Chapter 2

Composition of breast milk in women on a low-carbohydrate diet: a report of two cases

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Abstract
There is no clear definition of low-carbohydrate diets (LCDs). What LCDs have in common, however, is that they restrict the intake of carbohydrates relative to standard recommended diets. Breast milk is the best form of nutrition for newborns and infants. This study reports two cases of women who followed a LCD while breastfeeding. The breast milk sample collected from patient 1 eighteen days after the introduction of a LCD had a fat content of 2.7 g/dL, whereas the breast milk sample collected from the patient fifty days after the introduction

of the diet had a fat content of 2.9 g/dL. Both the samples had a protein content of 1.3 g/dL and a carbohydrate content of 7.9 g/dL. The breast milk sample collected from patient 2 had a fat content of 3.5 g/dL, protein content of 1.9 g/dL, carbohydrate content of 8.2 g/dL and calorie content of 73 kcal/dL. The samples of breast milk collected from patients on a LCD contained higher protein levels. Breastfeeding women are particularly at risk of the negative consequences of dietary mistakes.
Key words: breast milk, low-carbohydrate diet, protein

Introduction

There is no univocal definition of the term "low-carbohydrate diet" (LCD), which covers heterogeneous nutritional regimens. What LCDs have in common, however, is that they restrict the intake of carbohydrates relative to standard recommended diets. In a LCD, less than 45% of daily macronutrient intake should come from carbohydrates [1].

The ketogenic diet (KD) is the most restrictive LCD. The aim of reducing carbohydrate intake to 20–50 g/day is to induce nutritional ketosis. A carbohydrate intake of less than 50 g/day results in glycogen depletion and ketone production through the mobilisation of fat stores. Ketone bodies produced during nutritional ketosis, such as acetoacetate, acetone and beta-hydroxybutyrate, can be measured as serum or urine ketone concentrations [2]. Wells *et al.* defined the term "ketogenic diet" as any diet therapy resulting in a ketogenic state of human metabolism [3].

A review by de Brito Sampaio shows that the KD has for many years been used as a treatment option for drug-resistant epilepsy, both in children and in adults. However, the underlying mechanism of the action of the KD remains unclear, with studies in animal models of epilepsy indicating that it is much more complicated than has been reported so far and involves changes in mitochondrial function, the impact of ketone bodies on neuronal function and the release of neurotransmitters, antiepileptic effects exerted by fatty acids and/or glucose stabilisation [4].

The following four major KD therapies are used in the treatment of drug-resistant epilepsy: the classic KD, the Atkins diet, the medium chain triglyceride KD and the low glycaemic index treatment [3]. LCDs are also

increasingly used as a treatment option for obesity, diabetes, polycystic ovary syndrome, neurological disorders and cancer. However, further research is necessary to investigate the effectiveness and safety of the use of LCDs in the treatment of these conditions [5].

Accordingly, we are seeing an increasing number of pregnant or breastfeeding women following a LCD, even though the diet is not recommended to be used during this period of life [6]. Thus, questions arise as regards the composition of breast milk in women in ketosis. Breast milk is the best form of nutrition for newborns and infants. It provides all the nutrients and bioactive substances that a baby needs for healthy growth and development for the first six months. After that time, when complementary foods need to be introduced due to breast milk not providing sufficient energy, breast milk remains the basic food source of protein. The bioactive components of breast milk play different roles, influencing the development of the immune system and intestinal microflora of infants [7]. It is known that the quality of fats consumed by breastfeeding women is important given the varying proportions of trans isomers and fatty acids which are the precursors of long-chain polyunsaturated fatty acids (LCPUFA) in breast milk depending on what the mother eats [8]. The composition of breast milk varies depending on the stage of lactation. The breasts may start to produce prepartum milk as early as after the sixteenth week of gestation. Prepartum milk is characterised by high protein, sodium and chloride levels and low levels of lactose, glucose, potassium and fat. In the first few days after birth, the breasts produce colostrum, which is a thick, yellow fluid that contains high concentrations of immunoglobulins and leukocytes. Colostrum is produced in small quantities and contains higher protein levels and lower levels of fat and lactose compared with mature milk. Transitional milk replaces colostrum approximately five days after birth. It contains lower levels of protein and immunoglobulins and higher levels of lactose, fat and water-soluble vitamins. After approximately two weeks, the breasts start to produce mature milk, which contains more calories, higher levels of lactose and fat and lower levels of protein [8–10]. The aim of this study is to analyse the composition of breast milk in women on a LCD.

Material and methods

This study reports two cases of women following a LCD while breastfeeding.

Patient 1 was breastfeeding a thirteen-month-old baby. Two breast milk samples were collected from the patient: the first sample was collected eighteen days after the introduction of a LCD (with transition to ketosis) and the second one was collected fifty days after the introduction of the diet. Capillary blood ketone levels were monitored. In addition, basic blood tests were performed and the capillary blood acid-base balance was measured during the diet period.

Patient 2 had followed a KD for approximately four years before pregnancy and followed a LCD during pregnancy and while breastfeeding. One breast milk sample was collected from the patient in the first week of breastfeeding. A complete blood count was performed for the patient when she was breastfeeding while on a LCD.

The breast milk samples were adequately prepared and analysed using the MIRIS Human Milk Analyzer. The results are expressed in g/dL. The Human Milk Analyzer is based on mid-infrared transmission spectroscopy.

Ketone levels were measured using the OptiumXido Neo glucometer (Abbott) with blood β-ketone test strips.

Blood tests were performed in the following laboratories: Dolnośląskie Centrum Diagnostyki Laboratoryjnej (Lower Silesia Diagnostic Laboratory Centre), Uniwersytecki Szpital Kliniczny we Wrocławiu (University Teaching Hospital in Wrocław) and Synevo, Wrocław.

Results

The breast milk sample collected from patient 1 eighteen days after the introduction of a LCD had a fat content of 2.7 g/dL, whereas the breast milk sample collected from the patient fifty days after the introduction of the diet had a fat content of 2.9 g/dL. Both the samples had a protein content of 1.3 g/dL and a carbohydrate content of 7.9 g/dL. The calorie content of

the breast milk sample collected on day 18 was 62 kcal/dL, whereas the calorie content of the sample collected on day 50 was 64 kcal/dL (Table 1). The patient was in good overall health during the entire observation period, which is also confirmed by the patient's test results (Table 2,3). It was only in the case of Ca++ and Cl- levels that slight deviations were found. However, the results after calculating of the anion gap were within the reference range (Table 4).

Table 1. Composition of breast milk in patient 1 during the low-carbohydrate diet period

Breast Milk Macronutrient Content	Fat [g/dL]	Protein [g/dL]	Carbohydrate [g/dL]	Total solids [g/dL]	Energy [kcal/dL]	True protein [g/dL]
Day 18 of the low-carbohydrate diet	2.7	1.3	7.9	12.1	62	1.1
Day 50 of the low-carbohydrate diet	2.9	1.3	7.9	12.3	64	1.0

Source: compilation based on authors' own research.

Table 2. Ketone levels in patient 1 during the observation period

Date	10 Oct 2021	14 Oct 2021	24 Oct 2021	26 Oct 2021
Level (mmol/L)	2.2	1.5	1.4	1.9

Source: compilation based on authors' own research.

Table 3. Results of blood tests performed for patient 1 during the low-carbohydrate diet period

Test	Result	Unit	Ref. values
Leukocytes	7.5	10*3/uL	4.00–10.00
Erythrocytes	4.86	10*6/uL	4.00–5.00
Haemoglobin	15.5	g/dL	12.0–16.0
Haematocrit	45.1	%	37.0–47.0
MCV	92.8	fL	80.0–97.0
MCH	31.9	Pg	26.0–34.0
MCHC	34.4	g/dl	31.0–36.0
RDW-SD	46.9	fL	39.0–52.0
RDW-CV	13.7	%	11.5–14.5
PLT	265	10*3/uL	140–440

Test	Result	Unit	Ref. values
PDW	11.8	fL	9.0–16.0
MPV	10.0	fL	7.0–12.0
P-LCR	24.9	%	19.0–47.0
PCT	0.26	%	0.12–0.36
Erythroblasts	0.0	/100 WBC	0–0.0
Erythroblasts #	0.00	10*3/uL	0–0.00
ALAT	24	U/L	0–55
ASPAT	21	U/L	5–34

Source: compilation based on authors' own research.

Table 4. Results of capillary blood acid-base balance assessment in patient 1

Test	Result	Unit	Ref. values
pH	7.393	-	7.350–7.450
PCO2	38	mmHg	35–45
PO2	87	mmHg	75–100
Na+	140	mmol/l	134–146
K+	4.2	mmol/l	3.6–4.9
Ca++	1.07	mmol/l	1.15–1.32
Cl – chloride ion concentration	110	mmol/l	98–106
HCO3 act.	22.5	mmol/l	22.0–28.0
BE(B)	-1.5	mmol/l	+/- 2.5 mmol/l

Source: compilation based on authors' own research.

The breast milk sample collected from patient 2 had a fat content of 3.5 g/dL, protein content of 1.9 g/dL, carbohydrate content of 8.2 g/dL and calorie content of 73 kcal/dL (Table 5). The patient was in good overall health during the entire observation period, as confirmed by the test results shown in Table 6.

Table 5. Composition of breast milk in patient 2 during the low-carbohydrate diet period

Breast Milk Macronutrient Content	Fat [g/dL]	Protein [g/dL]	Carbohydrate [g/dL]	Total solids [g/dL]	Energy [kcal/dL]	True protein [g/dL]
Low-carbohydrate diet	3.5	1.9	8.2	13.7	73	1.5

Source: compilation based on authors' own research.

Table 6. The results of the blood test performed for patient 2 during the low-carbohydrate diet period

Test	Result	Unit	Reference Values
Leukocytes	4.44	10*3/uL	4.00–10.00
Erythrocytes	4.72	10*6/uL	4.00–5.00
Haemoglobin	15.2	g/dL	12.0–16.0
Haematocrit	43.4	%	37.0–47.0
MCV	91.9	fL	80.0–97.0
MCH	32.2	Pg	26.0–34.0
MCHC	35	g/dl	31.0–36.0
RDW-SD	38.4	fL	39.0–52.0
RDW-CV	11.3	%	11.5–14.5
PLT	254	10*3/uL	140–440
PDW	12.1	fL	9.0–16.0
MPV	10.1	fL	7.0–12.0
P-LCR	27.3	%	19.0–47.0
PCT	0.26	%	0.12–0.36

Source: compilation based on authors' own research.

Discussion

We were unable to find any other studies that analysed the composition of breast milk in women following a LCD. The breast milk samples analysed in our study were collected at two different stages of lactation. Patient 1 had been breastfeeding her baby for over a year. In their study titled *Breast Milk Macronutrient Components in Prolonged Lactation*, Czosnykowska-Łukacka *et al.* [10] analysed the composition of breast milk during prolonged lactation in women on a standard diet. The results of the study for breast milk samples collected between the twelfth and eighteenth month of lactation are shown in Table 7.

Table 7. Macronutrient and energy content of breast milk during prolonged lactation [10, data from Table 2]

Breast Milk Macronutrient Content	Fat [g/dL]	Protein [g/dL]	Carbohydrate [g/dL]	Total solids [g/dL]	Energy [kcal/dL]	True protein [g/dL]
Months 12–18 n = 35	4.6	0.9	7.2	13.1	76	0.7

Compared to the results reported by Czosnykowska-Łukacka *et al.*, the breast milk samples collected from our patient 1 contained lower levels of fat (4.6 vs 2.7/2.9), fewer calories (76 vs 62/64) and higher levels of protein (0.9 vs 1.3) and carbohydrates (7.2 vs 7.9).

In the case of patient 2, the breast milk sample analysed was collected during the period of transitional milk production. The composition of breast milk at this stage of lactation in women on a standard diet was analysed by Ryoo and Kang [11]. The following table shows a summary of the results of that study.

Table 8. Composition of transitional milk [11, data from Table 2]

Macronutrient content of breast milk	Fat (g/dL)	Protein (g/dL)	Carbohydrate (g/dL)	Energy (kcal/dL)
Values	3.45 ± 1.28	1.32 ± 0.25	6.64 ± 0.27	63.18 ± 11.22

Compared to the results reported by Ryoo and Kang, the breast milk sample collected from our patient 2 had similar levels of fat (3.45 vs 3.5) and significantly higher protein levels (1.32 vs 1.9). Moreover, the breast milk sample collected from our patient had a higher carbohydrate content (6.64 vs 8.2) and contained more calories (63.18 vs 73).

In their study, Chang *et al.* [12] analysed the composition of human milk at different stages of lactation. We focused on the results reported by the authors relating to the composition of breast milk samples collected in the first week postpartum. A total of 246 such samples were analysed. The mean lipid content was 2.7 g/dL, the mean protein content was 2.2 g/dL, the mean lactose concentration was 7.0 g/dL and the mean energy content was 61 kcal/dL. Thus, compared with the breast milk samples analysed by Chang *et al.*, the breast milk sample collected from our patient 2 contained higher levels of fat (3.5 vs 2.7), more calories (73 vs 61) and lower protein levels (1.9 vs 2.2).

In their article, Osborne and Oliver [13] reported a case of a breastfeeding woman with ketoacidosis. The patient was eight weeks postpartum and was breastfeeding while on a KD. She developed dyspnea, chest pain and nausea and was unable to tolerate oral intake for several days. The

patient's laboratory tests showed ketoacidosis. After receiving appropriate pharmacological and dietary treatments, the patient made a full recovery.

Liu and Bertsch [14] reported a case of an eight-week postpartum woman who developed ketoacidosis. She presented to the hospital with nausea, vomiting, cough and rhinorrhoea. She was diagnosed with pneumonia and ketoacidosis. The patient reported following a KD to lose weight and was limiting carbohydrates to 25 g/day. She was treated with normal saline and antibiotics, received nutritional education and was discharged in good health.

Nnodum *et al.* [15] also reported a case of a breastfeeding woman with severe ketoacidosis. According to the authors, it was the first reported case of life-threatening ketoacidosis in the lactation period associated with the use of a KD while consuming an appropriate number of calories per day. The patient was twenty-four years old and was eighteen weeks postpartum. She presented to the emergency department with severe nausea and vomiting as well as several episodes of diarrhoea. She reported following a strict KD and was consistently tracking her macronutrient intake at an average of 2,200 kcal/day. The patient was treated with carbohydrates and dextrose and was discharged on day four of her hospital stay with close nephrological and primary care follow-up as well as symptom resolution. The follow-up laboratory tests performed for the patient after discharge remained normal.

Alkhayat *et al.* [16] reported a case of a thirty-seven-year-old breastfeeding woman, eight weeks postpartum, who was diagnosed with high anion gap metabolic acidosis.

Similarly, Gleeson *et al.* [17] reported a case of severe ketoacidosis in a thirty-one-year-old woman who was breastfeeding her ten-month-old baby. The patient was not following a LCD. The case report indicates that lactation placed a heavy burden on the breastfeeding mother. The patient's symptoms resolved completely after rehydration and energy replacement.

The two patients included in our study felt well during the study and all the tests performed on the patients indicated that they were in good health. However, their diets included an extra 500 kcal/day to meet the

energy demands of lactation. Neither of the patients reported that they were dieting to lose weight.

One important aspect to which Dressler *et al.* and Dressler and Trimmel-Schwahofer [18,19] and Le Pichon *et al.* [20] draw attention is the dietary treatment of infants with drug-resistant epilepsy. The authors acknowledge the benefits of breast milk and confirm that in children with drug-resistant epilepsy, breast milk can be incorporated into the children's LCD. It is worth noting that in the case of epilepsies of genetic origin [21], both the mother and the child may need to be treated with a KD. Thus, thanks to knowing the composition of breast milk in women following a KD, we are able to specify more precisely the amount of breast milk that a child with epilepsy can consume daily in addition to a specialist formula. The breast milk samples analysed in our study, which were collected from women following a LCD, contained higher protein levels compared with the protein content of breast milk in women on a standard diet.

Conclusions

The samples of breast milk collected from our patients following a low-carbohydrate diet contained higher protein levels.

Breastfeeding women are particularly at particular risk of the negative consequences of dietary mistakes due to the increased energy demand of lactation, stress and exhaustion from caring for a baby. Therefore, where a low-carbohydrate or ketogenic diet is to be introduced in a given patient, it is important to ensure that the diet is well-balanced and that the patient is under the care of a dietician.

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