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Research Article

Changes in the Concentration of fat, Protein and Carbohydrates During the Excretion of Milk by Vacuum Breast Pump and Breast Pump with Compression

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Abstract:

Background: The purpose of the work is to investigate the contents of the main nutrients of milk (fat, protein, lactose), as well as the energy value of milk in the process of expression milk using an vacuum electric breast pump and vacuum electric breast pump with compression pulses simultaneously.

Method: Surveys were conducted on 9 women 5-8 weeks of lactation. The analysis was carried out in 10 ml samples of milk, which were continuously expression with breast pump «Laktopuls»: only with vacuum stimuli, and simultaneously with vacuum and compression stimuli. The sampling continuity was ensured by a specially developed procedure. Milk analysis in the samples was performed 1-1.5 hours after gland expression on a Miris AB Uppsala, Sweden, human milk analyzer.

Finding: The largest changes in milk samples were observed in fat concentration. The fat content in milk increased in each subsequent sample and in the latter samples could exceed its content in the initial samples by 3-4 times. The total amount of fat was about 25% more when milk ejected by breast pump with vacuum and compression stimuli than with vacuum stimulus only. When determining the protein concentration in milk samples, an increase in its concentration was also found during milk ejection, but on 10-20%. In contrast to the dynamics of fat and protein concentrations, the carbohydrate concentration did not change in all women during the milk ejection.

Conclusion: A method has been developed that allows analyzing milk nutrients during the continuous removal of milk from the gland. Surveys have shown that ejection of milk with breast pump with vacuum and compression stimuli, increases the amount of fat and protein in breast milk.

Keywords: hormone therapy; menopause; cancer; cryopreservation and ovarian tissue transplantation

Introduction

Currently, there is no doubt that breast milk has unique nutritional and immune properties for the health and development of the child (American Academy of Pediatrics, 2012). Mother's milk is of particular importance for the health and development of prematurely born children (Fewtrell et al, 2001). At the same time, children born before the 34th week of pregnancy cannot yet feed themselves from the mother's breast (Fewtrell et al, 2001). Pumping milk allows you to feed a sick child who does not have a sucking reflex or who cannot suck out enough milk, and also helps to maintain lactation while the mother or child is ill, prevent milk loss when separated from the child. If it is necessary to express milk for a long time, the question always arises how best to express it – by hand or using special breast pumps. When pumping milk by hand without special devices and breast pumps, it is possible to express milk at any time and in any place, however, in the absence of skill, the mother can injure the breast tissue; the possibility of microorganisms from the hands in violation of hygiene also increases. It is easy to manually express soft breasts and it is much more difficult to express breasts with swelling and lactostasis forming. For more comfortable pumping, it is recommended to use breast pumps with sterile containers, both stationary and individual, electric and manual. The breast pumps must meet a number of requirements: a) effectively stimulate the areola receptors of the mammary gland to form reflexes of milk secretion and excretion in a woman;

b) empty the mammary gland accordingly quickly and sufficiently; c) should be easy to operate and not cause painful sensations in a woman, not damage the nipple and the areola of the breast. To date, there are a number of works in the literature in which studies have been conducted to optimize the mechanisms of functioning breast pump aimed at increasing the speed and increasing the amount of milk during pumping (Alekseev and Ilyin ,2016; Alekseev et al, 2020; Ilyin et al, 2019; Mitoulas et al, 2002).

At the same time, it is important to point out that breast pump, along with the optimal speed and amount of milk withdrawn, should ensure a sufficiently high quality of the expressed milk. It is interesting to note here that there are experimental data indicating a connection between the composition of milk and its pumping methods. In particular, the fat content of milk increases with the use of mechanical massage of the mammary glands during pumping by a milk-pumping apparatus, as well as with manual pumping, i.e. when using compression stimuli rather than vacuum stimuli to remove milk (Foda et al, 2004; Mangel et al, 2015).

In this regard, the purpose of this study was to find out the content of fat, protein, lactose in the process of continuous milk excretion using breast pump in vacuum pumping mode and when using vacuum and compression pulses for pumping milk simultaneously

Method

Breast milk samples obtained from 9 women aged 25-34 years at the 5th-8th week of lactation were examined: 6 women were primiparous, 3 were secondiparous. All the women breastfed their children. The analysis was performed in 10 ml of milk, which were continuously pumped breast pump "Lactopuls" The breast pump « Lactopulse» is approved for use in medical practice by the Ministry of Health of Russia and is produced by Capella LLC.

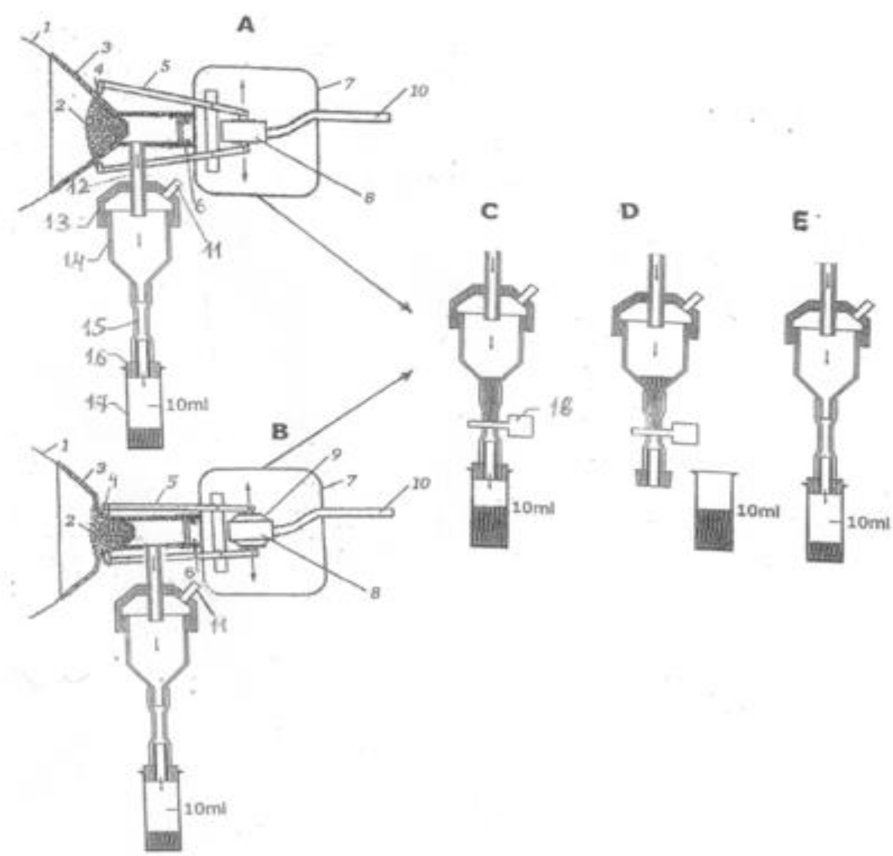

Figure 1: The scheme of operation of the breast pump "Lactopulse" when removing milk only by vacuum stimuli (A) and simultaneously by vacuum and compression stimuli (B) and the method of continuous sampling of milk. (C, D, E).

The breast pump "Lactopulse" (fig.1) consists of a control unit with a compressor and a remote cup (3), which is placed on the breast of a woman. It consists of conical and cylindrical parts. However, unlike vacuum breast pumps, the cone shaped cup is made of elastic material, for example, silicone rubber. The cone part is placed on the mammary gland (1). Rigid plates (4) are in contact with the elastic cone from two opposite external sides, which are fixed at the front ends of the levers (5). The rear parts of the levers are connected to the movable membranes (9) of the pneumatic pusher (8), to which pressure pulses are supplied from the control unit through ne the pumatic line (10). The pneumatic pusher is placed in the housing (7), to which a cylindrical part of the lining is attached from the outside to a special movable protrusion (6).

The breast pump operates in the mode of combined action of vacuum and compression pulses (Fig.1B) as follows. Vacuum and compression stimuli are applied to the remote cup from the control unit in a certain sequence. Just as when milk is excreted by a child (Luther et al, 1974; Mizuno and Ueda ,2001), at the beginning, a vacuum act on the mammary gland, which enters in the cup through a pneumatic duct through a fitting (11) into a milk collector connected to the inside of the elastic cup (3).

The areola of the mammary gland (2) begins to stretch by vacuum, stimulating the skin stretch receptors at the same time, under the influence of vacuum, milk begins to come out of the ducts. After the vacuum inside the elastic cone tube reaches its maximum value, positive pressure stimuli are fed into the pneumatic pusher. The movement of the pneumatic pusher membranes is transmitted to levers (5) and rigid plates (4) produce compression of the conical part and the areolar area of the gland with milk ducts located in it. It is important to note here that, just as in the case of milk excretion by a child, the amplitude of compression and vacuum stimuli can be independently regulated. Compression stimuli additionally more effectively stimulate mechanoreceptors mammary gland areola and, accordingly, contribute to a more effective formation of milk excretion and secretion reflexes, while increasing the output of lactogenic hormones (Alekseev et al, 1998). Milk from the gland enters the cylindrical part of the lining, and then into the milk collector (17).

In the mode of vacuum removal of milk (Figure.1A), only vacuum stimuli act on the gland, which, as in the first case, are transmitted inside the cup via a pneumatic duct through a fitting (11). The continuity of sampling was ensured by a specially developed technique. (Fig.1C, D, E). An elastic cup (Fig.1A, B,3) was placed on the areolar-nipple area (Figure.1A,1) of the woman's breast. The mode of operation of the device was set and the milk began to be excreted from the gland. Milk was supplied to the measuring vessel (17) through a milk outlet (12), an auxiliary container (14) and an elastic silicone tube (15). After 10 ml of milk was collected in the measuring container (Figure.1C), the elastic silicone tube was clamped with a clamp (18), the measuring container was disconnected (Figure.1D), then an empty measuring container similar in volume was attached. At this time, milk excretion did not stop, and it accumulated in an auxiliary container (14). Then the clamp was removed and the milk accumulated in the auxiliary container and the newly withdrawn milk began to flow into the measuring container (Figure.1E). until 10 ml of milk was collected in the measuring container again.

Milk from the disconnected measuring container was poured into a special container for its subsequent analysis. It should be noted that the replacement time of measuring container took no more than 10 seconds. During this time, no more than 5 ml of milk was collected in the auxiliary container at maximum milk output rates from the gland. The same gland was expressed in two different modes of milk excretion: 1) using vacuum only 2) simultaneously by vacuum and squeezing.

Considering that the composition of milk has a circadian character (Paulaviciene et al, 2020) the mammary gland was expressed in both modes at the same time of day. The analysis of milk in the samples was carried out 1-1.5 hours after the pumping of the gland on the analyzer of female milk Miris AB Uppsala, Sweden.

Milk output was measured with accuracy of 0.5 ml and presented of the form histograms.

Findings

When conducting surveys among women, noticeable variations were found in the amount of milk excreted and in the concentration of the milk nutrients studied. At the same time, the dynamics of nutrient concentrations in the process of milk excretion was similar in all women (table.1,2). Surveys have shown that the greatest changes in milk samples are observed in the fat concentration. The fat content in milk increased in each subsequent sample and in the last samples could exceed 3-4 times its content in the initial samples (table.1). Figure 2A shows the total amount of fat in milk in all nine examined patients in the first (figure.2A1) and second halves (figure.2A2) of the volume of milk excreted. The total amount of fat in the second half of the volume of milk excreted (Figure.2A,2) exceeded the amount of fat in the first half of the volume (Figure.2A,1). At the same time, when pumping by vacuum with compression, the total amount of fat removed was about 25% more than when pumping only with vacuum.

When determining the protein concentration in milk samples, an increase in its concentration during pumping was also detected, but not by several times as in the case of fat concentration, but by 10-20% (table.1). The protein concentration in the second half of the volume of milk excreted was 13-20% higher than in the volume of the first half (Figure.2.B 1). Just as in the case of fat determination, the protein concentration was higher in samples derived simultaneously by vacuum and compression stimuli (Table. 1).

Woman		Fat g/100ml												Protein g/100ml											
		Number samples												Number samples											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Nat	V	1,6	2,1	2,2	2,4	3,0	3,4	4,4	4,5					1,0	1,0	1,1	1,1	1,1	1,2	1,2	1,2				
	VC	1,9	2,5	2,9	2,9	3,6	4,9	5,9	6,1	6,9				1,0	1,0	1,1	1,1	1,1	1,3	1,4	1,4	1,4			
Cr	V	1,9	2,2	2,5	3,5	4,1	5,3	6,4	6,5					1,4	1,4	1,4	1,5	1,6	1,6	1,8	1,8				
	VC	2,2	2,8	3,2	4,2	4,1	5,9	6,7	7,6	8,3				1,4	1,5	1,6	1,6	1,5	1,6	1,8	1,9	2,2			
Nad	V	1,2	1,3	1,6	2,1	2,1	2,1	1,8	1,9					0,8	1,0	1,0	1,0	0,9	0,8	0,8	0,8				
	VC	1,3	1,3	1,9	2,4	2,6	3,3	3,3	2,7					0,7	0,8	0,9	1,2	1,1	1,3	1,0	0,9				
Nut	V	3,3	4,7	4,9	6,4	6,9	7,8	6,9	6,9					0,8	0,9	1,0	1,0	1,0	1,2	1,2	1,2				
	VC	3,7	6,1	5,1	6,5	7,1	8,2	7,8	7,6					0,7	0,9	0,9	1,2	1,2	1,5	1,5	1,5				
El	V	1,2	1,7	1,9	2,1	3,0	3,4	4,3	4,5	4,7	6,0			0,7	0,8	0,8	1,0	1,0	1,1	1,1	1,2	1,1	1,1		
	VC	1,9	1,9	2,4	4,2	4,7	4,7	5,0	5,2	6,1	6,7			0,8	0,8	0,8	0,8	0,9	0,8	1,0	1,0	1,0	1,0		
Vic	V	1,4	1,2	1,2	1,3	2,0	2,2	3,0	3,8	3,9	4,2	5,7		0,7	0,7	0,7	0,8	0,8	0,9	0,9	0,9	0,9	0,9	1,0	
	VC	2,6	2,3	3,2	2,7	3,6	4,3	4,6	3,6	5,5	6,2	7,1	6,8	0,8	0,9	1,0	0,9	0,9	1,0	0,9	1,0	1,1	1,1	1,1	1,1
Kat	V	3,2	3,9	6,0	6,0	6,0	7,3	8,4	8,5					0,7	0,8	1,0	1,0	1,0	1,1	1,2	1,3				
	VC	3,2	5,3	6,2	6,6	6,9	8,2	9,0	9,1					0,8	1,0	1,1	1,0	1,0	1,2	1,3	1,3				
Cri	V	1,8	1,7	1,9	2,5	3,8	4,6	5,5	6,7					1,5	1,6	1,6	1,6	1,7	1,8	1,8	1,9				
	VC	4,2	4,5	5,8	5,7	5,7	5,3	6,7	7,5					1,8	1,8	2,1	2,1	2,0	2,0	2,2	2,2				
Ul	V	1,7	1,8	2,8	2,9	2,9	3,0	3,1	3,1					0,9	0,9	0,9	1,0	1,0	1,0	1,0	1,0				
	VC	2,3	2,4	3,4	3,6	3,9	4,0	4,1	3,9					0,9	0,9	1,0	1,0	1,1	1,1	1,0	1,1				

Table 1 :V - milk ejection only with vacuum stimuli

VC - milk ejection with vacuum and compression stimuli

Woman		Carbohydrate g/100ml											
		Number samples											
		1	2	3	4	5	6	7	8	9	10	11	12
Nat	V	7,0	7,0	7,1	7,1	7,0	6,9	6,9	7,0				
	VC	7,4	7,4	7,4	7,5	7,4	7,3	7,2	7,2	7,2			
Cr	V	7,3	7,3	7,3	7,2	7,2	7,1	7,0	6,9				
	VC	7,1	7,1	7,1	7,1	7,1	7,1	6,9	6,8	7,0			
Nad	V	7,1	7,2	7,1	7,1	7,2	7,3	7,3	7,2				
	VC	7,2	7,3	7,2	6,9	6,8	7,1	7,1	7,3				
Nut	V	7,0	7,0	7,1	7,0	6,9	6,8	6,8	6,8				
	VC	7,0	7,1	7,0	7,0	6,9	6,9	6,9	6,9				
El	V	7,3	7,3	7,3	7,3	7,2	7,1	7,0	7,1	7,1	7,1		
	VC	7,1	7,4	7,4	7,2	7,3	7,2	7,4	7,1	7,1	7,1		
Vic	V	7,4	7,4	7,4	7,4	7,2	7,3	7,3	7,4	7,3	7,2	7,2	
	VC	7,0	7,4	7,4	7,4	7,2	7,4	7,1	7,4	7,4	7,1	7,0	7,0
Kat	V	7,3	7,4	7,3	7,2	7,2	7,0	6,0	6,9				
	VC	7,4	7,4	7,2	7,2	7,2	7,1	6,9	6,9	6,9			
Cri	V	7,2	7,1	7,0	6,8	7,0	6,9	6,9	6,8				
	VC	7,1	7,1	7,2	7,1	7,1	7,0	6,8	6,8				
Ul	V	7,2	7,3	7,2	7,2	7,2	7,1	7,1	7,1				
	VC	7,3	7,2	7,3	7,2	7,3	7,3	7,2	7,2				

Woman		Energy kcal/100ml											
		Number samples											
		1	2	3	4	5	6	7	8	9	10	11	12
Nat	V	49	54	55	57	62	73	74	74				
	VC	50	56	60	61	66	80	94	96	98			
Cr	V	53	56	59	68	74	85	95	107				
	VC	55	61	65	74	76	90	98	106	144			
Nad	V	43	45	48	52	52	51	50	55				
	VC	45	44	50	55	57	64	63	57				
Nut	V	62	76	78	93	96	106	10,3	10,3				
	VC	65	89	79	93	98	108	103	10,5				
El	V	43	48	50	52	60	64	72	75	77	91		
	VC	49	52	55	72	77	77	81	82	90	96		
Vic	V	47	45	45	48	52	54	63	70	72	73	87	
	VC	57	56	64	59	68	75	75	78	87	91	100	107
Kat	V	63	71	91	96	98	101	111	1,11				
	VC	64	84	92	90	90	111	118	125				
Cri	V	51	52	53	59	71	78	87	93				
	VC	75	78	91	107	89	85	117	106				
Ul	V	49	49	59	60	60	64	64	65				
	VC	54	56	65	67	70	75	70	70				

Table:2 V - milk ejection only with vacuum stimuli

VC - milk ejection with vacuum and compression stimuli

In contrast to the dynamics of fat and protein concentrations, the concentration of carbohydrates practically did not change in all women during milk pumping (Table 2)

The energy value of milk is determined by the content of fat, protein, carbohydrates (Perrin ,1954). Since, in our case, the fat content changed to a greater extent in the samples during milk excretion, it is not difficult to notice that changes in the energy value of milk (table 2. fig.2 D) have a similarity with the changes in the fat content of milk.

Discussion

Data on the effect of compression stimuli on the dynamics and concentration of nutrients in milk samples are of great interest. Surveys have shown that in women, compression stimuli increase the concentration of fat, protein and, accordingly, the energy value in milk samples. The experimental data available to date suggest that the increase in fat content is due to more efficient milk excretion due to the formation of milk excretion reflexes (Alekseev et al, 1998) , as well as due to a direct increase in the rate of milk excretion by compression stimuli (Alekseev and Ilyin ,2016). Recall that the intake lactose and proteins of milk into the alveolar cavity is carried out by the process of exocytosis. These nutrients are packed into vesicles in the Golgi apparatus of the secretory cells of the alveoli, and then transported to the apical region, merge with the apical membrane, which is perforated and the contents of the vesicles are removed into the lumen of the alveoli (Shennan and Peaker, 2000) Lipids are synthesized in a smooth plasma reticulum localized in the basal part of the cell from fatty acids and glycerol. Synthesized lipid molecules form lipid droplets, which are covered by a protein shell. When approaching the apical part of the secretory cell, the droplets increase in size, merging with each other. In contact with the apical membrane, fat droplets are enveloped by the cell membrane, form fat globules, and then separated, unlaced from the cell so that the integrity of the cell is not violated. The membrane surrounding the globule prevents the formation of large fat droplets, which can hinder the movement and exit of milk from the alveolar duct system. However, the size of lipid globules is much larger than the size of protein molecules and lactose. Therefore, the diffusion of lipid globules is difficult in the thin ducts (70-80 microns) connecting the cavity of the alveoli with medium and thick ducts, from which it is relatively easy to withdraw milk to a child or an apparatus. In addition, it is assumed that fat globules are additionally absorbed to the membranes of cells forming alveoli and duct (Patton and Fowkes, 1967). All this contributes to the fact that milk with a large amount of fat accumulates in the alveoli and thin ducts. Therefore, according to Whittleston's filtration theory (Whittleston, 1953), milk with fat droplets should be "pushed" into medium and thick ducts. This is done due to neuroendocrine reflexes of milk excretion. In response to stimulation of the receptors of the areolar-nipple complex of the mammary gland, when milk is excreted by a child or a breast pump, oxytocin is released impulsively from the neurohypophysis, which causes a contraction of myoepithelial cells, an increase in milk pressure inside the ducts and the milk is pushed out into wider ducts. The available experimental material indicates that the greater the increase in the concentration of oxytocin during the formation of milk ejection reflexes, the higher the intra-alveolar and intra-current pressure rises and, accordingly, the faster the milk exits into the wide ducts. At the same time, due to the arrival of "fatty" milk from the alveoli and thin ducts, the fat content of milk in the samples increases. The use of compression stimuli in the apparatus enhances the formation of the milk excretion reflex. Small changes in the concentrations of protein or lactose in the samples as milk is excreted could be due to the fact that protein and lactose molecules are distributed relatively quickly in the volume of milk in the ductal system of the gland during the period between milk pumping by diffusion. Therefore, there were no such significant differences in the concentration of protein and lactose in milk samples as for the fat content of milk.

References

1. Alekseev N.P,Ilyin V.I, Yaroslavsky V.K, Gaidukov S.N, Tichonova T.K, Specivcev Y.A et al. (1998). Compression stimuli increase the efficacy of breast pump function. Eur J Obstet Gynecol Reprod Biol., 77(2),131-139.
2. Alekseev N.P, Ilyin V.I. (2016). The mechanics of breast pumping: compression stimuli increased milk ejection. Breastfeed. Med. 11, 370-375

3. Alekseev N.P., Ilyin V.I., Troschkin M.M., Uleziko V.A. (2020). A comparative study of the efficacy of breast milk expression using Lactopulse and Medela Symphony breast pumps. Biomed. Engineering. 54, 70-72.
4. American Academy of Pediatrics. (2012). Breastfeeding and the use of human milk. Pediatrics.129 (3), e827-e841
5. Fewtrell M.S, Lucas P, Collier S, Singhal A. Ahluwalia J.S, Lucas A, (2001). Randomized trial comparing the efficacy of a novel manual breast pump with a standard electric breast pump in mothers who delivered preterm infants. Pediatrics.107,1291-1297.
6. Foda M.L Kawashima T, Nakamura S, Kobayashi M, Oku T. (2004). Composition of milk obtained from unmassaged versus massaged breasts of lactating mothers. J Pediatr Gastroenterol Nutr 38(5),484-487
7. Ilyin V.I., Alekseev N.P., Troschkin M.M., Uleziko V.A. (2019). Comparative assessment of excretion of milk from two breast pumps with different vacuum strength an duration. Breastfeed Med. 14(3),177-184
8. Luther E.C, Arballo J.C, Sala N, L (1974). Suckling pressure in humans: relationship to oxytocin-reproducing reflex milk ejection. J. Appl. Physiol. 36 ,350-353,
9. Mangel L, Ovental A, Batscha N, Arnon M, Yarkoni I, Dolberg S. (2015). Higher fat content in breastmilk expressed manually: A randomized trial..Breastfeed Med. 10(7),352-354.
10. Mitoulas LR, Lai CT, Gurrin L.C, Larsson M, Hartmann PE., (2002). Effect of vacuum profile on breast milk expression using an electric breast pump. *J Hum Lact* 18,353-360
11. Mizuno K, Ueda A. (2001). Development of sucking behavior in infants with Down's syndrome. Acta Paediatr., 90,1384-1388
12. Patton S, Fowkes FM. (1967). The role of the plasma membrane in the secretion of milk fat. J Theor Biol. 15(3),274-281.
13. Paulaviciene I.J., Liubsys A, Molyte A, (2020). Circadian changes in the composition of human milk macronutrients depending on pregnancy duration: a cross-sectional study. Int Breastfeed J. 15, 49-55.
14. Perrin D.R. (1954). The composition of soẇ's milk during the course of lactation. J. DairyRes. 21,55-61.
15. Shennan D.B, Peaker M. (2000). Transport of milk constituents by the mammary gland. Physiol Rev.80(3) ,925-935
16. Whttlestone W.G. (1953). Variation in the fat content of milk throughout the milking process. J Dairy Res. 20, 146-149.

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