Adequacy of human milk viscosity to respond to infants with dysphagia: experimental study

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ABSTRACT

Neonatal nutrition is an important subject in health in the short, medium and long term. In preterm newborns, nutrition assumes a predominant role for the child's overall development. Babies with uncoordinated swallowing or respiration may not have the necessary oral abilities to suck the mother's breast and will need to implement different feeding practices; one of them is changing the consistency of the milk offered. Objectives: Determine viscosity variations of untreated human and pasteurized milk without and with thickening to adapt the diet to the needs of dysphagic infants hospitalized in the Neonatal Intensive Cara Unit (NICU). Material and Methods: The authors altered the viscosity of natural infant powdered milk and, after thickening, determined and adopted a thickening standard for human milk. Untreated human and pasteurized milk was thickened in concentrations of 2%, 3%, 5% and 7% and the viscosity were determined every 20 minutes for a period of 60 minutes at a temperature of 37ºC. Results: The infant lactose formula thickened at concentrations of 2% and 3% produced viscosities of 8.97cP and 27.73 cP, respectively. The increases were significantly different after 1 hour. Inversely, untreated human milk at 2%, 3%, 5% and 7% produced diminished viscosity over time; the changes were more accentuated in the first 20 minutes. In pasteurized human milk, the 2% concentration had no variation in viscosity, but with the 3%, 5% and 7% concentrations, there was a significant decrease in the first 20 minutes with stability observed in the subsequent times. Conclusion: In powdered milk, the viscosity increases over time; the viscosity in human milk diminishes. The results point out the importance not only of considering the concentration of the thickener but also the time being administered after its addition to effectively treat dysphagic infants.

Key words: Deglutition disorders. Dysphagia. Deglutition. Human milk. Viscosity. Rheology.

INTRODUCTION

Neonatal nutrition is an important subject in community health and social planning policies, especially for questions arising from the lack of maternal nursing. Particularly in preterm newborns, nutrition takes on a predominant role for the child's overall development. Clinical and epidemiological data reinforce the conclusion that lack of human milk in this phase of life increases the incidence of diarrhea, respiratory infections, urinary infections, otitis media and necrotizing enterocolitis[7] as well as depriving infants of components that contribute to adequate development.

Health professionals confront challenges in adequately feeding newborns[13]. In the Neonatal Intensive Care Unit (NICU), in general, preterm newborns present respiratory problems, asphyxia, cardiomyopathies, metabolic disturbances, genetic syndromes and congenital malformations, among others, that are often challenges for adequate nutrition.

Various obstacles can prevent adequate nutrition for this population during the hospitalization period: difficulties in feeding orally due to a delay in maturation and in acquiring the necessary oral sensory motor skills, prolonged use of tracheal-oral tubes and gastric probes, immaturity of the cardiorespiratory system, central nervous system and oro-facial musculature. These factors can also interfere with the nutritional process provoked by the disorganization of the normal pattern of sucking, hyper-sensibility to peri-touch and/or intra-oral stimuli. There also can be a lack of coordination in sucking, respiration and swallowing, resulting in complications such as food being aspirated into air passages when swallowing does not occur effectively[6,11,14,15].

Moreover, babies that present with uncoordinated swallowing often do not have the necessary oral skills to suck the mother's breast and will require implementation of practices to adapt feeding practices, including a change in the consistency of the milk offered.

Souza, et al.[16] (2001) confirmed that the thin liquid causes a lack of coordination among sucking, breathing and swallowing in patients. Thus, it is necessary to understand the importance of the consistency to create diets since consistency will influence the acceptance of and swallowing of food. In the National Dysphagia Diet[2], seven rheological properties in food of major significance in the treatment of dysphagias have been identified. Among these, viscosity is the most important property for swallowing.

The goal of this study is to determine the variation in viscosity of untreated human and pasteurized milk without and with different degrees of thickening. This will offer health professionals information that can enable them to respond to the needs of the dysphagic infants hospitalized in the NICU without interrupting the use of human milk.

MATERIAL AND METHODS

The study was undertaken in the Quality Control Laboratory of the Human Milk Bank of the Fernandes Figueira Institute - Oswaldo Cruz Foundation (IFF/FIOCRUZ). The study was approved by the IFF/FIOCRUZ's Committee for Ethics in Research on Human Beings. All human milk samples came from donors registered at the BLH-IFF, complying with legislation that regulates the establishment and functioning of the Human Milk Bank throughout the National Territory[5].

An experimental study was undertaken in casual groups[8] determined using version 13.0 of the SPSS program. The data collected were submitted to descriptive and statistical analysis using the Student's T test in variables with normal distribution and the Kruskal-Wallis test for non-parameter variables with a level of significance of 95% in accordance with the effects to be tested in each of six stages, described as follows:

1) Standardize the technique to determine viscosity of pumped human milk using Ford Viscometer cups

This step was necessary because although the Ford Viscometer cup has been used for various Newtonian fluids, it was not possible to identify prior publications that established the analytic technique necessary to be followed for determining the viscosity of human milk according to this method. It was necessary to determine which orifice of the Viscometer was most appropriate for the viscosity of fluid human milk and for thickened milk.

For the rheological characterization, we used the determination of cinematic viscosity according to standard NBR 5849[3] for the investigation of Newtonian fluids (such as milk) that extend the space of time for conduction between 20 s to 100 s for orifices 2, 3 and 4. Viscosity was determined by the Quimis brand model Q 280 Ford Viscometer cup.

Viscosity was determined by the flow time of the fluid and by gravity through the Viscometer. The time in seconds was converted into cinematic viscosity (centistoke) and then into dynamic viscosity (centipoise) using formulas based on the diameter of the Ford cup orifice.

2) Study the effect of time on the viscosity of untreated human milk pumped and pasteurized milk was maintained at a temperature of 37°C with variation of ±2ºC

This study corresponds to two trials. Determination took place every 3 hours for a period of 9 hours. Repeated observations of the same product were aimed at controlling the temperature and reducing experimental errors. The temperature is a determinant of the product's quality and it was affected according its use in the service routine.

1.8 L of pumped untreated human milk was used with three repetitions of 600 mL to make triplicates with the volume of 200 mL in each trial. The repetitions were done with different samples of human milk and the triplicates composed by the same product. Each trial was undertaken separately and the determination of the viscosity was developed and is described in the results. Human milk was thawed; afterwards, with the help of a beaker, re-pouring the product created three repetitions with the 600 mL volume forming triplicates with volumes of 200 mL each. The pasteurization of human milk occurred as described by the ANVISA[4] (2008). After thermal equilibrium at the study's temperature, the viscosity was determined.

To determine the kinematic viscosity in centistokes at this stage, orifice 2 was used and the following formula was used, provided by NBR 5849: Viscosity=[(2,388xt) – (0,007xt²) – 57,008]

Variable t represents the time of rapid flowing in seconds. The result was converted into centipoise.

3) Study the effect of time on the infant's powdered milk viscosity appropriate for the first semester maintained at 37°C with a variation of ±2ºC.

In this study, we used six repetitions with 150 mL and analyzed changes in the viscosity at 20-minute intervals for a period of 60 minutes, maintaining the product in thermal equilibrium at 37ºC. We adopted first semester infant powdered milk purchased locally as a thickener; the concentrations were 2% and 3%. The viscosity changes were initially undertaken without the thickener and prepared according to manufacturer recommendations. This permitted recognition of the pattern of the viscosity. The same viscosity formula was used as that in the previous step.

4) Study the effect of time on the viscosity of infant powdered milk appropriate for the first semester, thickened at 2% and 3% and maintained at a temperature of 37°C with a variation of ±2ºC.

We used 12 repetitions of the powdered milk. Six were thickened with the 2% concentration and six with the 3% concentration. The viscosity of each repetition was determined in four intervals of 20 minutes for a period of 60 minutes maintaining the product at thermal equilibrium at 37ºC. Thicken Up® (Nestlé Resource, São Paulo, Brazil) was the commercial thickener chosen, and it was purchased locally.

Considering the benefits from thickening, we based the testing on our clinical practice and used a thin consistency (1-50 cP) that enabled suction of the feeding bottle or feeding with the little cup. We followed the table recommended by the American Dietetic Association[2].

Each concentration of the thickener was weighed on the Marte brand model A500 digital scale and afterwards the powdered milk was added according to the manufacturer's recommendation. The timing included a two-minute pause for thickening to be completed.

For the 2% concentration, the same formula was used as that of the previous study and for the 3% concentration, the viscosity was determined with orifice 3 and the following formula was applied: Viscosity=[(2.314xt)–15,200]

5) Study the effect of time on the viscosity of untreated human milk, thickened in 2%, 3%, 5% and 7% concentrations and maintained at a temperature of 37°C with a variation of ±2ºC.

For this study, a pool of human milk was created for testing the 2% and 3% concentrations and another pool for the 5% and 7% concentrations. Six duplicates were collected for pasteurization and six were untreated for each concentration. In each concentration, each duplicate was accompanied by a period of an hour and its viscosity was determined in 20-minute intervals for a total of four measurements.

For the 2%, 3% and 5% concentrations, the formula was applied for orifice 2. For the 7% concentration, viscosity was determined with orifice 3, and the corresponding formula was applied.

In studying 5% and 7% concentrations, the goal was to reach the necessary degree of thickening for infants with dysphagia, comparing it with the viscosity obtained in the concentration of infant powdered milk already known and used clinically at 2% and 3% concentrations.

6) Study the effect of time on the viscosity of pumped pasteurized human milk, thickened in 2%, 3%, 5% and 7% concentrations and maintained at a temperature of 37°C with a variation of ±2ºC.

The study design followed the same model of the untreated pumped human milk thickened in the same concentrations.

RESULTS

Samples of untreated human and pasteurized milk maintained at 37ºC for a period of nine hours did not alter the viscosity values when compared by analysis of the variance to determine a 5% level of probability and a median value of 2.84 cP

Table 1- Effect of time on the viscosity of untreated human milk and pasteurized milk maintained at a temperature of 37°C

Time (hours)	Viscosity (cP) UHMP	Viscosity (cP) PHMP
0	2.84±0.30[a]	3.40±0.67[a]
3	2.73±0.51[a]	3.59±0.84[a]
6	2.48±0.74[a]	3.40±0.74[a]
9	3.35±0.50[a]	3.98±1.05[a]

Values followed by same letter do not differ at 5% probability ($p<0.05$)

UHMP=Untreated Human Milk Pumped; PHMP= Pasteurized Human Milk Pumped in untreated milk and 3.40 cP in pasteurized milk as observed in Table 1.

The viscosity determination values for first semester infant powdered milk was undertaken every 20 minutes after its preparation and maintained at 37ºC for a period of up to one hour, is presented in Table 2.

A 17.39% ($p<0.05$) reduction was observed over the first 20 minutes after preparation and was associated with the product's chemical stabilization. That is, in the initial period, the hydration of formula components takes place after its dissolution. It is worth pointing out that even though the product instantaneously dissolves, the subsequent hydration requires time to occur. This conclusion is reinforced by the fact that the viscosity is maintained stable with values that are statistically equal over 40 subsequent minutes.

The median value of viscosity of the powered milk was 4.49 cP. When compared with untreated pumped human milk or pasteurized pumped human milk at 37°C, the powdered milk had a higher viscosity.

The addition of 2% of thickener in the powdered milk at 37ºC produced double the increase in viscosity compared to results from the powdered milk without added thickener during the first 20 minutes. The addition of 3% concentration increases the powdered milk's viscosity six-fold in relation to time zero.

Comparing all concentrations of thickener of raw pumped human milk analyzed, the average viscosity values decreased significantly in relation to time (Table 3).

In all analyzed concentrations, the decrease in the viscosity is more accentuated in the first 20 minutes, maintaining a stability for between 40 and 60 minutes, except in the 3% concentration, which continues to exhibit diminishing viscosity with the passage of time ($p<0.05$).

In relation to untreated pumped human milk without thickener, we observed that the addition of 7% of the thickener increased the viscosity up to nine-fold.

Table 2- Effect of time on the viscosity of infant powdered milk maintained at 37°C

Time (minutes)	Viscosity (cP)	Viscosity (cP) 2%	Viscosity (cP) 3%
0	4.49±0.54[a]	8.97±1.11[a]	27.73±1.88[e]
20	3.71±0.49[b]	13.43±0.55[b]	47.74±1.40[f]
40	3.81±0.33[b]	15.58±0.54[c]	47.57±1.22[f]
60	4.08±0.47[b]	15.92±0.52[d]	48.07±1.26[f]

Values followed by same letter do not differ at 5% probability ($p<0.05$)

Table 3- Effect of time on the viscosity of untreated human milk thickened maintained at 37°C

Time (minutes)	Viscosity (cP) 2%	Viscosity (cP) 3%	Viscosity (cP)5%	Viscosity (cP) 7%
0	4.54±0.25[a]	5.05±0.48[d]	7.59±0.92[h]	25.55±0.37[k]
20	3.39±0.20[b]	3.58±0.32[e]	4.67±0.40[i]	20.77±0.25[l]
40	3.81±0.25[c]	4.25±0.27[f]	4.11±0.20[j]	20.50±0.28[m]
60	4.12±0.53[c]	3.65±0.28[g]	3.86±0.40[j]	20.68±0.20[m]

Values followed by same letter do not differ at 5% probability ($p<0.05$)

Table 4- Effect of time on the viscosity of pasteurized human milk thickened maintained at 37°C

Time (minutes)	Viscosity (cP) 2%	Viscosity (cP) 3%	Viscosity (cP) 5%	Viscosity (cP) 7%
0	4.06±0.82[a]	5.53±0.68[b]	7.98±0.87[e]	27.09±1.01[h]
20	3.58±0.64[a]	4.43±0.22[c]	4.82±0.35[f]	20.92±0.38[i]
40	3.57±0.34[a]	4.43±0.28[c]	4.80±0.18[f]	20.59±0.20[i]
60	3.60±0.31[a]	4.01±0.30[d]	4.57±0.16[g]	20.76±0.18[i]

Values followed by same letter do not differ at 5% probability ($p<0.05$)

The addition of 2% of thickener in pasteurized pumped human milk did not modify its viscosity significantly over time. With the 3%, 5% and 7% concentrations, we verified that there was a significant decrease in the viscosity over time, mainly in the first 20 minutes. The tendency was to stabilize viscosity between 20 and 40 minutes (Table 4).

In relation to pasteurized pumped human milk without thickener, we verified that the addition of 7% of thickener increased up to eight-fold the viscosity of pasteurized pumped human milk observed at time zero.

DISCUSSION

The samples maintained at 37ºC for a period of nine hours of untreated human and pasteurized milk did not have altered viscosity values.

In powdered milk, the viscosity was maintained stable with statistically equal values over 40 subsequent minutes. In the powdered milk thickened at 2% and 3%, a considerable increase in viscosity over time was observed.

Compared with powdered milk, human milk produced an inverse viscosity behavior: the viscosity diminished with time. With the powdered milk, there was a progressive and rapid increase with a tendency to stabilize. In this way, we imagine that the immediate offer of human milk after the addition of thickener could minimize such effects and preserve the desired degree of thickening.

The results reinforce that the use of thickeners should take into consideration not only the concentration of the product as well as the time elapsing after preparation before administration is important in responding to the needs of the dysphagic infant.

From the theoretical point of view, the reduction in the viscosity of thickened human milk is associated with the presence of the amylase enzyme in human milk that promotes of partial hydrolysis of the starch contained in the thickener[10]. This leads to the reduction, proving that pasteurization does not cause total inactivity of this enzyme in human milk.

Therefore, amylase becomes an important ally in the nutrition of the dysphagic infants. This enzyme, in very small amounts in the first three or four months of life in the digestive tube of babies, is present in human milk[9,12]. Its presence in the thickened human milk facilitates the digestive process. This doesn’t happen with the thickened infant powdered milk, as it will depend on the babies’ enzyme. So, the thickening of the human milk is beneficial, as this technique maintains the human milk its exclusive nutritional quality and acts as a facilitator of the digestive process.

For the standardization of the thickening procedure of diet in the routine of hospital nutrition and speech therapy services, pasteurized pumped human milk with thickener could be administered in four consistencies: 2%, 3%, 5% and 7% according to the speech pathologist’s evaluation.

The study points to the fact that the result of the thickening process for human milk is different than that with infant powdered milk. This could reflect the influence of amylase’s action especially in untreated human milk leading to a decrease in the thickened product’s viscosity.

A limiting factor in this study was the method for determining the viscosity. It requires large volumes of milk, and it is difficult to control the temperature.

Our results indicate that it is possible, in practical terms, to seek alternatives for thickening human milk with human milk components. The post-pasteurization viscosity variations arising from alterations in the quaternary structure of the milk proteins suggest that the paths for developing thickeners using the cream of human milk or with the help of bacteria should be investigated[1]. The thickeners could be able to promote the sweet coagulation of human milk, increasing its viscosity without acidifying it. It is worth noting that the food industry has used a similar technology for a long time to produce “flan” and skimmed creamy cheese. Studies of this type will contribute to new strategies for the feeding of the dysphagic infant, permitting the infant to benefit from the use of human milk.

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