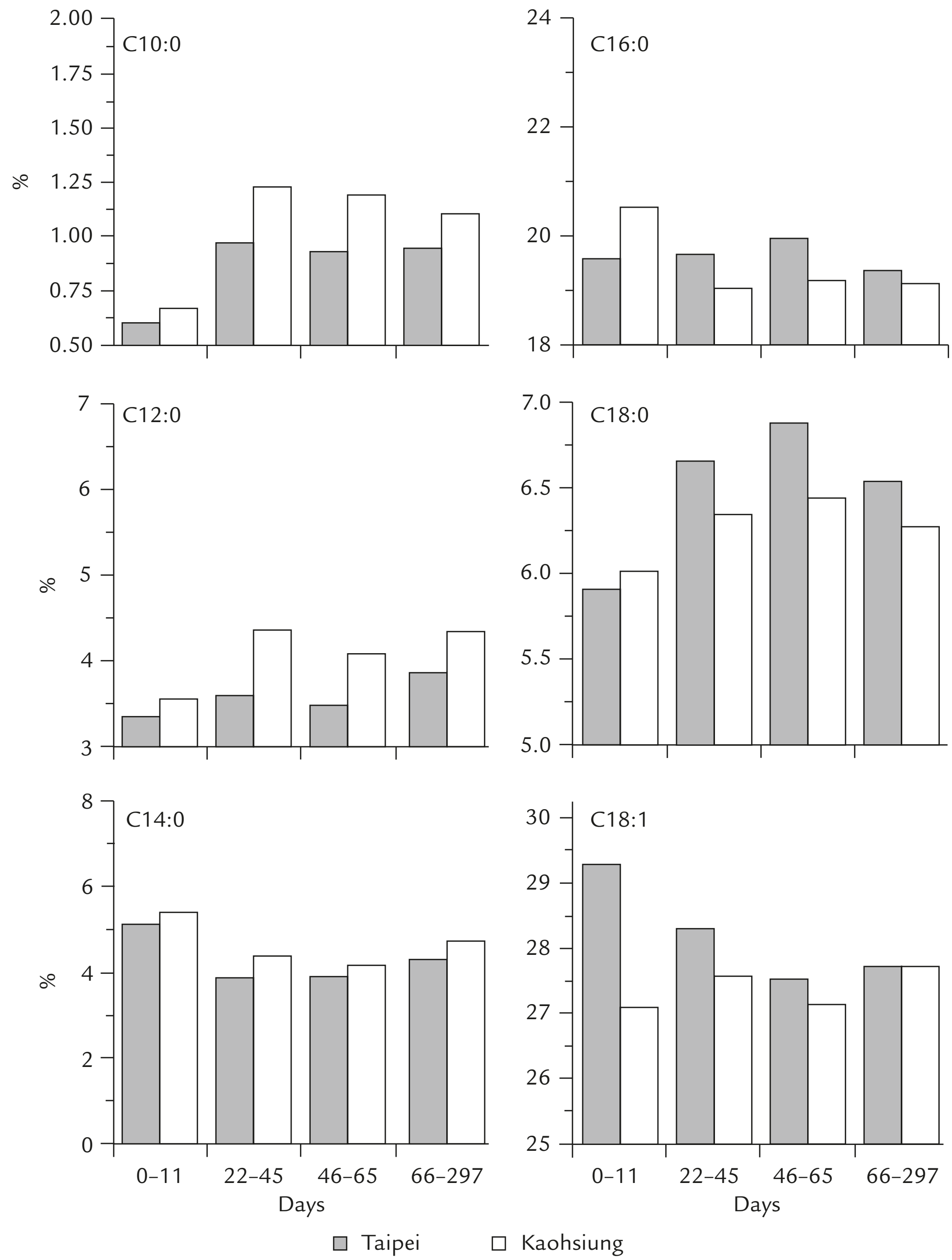

Figure 1. Changes in the composition of saturated and monounsaturated fatty acids in human milk with lactation duration.

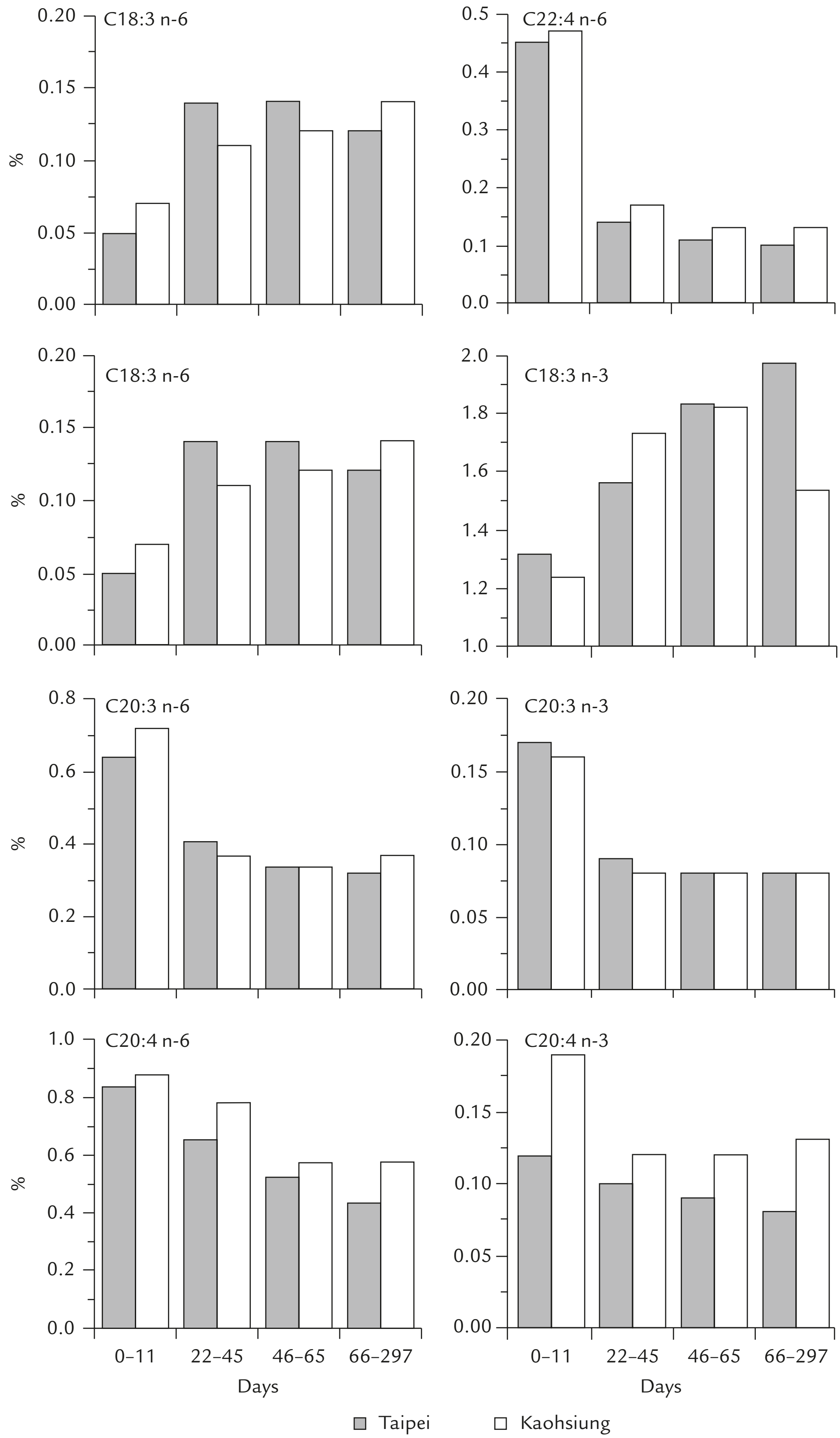

Figure 2. Changes in n-6 and n-3 series fatty acids in human milk with lactation duration.

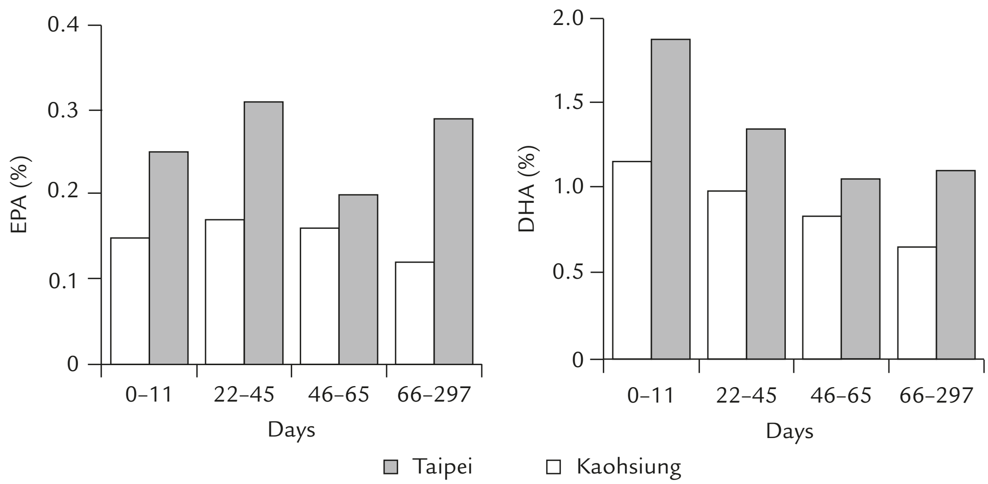

Figure 3. Changes in the content of eicosapentaenoic acid and docosahexaenoic acid in human milk from Taipei and Kaohsiung with lactation duration.

countries or between regions of the same country have been reported to affect the composition of human milk.[11–15] For instance, previous studies have shown that Asian or African milk contains more saturated fatty acid than that of Western countries.[16–20] Although Taiwan is geographically located in Asia, our results did not show typical characteristics for a population with a relatively high consumption of carbohydrate and low consumption of fat, as we expected. In fact, the proportion of saturated fatty acids in Taiwanese human milk was only 36.7%, which is lower than that in other Asian or West African countries. Lee et al[21] reported a large-scale dietary survey that was conducted in Taiwan between 1986 and 1988. They found that a greater amount of fat was consumed in Taiwan during that period when compared with the amount consumed 6 years before their survey took place (35.6% and 31.6% of energy intake, respectively).[21] This suggests that, as Taiwan's economy develops, the population's dietary habits are changing to match those in Western countries. This phenomenon has also been observed in other developing countries.

In the present study, as lactation progressed, we observed that there was an increased proportion of middle-chain fatty acids (MCFAs) compatible with the character of human milk, presumably as the needs of infants changed. This change in MCFAs was similar to that found in studies from Western countries.[16,22–25] Colostrum contains more metabolites of LA and ALA than mature milk does. Although the levels of LCPUFAs decrease as lactation progresses, increasing levels of LA and ALA compensate for the decreasing concentrations of LCPUFAs. Thus, this change ensures an adequate source of biological essential fatty acids for the normal nutrition of infants.

One of the important functions of LCPUFAs is as a fundamental source of central nervous system development in early life. They are found abundantly in the prefrontal cortex and are associated with the development of retinal cells.[26] Recent studies have even found improvement in psychological disorders such as attention-deficit/hyperactivity disorder, dyspraxia, and autism after dietary supplementation with LCPUFAs.[27] Consequently, particular note has been taken in the content of essential fatty acids in human milk. The content of LA in our study was 22–23%. Although this value was similar to that found in the human milk of Egyptian women (24.6% for 22 women), as reported by Borschel et al,[28] it was higher than that found in the milk of Spanish, German and American women. Presa-Owens et al reported an LA content of 12.3% in 40 Spanish women,[17] and Koletzko et al reported 10.6% for German women.[20] These results suggest that Taiwanese women ingest a considerable amount of LA, namely vegetable oil, in their diet.

The proportion of ALA was approximately 1.8%, which was higher than the 0.79%, 0.81% and 1.3% reported by Presa-Owens et al,[17] Koletzo et al[20] and Borschel et al,[28] respectively. Some vegetables, such as soy beans, contain a large amount of ALA. Our results suggest that Taiwanese women consume this type of vegetable to a greater extent than those in Western countries. However, the ratio of LA to ALA in Taiwanese milk was 13:1 and remained constant throughout lactation. As LA and ALA compete for the same enzymes for LCPUFA biosynthesis, and ALA has a higher affinity than LA for δ-6-desaturase, the dietary ratio of LA/ALA is more important than the absolute intake of each essential fatty acid. The mean levels of LA and ALA found in Taiwanese human milk were close to the recommendation of the European Society for Paediatric Gastroenterology and Nutrition.[29]

The elongation and desaturation of LA and ALA to form LCPUFAs such as AA, EPA and DHA have been known for a long time. The 2 major brain PUFAs are DHA and AA. Human milk does contain sufficient AA, EPA and DHA to fulfill the infant's requirement for brain development in early life. Mothers who eat fish containing DHA and EPA can elevate the level of DHA and EPA in their milk significantly.[30] Although the level of DHA (0.79%) and EPA (0.17%) in Taiwanese human milk was higher than that found in the milk of Finnish, West German and Spanish mothers,[12,15,16] it was similar to that found in the milk of women living on Penang Island, Malaysia.[13] This suggests that human milk from mothers who live on islands or along the coast where fish and marine products are easily available will have higher concentrations of EPA and DHA.

As shown in Figure 3, the proportion of n-3 series LCUPFAs, especially DHA and EPA, was significantly higher in the milk of mothers from Kaohsiung than those from Taipei. Kaohsiung is located close to the sea, and it is believed that people who live in Kaohsiung consume much more fish and seafood than people in Taipei. This also shows that the food and nutritional status of mothers affect the fatty acid composition of their milk.

In conclusion, Taiwanese human milk contains a high proportion of PUFAs, especially LA. This is a peculiarity of Taiwanese human milk. The effect of this on infant growth and development should be investigated in the future.

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