Investigation into the flow rate of bottle teats typically used on an Australian NICU

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ABSTRACT

Aims and Objectives: Premature and medically fragile infants in neonatal intensive care may be establishing oral feeding skills during their admission. Not all infants can achieve breastfeeding and bottle feeding is the recognised alternative. Choosing a bottle with a manageable flow rate can enable a positive feeding experience. The flow rate of teats used on an Australian NICU were tested to determine their actual flow rate and the variation of flow observed.

Design and Methods: Flow rate of five different teats were tested by attaching each teat to a breast pump and measuring the output of milk after 1 minute. Range of flow rate and variability in flow rate values of the five teats used were compared.

Results and Conclusions: The results identified differing flow rates as well as individual variation of flow rates for all teats used on an Australian NICU.

The Sepal Green /small size nipple/slow flow was the fastest flow rate teat (mean 25.34 mL /minute). The Sepal White / ultra-slow flow teat had the slowest flow rate (mean 7.34 mL/minute). Measurement of variability in flow rate identified a moderate - high mean flow rate for the Sepal White ultra -slow flow teats (CoV = 0.2), with a low mean flow rate for Sepal Green slow flow / small nipple (CoV = 0.06). Data confirmed variability of flow rates both within and between teats used.

. Flow rate and variability are important factors to consider when selecting supportive feeding equipment for preterm infants.

Keywords

Milk flow rate; suck, swallow breathe (SSB) coordination; preterm infants; medically fragile infants; neonatal care; bottle feeding

INTRODUCTION

Learning to feed, for infants on Neonatal Intensive Care Units (NICUs) who are born prematurely or those who are medically fragile can be a lengthy process (Burklow, McGrath, Valerius & Rudolph, 2002). Infants need time to establish the ability to coordinate sucking, swallowing and breathing, alongside physiological and neurological maturation so that safe oral feeding can develop (Jadcherla, Wang, Vijayapal, Leuthner, 2010). Subsequently, establishing oral feeding can take time and delay discharge home from the NICU (Browne & Ross, 2011). Not all mothers who have infants in neonatal care are able to establish exclusive breastfeeding, and bottle feeding is therefore necessary. However, selecting the right bottle to suit an infant's level of oral skill in relation to texture and flow is a complex process.

Bottle feeding skills

Selecting a bottle to suit an individual infant's skills and preference is challenging, as infants tend to develop individual preferences and strategies to manage flow rates which in turn impacts on breathing and sucking during feeding (Mathew 1991; Segami, Mizuno & Itabashi, 2013). Typically developing infants who bottle feed develop a swallow episode first which is then followed by respiratory inhalation and exhalation (Lagarde et al, 2019). Lagarde, van Alfen, de Groot, Geurts, & van den Engel-Hoek (2019) identified that when feeding using bottles of different flow rates, infants showed variation in inhalation and exhalation patterns, but were able to adapt to flow rate, shape and flex of differing teats.

The shape, size and other properties of teats can influence an infant learning to feed. Variation within teats of a product from one manufacturing source have been identified (McGrattan, McFarland, Dean, Hill, White & Martin – Harris, 2017, Mathew 1991). Zimmerman and Barlow (2008) investigated variation in material, shape and mechanical

properties (stiffness) of different pacifiers on non-nutritive suck patterns of preterm infants. The authors demonstrated that infants responded to variations in pacifier shape and mechanical properties with differences in non-nutritive suck patterns. In addition, Zimmerman, Forlano and Gouldstone (2017) went on to describe the wide variation of nipple and base shape, size, and stiffness in commercially available teats and how these properties influenced the non-nutritive suck pattern of term infants. Although the authors were specifically investigating the impact of pacifiers on non-nutritive sucking performance, conclusions about nutritive sucking and the impact on central pattern generator maturation and infant responses to specific bottle teat characteristics would be useful.

Flow rate has been described as the rate in which milk flows from the bottle or breast into the infant's mouth (Pados, Park, Thoyre, Estrem & Nix, 2015). With bottle feeding, the flow rate is influenced by the number of holes in a bottle teat, teat material and the infant's ability to create suction and expression in order to remove the milk. Infants who are establishing bottle feeding skills on a NICU may require additional external strategies such as positioning or pacing (Harding, Frank, Botting and Hilari, 2015). Mathew (1991) and Pados, Park, Thoyre, Estrem & Nix, (2015) identified the impact of the flow rate of milk into an infant's oral cavity on swallow trigger, timing and coordination. With increased flow, infants will have more frequent breaks in respiration at the point of the swallow, leading to decreased blood oxygenation impacting respiratory rate and recovery throughout the feed. In addition, responsive bottle feeding with paced rest periods can support physiological stability (Kirk, Adler & King, 2007; Thoyre, Park, Pados, & Hubbard,2013). Variable coordination of sucking, swallowing and breathing, when a flow rate is hard to control, places the infant at risk of aspiration (Pados, Park, Thoyre, Estrem & Nix, 2015). Slow flow teats have been shown to support development of coordinated sucking, swallowing and breathing, more efficient feeding, stable physiological signs and reduced risk of aspiration, thus enabling positive oral feeding experiences (Pados, Park & Dodrill, 2018). However, there are many factors that can impact on bottle teat flow rate. These include the size of the teat orifice hole (Chang, Lin, Lin & Lin, 2007); the infant's ability to use a sustained suck pressure when feeding and the pressure within the bottle itself (Almeida, Almeida, Moreira, & Novak 2011; Segami , Mizuno & Itabashi, 2013); the composition of the teat material (Oommen,1990); and the viscosity and temperature of the milk feed (Sunaric, Jovanovic, Spasic, Denic, & Kocic, 2016).

Recent studies such as that by Pados, Park, Thoyre & Estrem (2015); Pados, Park & Dodrill (2018) and Bell and Harding (2019) have already highlighted the variation in flow of hospital and commercially available teats in the USA and UK. Bell and Harding (2019) were able to show variability of flow rate within the same teat when tested multiple times. This variation in flow that has been described in the above studies is significant as a varied flow of milk from a bottle at each feeding will have an impact on an infant's feeding experience and their ability to learn to control fluid and feed safely. Most infants who spend time on a NICU will be developing oral feeding with hospital single use teats. When these families are discharged they are more likely to go home to continue to establish feeding with a commercially available teat. Pados, Park, Thoyre & Estrem (2016) demonstrated the variability in flow of commercial bottle teats available to families following discharge and showed that teats marketed as 'slow flow' for new-born or premature infants had a flow varying from 1.68mL- 15.12 mL/minute. This is a significantly wide range of flow that could potentially influence oral feeding development and experience. Recommendations suggest that families bring the teat planned for use at home to the NICU prior to discharge to establish feeding with the chosen teat.

Previously completed studies comparing flow rate have been shown to be country specific (United States of America, United Kingdom). Pados, Park & Dodrill (2018), recommended the importance of local replication of teat flow projects for bottle available to inform clinicians and families when supporting oral feeding progression

Study objectives

This study determined to test the flow rate of specific teats used on the NICU that the authors of the project work in, and to compare the flow of the two slow flow teats that are available for use on the Unit. The Sepal white ultra - slow flow teat was considered as an additional new slow flow teat resource to be tested and compared with the other bottles in current usage. This project aimed to add information to guide clinicians in Australia when choosing an appropriate teat for infants who are establishing oral feeding. All teats used on the NICU are commercially available for families to purchase following discharge. The results of the study may inform discussions around teats that families may decide to use once they have transitioned home from the NICU.

Hypothesis and Aims of the Study:

. The aims of the study were as follows:

- To determine the range of flow rates of neonatal single use teats used on a local NICU.
- To compare the variability of flow of teats used on a local NICU.

This study hypothesized that the teats used on the NICU would have a range of flow rates and that there would be some variability of flow rate within teats tested

MATERIALS AND METHODS

Design

This study investigated the flow rates of neonatal bottle teats used on an Australian NICU. All teats are available for commercial sale, and to families who are being discharged home from the NICU.

The teats included in the study were advertised as having flow rates appropriate for use with infants of varying ages. See Table 1 for information on teat characteristics. Teats were grouped as 'term' if recommended for use in term infants, 'preterm/medically fragile' if recommended for use with preterm or fragile infants, or 'specialized' if considered for specialized feeds. Teats included the Sepal Blue (extra small nipple/ extra slow flow recommended for 0-1 month); Sepal Blue (small nipple/extra slow flow) recommended for 0-5 months or infants who have difficulty with faster flow; Sepal Green (extra small nipple/ slow flow) recommended for specialist feeding with thickened feeds); Sepal Green (small nipple/ slow flow) recommended for 0-5 months and the Sepal White (ultra-slow flow) recommended for 0-1month infants with feeding difficulties. The blue and green Sepal teats came in two different nipple lengths- small and extra small. Smaller nipple lengths are recommended for younger infants or for those requiring specialized feeds. For these teats, both nipple lengths were tested for comparison.

At present on the NICU, the Medela Special Needs Feeder is available as a slow flow teat when infants are having difficulty coping with the flow of the Sepal Blue extra slow flow teat. It is marketed for infants who have difficulty creating a vacuum when sucking, or have weak inefficient suction. The Medela Special Needs feeder has a slit mechanism, and milk is extracted from the teat when positive pressure is applied (compression). The flow rate of milk from the Medela Special needs feeder is impacted by the position of the slit mechanism in the infant's mouth, the force of compression the infant applies to the teat and the hydrostatic pressure of available milk in the bottle. The Medela Special Needs feeder was not included as part of this study as the current method of testing flow rate does not consider these factors that will vary flow rate of milk and therefore results would not be transferrable. There is a need for further investigations into different methods of testing flow rates in order to allow comparison of flow across both standard and compression teats to guide decisions about feeding equipment in NICU.

-INSERT TABLE 1 HERE-

Method of testing flow rate

Five different types of teats were included in the study, see Table 1 for detail. To test for variability of flow within teats, three of each type of teat were included in the study. In total 15 teats were included in the study. All teats were attached to a Medela medium size breast shield (24mm) and putty was used to seal the teats and ensure no air leak affected the measure (See Figure 1). A Medela Symphony hospital grade breast pump, SKU 240108 was used to test teat flow rates. The pump was used on established maintenance phase with a pressure of 180mmHg (Pados, Park, Thoyre & Estrem 2015). The pressure of the pump was measured with a Medela pressure gauge. Pressure was checked at the start of the testing and each time a teat was changed to ensure that the pressure remained constant throughout testing. Although it is understood that intra - oral pressures will vary for individual infants as well as throughout feeds, the use of a standardized pressure allowed for comparison for all teats tested. To maintain constant hydrostatic pressure, teats were fixed to a stand at an angle of 30 degrees (Figure 1). To achieve this angle, the level measure from the fluid to the tip of the teat was maintained at 2.5cm. A volume of 50mL of

milk was used for each of the tests. The formula used in the tests was ready made Aptamil Gold standard formula at room temperature. Formula was changed after every three trials to prevent change to the viscosity of the fluid (Pados, Park, Thoyre & Estrem, 2015). For all tests, Sepal 150mL disposable bottles were used. Once fixed to the breast shield and pump, the formula for expressed for 1 minute and the expressed formula was measured following this. The testing process was recorded throughout and results confirmed.

- Put Figure 1 here -

Statistical analysis

Both the mean and the standard deviation were calculated when investigating the flow rate for each teat type that was tested. Data were used to calculate the variability between the flow rates for all teats tested using the coefficient of variation. Variability was designated as low if CV was <0.1, moderate if CV was 0.1-0.2, and high if CV was >0.2 (Pados Park, Thoyre & Estrem 2015). The study protocol was agreed by the hospital ethics committee. No infants or carer participants were involved in data collection, nor were any comments or opinions sought from professionals. Approval was from Monash Health Research Support Service and was found to be consistent within the NHMRC Ethical considerations in Quality Assurance and Evaluation (2014) guideline and thus was exempt from ethics approval. This was regarded as an audit of equipment used on a NICU.

RESULTS

Mean flow rates

Term Teats

The Sepal Green small/slow flow teat had the fastest mean flow of all teats tested at 25.34mL/min. The Sepal Blue small/extra slow flow teat had a mean flow rate of 17.67mL/min.

Premature/medically fragile teats

The teats that were marketed for use with premature and medically fragile infants had the lowest mean flow rate overall in the testing with the Sepal White ultra - slow flow

7.34mL/min. The Sepal Blue extra small/ extra slow flow teat had a mean flow rate of 14.67 mL/min. The flow rate of the Sepal White utra-slow flow teat 50% slower than the Blue Sepal extra small nipple/ extra slow flow teat which is the current premature flow teat on the NICU.

Specialised teats

The teat that was marketed for use with thickened feeds was the Sepal Green (extra small nipple/slow) flow teat. The flow rate of this teat was 22.67mL/min.

Sepal teats that were marketed as the same flow rate (Blue extra slow flow/Green slow flow) varied in flow rate when the nipple length increased. The Sepal Blue extra slow teat increased from 14.67mL/minute (extra small length nipple) to 16.67mL/minute (small length nipple). The Sepal Green slow teat increased from 22.67mL/minute (extra small length nipple) to 25.33 mL/minute (small length nipple). The fact that the Sepal green (extra small nipple/slow) flow teat is a teat recommended for thickened feeds was not clearly marked on individual packaging, which may impact choices made about teats based on nipple sizes where smaller nipples may be used for smaller or more complex infants.

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Variability of flow rates

There was a variability of flow rate in all of the teats measured by calculating the coefficient of variation (CoV). The variability of flow rate across all teats was low to moderate (CoV = 0.1).

Low Variability

There were two teats that measured low variability; Sepal Green small/slow flow (CoV = 0.06) and Sepal Green extra small/slow flow (CoV = 0.09).

Moderate Variability

There were two teats that measured moderate variability with the Sepal Blue small/extra slow (CoV = 0.19) and Sepal Blue extra small/extra slow (CoV = 0.10).

One teat measured moderately - high variability and this was the Sepal White ultra-slow (CoV = 0.2). The teats that were marketed specifically for premature or medically fragile infants had the highest variability in the sample (Sepal White ultra-slow; Sepal Blue extra small / extra slow), and then teats that were marketed for standard use had the lowest variability between tests (Sepal Green small /slow; Sepal Blue small/extra slow.

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DISCUSSION

This study investigated flow rates of teats available for use on one Australian NICU. Results identified a wide range of flow rates (7.33mL/min- 25.33mL/min) and variability of flow within each teat tested, confirming the study hypotheses that suggested this would be the case. Preterm and medically fragile infants present with immature oral feeding skills and often receive their first oral suck feed on the unit, developing and refining oral feeding competence alongside other skills in readiness for discharge home (Azuma and Maron 2020). Learning to bottle feed can be interrupted by variable flow rate of milk from a teat which subsequently influences timing and trigger of the swallow, thereby increasing risk of apnoeic episodes and aspiration (Chen, Wang, Chang & Chi, 2000**).**

Synchronization of sucking, swallowing and breathing is an important part of learning to feed successfully (Goldfield, Richardson, Lee & Margetts, 2006). Feeding tolerance through the ability to demonstrate increased sucks and sustained intra - oral pressure when sucking, with adequate cardiorespiratory stability and state regulation support effective feeding (Lang, Buist, Geary, Buckley, Adams, Jones & Rogers, 2011). When establishing feeding skills, infants experience somatosensory learning where trigeminal mechanosensitive afferent pathways in the oral cavity provide important sensory memory, contributing to motor learning, thus early positive sensory experiences of feeding are an

essential part of the learning (Estep & Barlow, 2007). Sensory learning may be influenced, sometimes negatively, by variations between each feed leading to inconsistent learning experiences which could possibly attributed to having multiple feeders, (Howe, Shue, Hinojosa, Lin & Holzman, 2007). These variations may further be impacted by variations in flow rate within the same teat at each feed.

The current study found there was variability of flow rate within each teat tested. Variability of flow was higher (CV=0.19-0.2) for teats marketed for more premature and medically fragile infants. Variability of flow between hospital teats is something that was also found in earlier studies in the UK (Bell & Harding 2019) and in the US (Pados, Park, Thoyre & Estrem, 2015). Both studies concluded that this variability, alongside environmental factors such as multiple feeding partners, could impact on an infant's ability to learn to feed orally in the neonatal setting, and that there was a need for bottles and teats with low variability to support development and progress. Variation with our study findings which used the same testing method as Pados, Park, Thoyre & Estrem (2015) illustrate the complexities when testing teat flow, and unlike these authors, we excluded the Medela Special Needs Feeder due to technical problems which prevented accurate data collection.

McGrattan, McFarland, Dean, Hill, White and Martin-Harris (2017) considered the use of single use, laser cut slow flow teats on milk ingestion and respiration of preterm infants, identifying that inconsistency within and between teats introduces an unknown variation in flow rate, and that limited available information from manufacturers about teat attributes as well as variable standardisation of production will limit understanding of these distinctions. Given that testing for each teat remained uniform in the current study, we conclude that variations due to manufacturing may be a contributing factor to flow rate within in the same brand and type of teat. It is important that feeding partners are able to recognise cues of stress or disengagement during the feed that may be influenced by the variation in flow rate across different feeds. In response, if those feeding infants have an awareness of potential variability of flow rate, adjustments to typical strategies to manage feeding can be implemented, i.e. pausing and pacing during the feed (Harding & Cockerill, 2015).

Limitations and future directions

The project was a single site investigation which examined a small number of bottle teats. Further research could include teats from other NICUs across the country to support decisions around choice of teats when infants are moving between hospitals as well as commercially available teats. Future findings could additionally support health care professionals to make choices with families around teats recommended for infants' post discharge from the unit. To supplement testing of bottle teat flow rate and variability of flow, future research could link this information to other factors that may influence sucking such as the size, shape, sensory characteristics, product variability and mechanical properties of the teat (McGrattan, McFarland, Dean, Hill, White & Martin - Harris, 2017; Zimmerman, Forlano & Gouldstone, 2017) as well as the intra – oral sucking pressures infants exert themselves. The pressure applied through the use of a standard breast pump does not mimic the varied sucking pressures applied by infants during nutritive sucking (Mizuno & Ueda,2006). Assessment of infant intra - oral pressure during feeding and how this is affects flow rate would be important for those working to develop safe infant oral feeding skills. Knowledge of intra - oral pressures may also help more accurate identification of the most appropriate bottle type required to match bottle types to individual infant needs. One area which has been under-researched is the variability within bottle products themselves. For example, teat orifice size within one manufactured product has been noted, along with methods of orifice manufacture, i.e. mechanical drill or laser penetration (McGrattan, McFarland, Dean, Hill, White & Martin -Harris, 2017). Further investigations to consider the somatosensory impact of teat textures would also provide important information about oral - sensory development and learning when feeding (Oder, Stalling & Barlow, 2013).

Rheological investigations should be included in future research in relation to bottle flow rates. This would need to include detailed analysis of viscosity through shearing of fluids as teat diameter, length as well as fluid viscosity affect flow rates. Liquid particles tend to be close together but move and collide randomly which accounts for variability in teat flow outcomes (Steffe, 1996). Understanding fluid particle behaviour of rheologically different fluids such as formula and breast milk in relation to bottle teat flow could improve clinical decision making (Geddes, Kok, Nancarrow, Hepworth, Simmer, 2018).

In future, more comprehensive comparisons could be made in relation to fluids through consideration of critical covariates of flow rate such as viscosity, density, sheer, temperature of fluids as these considerations were beyond the scope of this particular study.

Conclusions:

This study has identified that there is variation of flow rates across teats marketed for premature and medically fragile infants typically used on an Australian NICU. Clinicians can use the findings of this study to help guide clinical decisions about teat choices for infants establishing oral feeding on the NICU environment using the flow rate and variability of teats to guide selection and evaluate infant's feeding abilities. The study also found there are no clear recommendations for manufacturers around descriptions of flow rates when marketing teats for use with premature infants. A standardised guidance around what flow rate would constitute slow, standard and fast flow, as well as clear labelling on packaging would improve the ability of families and health care professionals to make informed choices in order to support an infant's early bottle-feeding abilities. In addition, this study highlights the need for manufacturers of bottle teats to continually evaluate their products to ensure the lowest variability of flow within each teat in order to support infants who are learning to feed.

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References

Almeida, M. B. D. M. D., Almeida, J. A. G. D., Moreira, M. E. L., & Novak, F. R. (2011). Adequacy of human milk viscosity to respond to infants with dysphagia: experimental study. *Journal of Applied Oral Science*, *19*(6), 554-559.

Azuma D, Maron JL (2020) Individualising Oral feeding Assessment and Therapies in the Newborn. *Research and reports in Neonatology* (10) May p 23-30.

Bell, N. & Harding, C. (2019). An investigation into flow rates of disposable bottle teats used to feed preterm and medically fragile infants in comparison with flow rates of commercially available bottle teats. *Journal of Speech language and Hearing* 22 (4) 227-235.

Browne, J., & Ross, E. (2011). Eating as a neurodevelopmental process for high risk newborns. *Clinics in Perinatology, 38*(4), 731-743. Doi:10.1016/j.clp.2011.08.00.

Chang, Y. J., Lin, C. P., Lin, Y. J., & Lin, C. H. (2007). Effects of single-hole and cross-cut nipple units on feeding efficiency and physiological parameters in premature infants. *The Journal of Nursing Research*, *15*(3), 215-223.

Chen, Wang, Chang and Chi (2000). The effect of breast and bottle feeding on oxygen saturation and body temperature in preterm infants. *Journal of Human Lactation 16 (1) 21-27.*

Estep, M. E., & Barlow, S. M. (2009). The Connectivity of Orofacial Systems. *Perspectives on Speech Science and Orofacial Disorders*, *19*(1), 28-36.

Geddes, D., Kok, C., Nancarrow, K., Hepworth, A., Simmer, K. (2018). Preterm Infant feeding: A mechanistic comparison between a vacuum triggered novel teat and breastfeeding. *Nutrients* 10 (3) 376 doi: 10.3390/nu10030376

Goldfield, E. C., Richardson, M.J., Lee, K.G., Margetts, S. (2006). Coordination of Sucking, Swallowing, and Breathing and Oxygen Saturation During Early infant Breast-feeding and Bottle-feeding. *International Pediatric Research Foundation,* 60(4), 450-455. Doi: 10.1203/01.pdr.0000238378.24238.9d.

Harding, C., Frank, L., Botting, N., & Hilari, K. (2015). Assessment and management of infant feeding. *Infant*, 11(3), 85-89

Howe, T. H., Sheu, C. F., Hinojosa, J., Lin, J., & Holzman, I. R. (2007). Multiple factors related to bottle-feeding performance in preterm infants. *Nursing Research*, *56*(5), 307-311.

Jadcherla, S. R., Wang, M., Vijayapal, A. S., & Leuthner, S. R. (2010). Impact of prematurity and co-morbidities on feeding milestones in neonates: a retrospective study. *Journal of Perinatology*, *30*(3), 201-208.

Kirk, A. T., Alder, S. C., & King, J. D. (2007). Cue-based oral feeding clinical pathway results in earlier attainment of full oral feeding in premature infants. *Journal of Perinatology*, 27(9), 572.

Lagarde, M. L. J., van Alfen, N., de Groot, S. A. F., Geurts, A. C. H., & van den Engel-Hoek, L. (2019). Adaptive capacity of 2-to 5-month-old infants to the flow, shape, and flexibility of different teats during bottle feeding: a cross-sectional study. *BMC Pediatrics*, *19*(1), 477.

Lang, W. C., Buist, N. R., Geary, A., Buckley, S., Adams, E., Jones, A. C., ... & Rogers, B. R. (2011). Quantification of intraoral pressures during nutritive sucking: Methods with normal infants. *Dysphagia*, 26(3), 277-286.

Mathew, O. P. (1991). Breathing patterns of preterm infants during bottle feeding: role of milk flow. *The Journal of Pediatrics*, *119*(6), 960-965.

McGrattan, K. E., McFarland, D. H., Dean, J. C., Hill, E., White, D. R., & Martin-Harris, B. (2017). Effect of single-use, laser-cut, slow-flow nipples on respiration and milk ingestion in preterm infants. *American journal of speech-language pathology*, *26*(3), 832-839.

Mizuno, K., & Ueda, A. (2006). Changes in sucking performance from nonnutritive sucking to nutritive sucking during breast-and bottle-feeding. *Pediatric research*, *59*(5), 728-731.

Oder, A. L., Stalling, D. L., & Barlow, S. M. (2013). Short-term effects of pacifier texture on NNS in neurotypical infants. *International journal of Pediatrics*, *2013*. vol. 2013, Article ID 168459, 8 pages, 2013. https://doi.org/10.1155/2013/168459

Oommen, M.P. (1990). Determinants of Milk Flow Through Nipple Units. Role of Hole Size and Nipple Thickness. *American Journal of Diseases of Children, 144*, 222-224.

Pados, B. F., Park, J., Thoyre, S. M., Estrem, H., & Nix, W. B. (2015). Milk flow rates from bottle nipples used for feeding infants who are hospitalized. *American journal of speech-language pathology*, 24(4), 671-679.

Pados, B. F., Park, J., Thoyre, S. M., Estrem, H., & Nix, W. B. (2016). Milk flow rates from bottle nipples used after hospital discharge. *MCN. The American journal of maternal child nursing*, 41(4), 237.

Pados, B. F, Park J, Dodrill P (2018) Know the flow: milk flow rates from bottle nipples used in hospital and after discharge. *Advances in neonatal care* 19(1) 32-41.

Segami, Y., Mizuno, K., & Itabashi, K. (2013). Perioral movements and sucking pattern during bottle feeding with a novel, experimental teat are similar to breastfeeding. *Journal of Perinatology, 33,* 319-323. Doi: 10.1038/jp.2012.113.

Sheppard, J. J. (2008). Using motor learning approaches for treating swallowing and feeding disorders: A review. *Language, Speech, and Hearing Services in Schools*, 39(2), 227 – 236.

Steffe, J. F. (1996). *Rheological methods in food process engineering*. Freeman press. Michigan State University, East Lansing, USA.

Sunaric, S., Jovanovic, T., Spasic, A., Denic, M., & Kocic, G. (2016). Comparative Analysis of the Physicochemical Parameters of Breast Milk, Starter Formulas and Commercial Cow Milks in Serbia. *Acta Facultatis Medicae Naissensis,* 33 (2), 101-108. Doi: 10.1515/afmnai-2016-0011.

Thoyre, S., Park, J., Pados, B., & Hubbard, C. (2013). Developing a co-regulated, cue-based feeding practice: The critical role of assessment and reflection. *Journal of Neonatal Nursing*, 19(4), 139-148.

Zimmerman, E., & Barlow, S. M. (2008). Pacifier Stiffness Alters the Dynamics of the Suck Central Pattern Generator. Journal of Neonatal Nursing, 14(3), 79-86.

Zimmerman, E., Forlano, J., & Gouldstone, A. (2017). Not All Pacifiers are Created Equal: A Mechanical Examination of Pacifiers and their Influence on Suck Patterning. American Journal of Speech-Language Pathology, 26, 1202-1212

Table 1: Characteristics of teats measured

Teat Name	Recommended infant age	Nipple length	Teat classification
White Sepal ultra-slow flow	0-1 month infants with feeding difficulties	34mm	Preterm/medically fragile
Blue Sepal extra small nipple/extra slow flow	0-5 months or infants with difficulty coping with faster flow	33mm	Preterm/medically fragile
Blue Sepal small nipple/extra slow flow	0-5 months	37mm	Term
Green Sepal extra small nipple/slow flow	Specialist teat for thickened feeds	34mm	Specialised teat
Green Sepal small nipple/slow flow	0-5 months	37mm	Term

Figure 1: Hydrostatic pressure measurement

Figure 2: Mean flow rate of teats tested

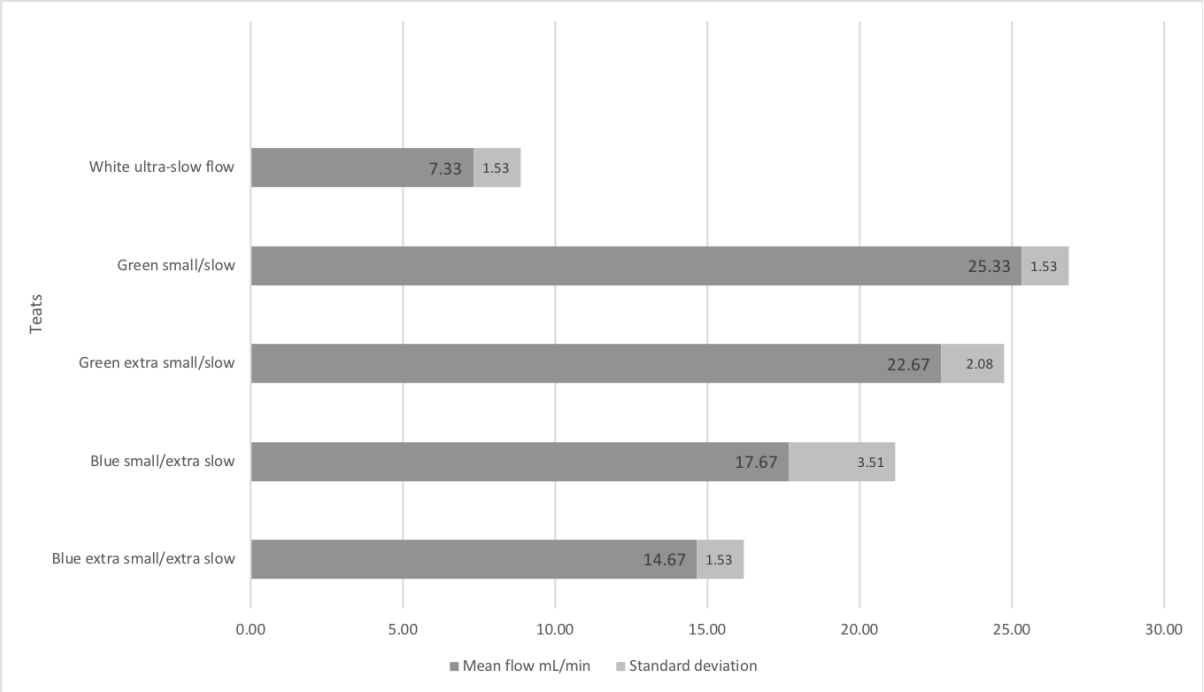

Figure 3: Coefficient of Variation