

VISCOSITY AND QUALITY OF IMAGES OF THICKENED LIQUID AFTER ADDING BARIUM CONTRAST FOR SWALLOW STUDIES

Viscosidade e qualidade da imagem do líquido espessado para videodefluoroscopia de deglutição com acréscimo do contraste de bário

Camila Ribeiro Gomide Queiroz ⁽¹⁾, Suely Prieto de Barros ⁽¹⁾, Hilton Coimbra Borgo ⁽¹⁾, Viviane Cristina de Castro Marino ⁽²⁾, Jeniffer de Cássia Rillo Dutka ⁽¹⁾

ABSTRACT

Purpose: study the viscosity of baby formula thickened at the swallow study after adding Barium. **Methods:** glasses with 200ml of formula were thickened to nectar, honey and pudding consistencies using seven different thickeners. Mean viscosity was verified with a viscometer at room temperature and after warming above 40°C and also after adding Barium contrast at concentrations of 50%, 25% and 12,5%. The prepared formula was exposed to fluoroscopy and the images were evaluated regarding visualization of the formula at different consistencies, concentrations of barium and thickeners. **Results:** when comparing mean centipoise (cps) measures the viscosity was significantly lower for the temperature above 40°C than room temperature. When Barium contrast was added to the formula thickened to nectar and to pudding consistencies a significant change into honey consistency was verified. There were no differences in quality of the images between the formula with Barium concentrations at 50% and 25%. **Conclusion:** significant changes in viscosity of nectar and pudding can occur after adding Barium to thickened baby formula. Reduction of Barium concentration to 25% did not result in significant changes in quality of images. Findings suggest importance of standardization of formula preparation for swallow studies regarding viscosity and concentration of Barium to assure consistency of the exam, prevent incorrect diagnose while optimizing orientation regarding diet modification in infant with dysphagia.

KEYWORDS: Deglutition; Deglutition Disorders; Barium; Viscosity; Fluoroscopy.

■ INTRODUCTION

Besides being important for explaining the presence of aspiration or micro aspiration¹, the study of swallowing using a radiological technique (Videodeglutogram or Videofluoroscopy of Swallowing) optimizes the identification of the safest way to feed a patient with dysphagia. The

exam often determines the need to supply the basic nutritional and necessary hydration through feeding alternatives that may involve the recommendation for changes in food consistency². Videofluoroscopy in Brazil requires the ingestion of food plus a Barium contrast in different consistencies permitting the evaluation of the oral and pharyngeal stages with greater effectiveness^{3,4}, with maximum accuracy in capturing^{2,5} and in the least time of exposure to radiation⁶. The contrast used during the exam is Barium sulfate (BaSO₄) at 100%. Its characteristics are those of an ideal radiological contrast with high radiological density, low viscosity, high fluidity, great stability and good adherence to mucosa. Use of the contrast permits a more precise and immediate visualization of the swallowing dynamic before,

⁽¹⁾ Hospital de Reabilitação de Anomalias Craniofaciais da Universidade de São Paulo, Bauru, SP, Brasil.

⁽²⁾ Faculdade de Filosofia e Ciências da Universidade Estadual Paulista, UNESP, Marília, SP, Brasil.

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during and after triggering the pharyngeal response. The bolus trajectory is visualized in real time and, thus, use of the contrast optimizes obtaining a high sensitivity and specificity exam in diagnosing tracheal aspiration⁴. And the exam is recorded for subsequent analysis^{2,4,7}.

Information from the videofluoroscopy plus that obtained from the clinical evaluation of swallowing is essential in investigating oral and pharyngeal dysphagia⁴. A care plan can be established based on the clinical and instrumental findings, including a nutritional plan that aims to avoid caloric-protein malnutrition, dehydration and aspiration pneumonia, translating the results obtained in the exams into nutritious, tasty foods that promote safe swallowing.

Thickening of liquids can promote safer swallowing, because with it the oropharyngeal transit time can be increased, creating more cohesive bolus, thus compensating some deficits in swallowing and reducing the risk of aspiration^{8,9}. The use of thickeners, in turn, alters food viscosity. This can be expressed in centipoises (cP)^{8,10} and it offers a physical correlation of consistency for a given preparation.

Scholars¹¹ observed that infant formulas dissolved with oat cereals revealed big changes in viscosity compared to formulas thickened with other types of thickeners. It was concluded that the use of different thickening agents can result in a big variation in food viscosity. This information reproduces the literature confirming that the type of thickening agent used affects the viscosity of the liquid in question. Due to the lack of standardization for modified diets incorporating thickening agents, the American Dietetic Association (ADA)¹², in 2002, established the National Dysphagia Diet (NDD), with a guide for thickened food supplements. The NDD proposes a viscosity index of thin (1-50cP), nectar (51-350cP), honey (351-1750cP) and pudding (>1750cP), thus creating a standardization^{13,14}.

During videofluoroscopy, selected foods are combined with the Barium contrast and the thickeners. One specific study¹⁵ suggested the need to standardize the consistencies tested during the videofluoroscopy with the consistencies indicated in the patients' nutritional treatment. Another study¹⁰ revealed it is possible to offer formulas with reproducible viscosities with and without the Barium contrast, in the radiological evaluation as well as the nutritional therapy, minimizing reproduction failures between evaluation and therapy.

Since videofluoroscopy uses ionizing radiation, it is necessary to optimize the technique adjusting consistency to a minimum amount of the Barium contrast, permitting a quality image, without interfering in food flavor and texture and in exposure time,

maintaining a safe dose of radiation¹⁶. A prior study¹⁷ revealed a significant difference in rheological parameters between the use of the liquid Barium contrast with thickened baby formula and with anti-reflux baby formula. Authors also reported that Barium mixed with foods alters its natural characteristics⁶. In the literature consulted, no standardization of viscosity was found in the formula offered to babies after adding the Barium contrast and thickening agents for videofluoroscopy^{10,14}.

In this study's clinical practice, in the videofluoroscopy exam run on babies with craniofacial anomalies and swallowing disorders, Barium (Bariogel 100%) diluted to 50% and a thickening agent available at the institution (brands may vary) were used. They were added to the milk used by the child or available at the institution. Standardizing the starting formula in relation to consistency and to the minimum amount of contrast to be used in videofluoroscopy is necessary to guarantee exam reproducibility and to control quality in terms of visualization of the food ingested during the exam. Use of the minimal amount of Barium possible can avoid changes in flavor and texture of the preparation, optimizing baby collaboration during the exam. However, reducing the amount of Barium can affect the interpretation of images obtained during fluoroscopy leading to an increase in exposure time when new images need to be obtained or resulting in incorrect interpretations of the exam, in this case the penetration or aspiration of the preparation cannot be observed.

Considering that verifying the relation between Barium dilution and viscosity of the preparation used in the videofluoroscopy is essential for establishing the smallest quantity of contrast that can be administered during the exam, and considering that the caretakers should replicate the safest form of food presentation, this study was elaborated with the objectives: to study the viscosity of the thickened starting formula (milk) and to evaluate changes in preparation viscosity and in exam quality after adding the Barium contrast.

■ METHODS

This study was conducted at the USP Hospital for the Rehabilitation of Craniofacial Anomalies (HRAC/SP) with the approval of the Research Ethics Committee (protocol no. 376/2011 - SVAPEPE-CEP). This is a prospective study that involved the manipulation of seven brands of thickening agents, three amounts of Barium contrast and a starting baby formula at two temperatures for each of the three consistencies studied (Nectar=N, Honey=M, Pudding=P), as illustrated in Figure

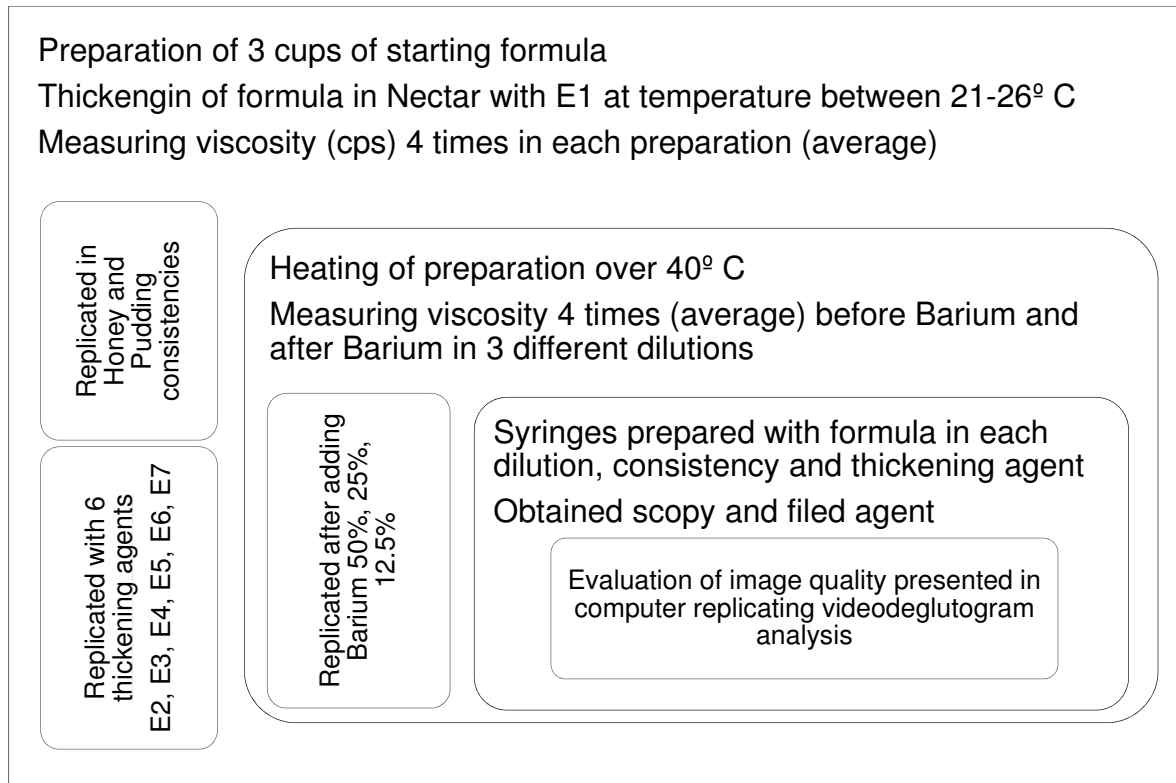


Figure 1 - Organizational chart of the experiment illustrating the preparation of 3 consistencies with 7 thickening agents (E1 - E7) and 3 Barium dilutions.

1. The thickening agents used and the selected starting formula are the products used in the videofluoroscopy on babies with cleft lip and palate and/or other associated anomalies that receive specialized care at the institution of origin.

During the videofluoroscopy exam conducted by a speech pathologist from the Speech Pathology Sector of this hospital, an amount of Barium contrast equal to the amount of formula (diluted to 50%, as used in other centers in the country) is used. This study evaluated the possibility to reduce the amount of Barium contrast added to the formula in the various viscosities and at two temperatures to avoid to the utmost any change in flavor of the milk offered the baby, but maintaining a visible image of the formula during the exam, without altering preparation consistency. The experiment was conducted using dilutions of 25% and 12.5% of contrast, besides the dilution routinely used at HRAC-USP, which is, 50%.

Seven brands of thickening agents were tested, named E1, E2, E3, E4, E5, E6 and E7. Composition E1, E3 and E7 was a modified starch base and maltodextrin; E2, E4 and E6 were only modified starch and E5 was xanthan gum. For each of these thickening agents, the test was run in triplicate, that is, three 200ml cups of starting

formula were prepared at 15% (170 ml of water with 30g of powder) at room temperature, which varied between 21°C and 26°C. Then, the thickening agent was added with teaspoons as the measuring unit for a nectar consistency in the three cups¹⁸. After 10 minutes, preparation viscosity was checked in the viscometer (Brookfield, model DV-E), according to the literature index¹². Four measurements of viscosity were made over an average period of 30 minutes after thickening to obtain average viscosity for each cup, because the milk is a non-Newtonian, time dependent and thixotropic liquid that tends to change viscosity during analysis.

After these markings, the preparations were heated in the microwave to a temperature over 40°C, verified with a thermometer. The measure of viscosity was conducted in minutes and the temperature checked again after final measurement. The same procedure was conducted for all consistencies (N, M, P) and all thickening agents (E1, E2, E3, E4, E5, E6, E7).

Finally, 100 ml of Barium contrast were added to 100 ml of milk (50%), 50 ml of Barium contrast to 150 ml of milk (25%), followed by 25 ml of Barium contrast to 175 ml of milk (12.5%), at the different consistencies (N, M, P) with viscosity measured again, this time only at temperatures over 40°C.

The preparations were then put in 10 ml syringes, identified in terms of thickening agent, Barium dilution and consistency used. The investigation did not involve exposure of beings and, the three syringes with the preparations at dilutions to 50% (a), 25% (b) and 12.5% (c) of Barium, at a same consistency and same thickening agent, were positioned temporarily in the radiology device's image intensifier. After identification and positioning, the syringes were irradiated and the images captured and recorded on DVD by the technician from the HRAC radiology section, under the supervision of the physician and speech pathologist responsible for the videofluoroscopy exams at the institution. Figure 2 illustrates the image obtained after syringe scopy with the preparation at the nectar (N) consistency obtained with thickening agent E1 at Barium dilutions to 50%, 25% and 12.5%. The same image was obtained at consistency N with 6 other thickening agents and the procedure repeated at consistencies M and P for each of the 7 thickening agents at the 3 dilutions. The filed images were presented on a computer screen, as used for interpretation of the videofluoroscopy, and two speech pathologists analyzed the images through visual inspection. Consensually, the speech pathologists indicated whether the preparations in the syringes were visible or not, and if, even visible, there was a difference in image quality among the three Barium dilutions (50%, 25% and 12.5%).

Average viscosity values in the three consistencies tested, at the two temperatures (room temperature and over 40 degrees) and with the seven brands of thickening agents were established

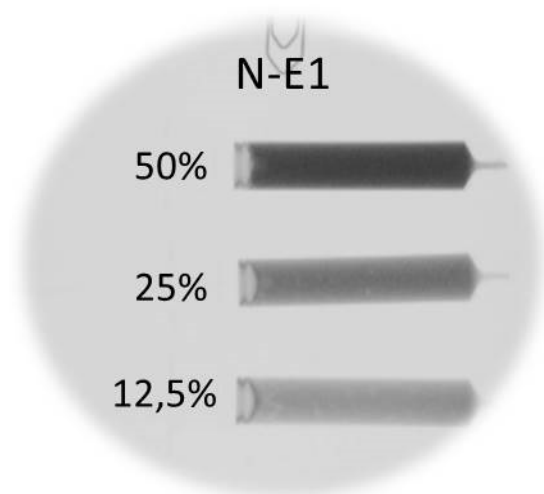


Figure 2 - Image of scopy of syringes positioned according to Barium dilution (50%, 25%, 12.5%) at Nectar consistency, with thickening agent 1 (E1)

and presented in graphs. The difference between the average viscosities at the room temperature and at the temperature over 40°C was shown on a table and compared using the Mann-Whitney statistical test ($p < 0.05$). Average viscosities for preparations at the three consistencies with and without Barium contrast at dilutions to 50%, 25% and 12.5%, at a temperature over 40°C, were calculated and shown on tables. The differences in viscosity between with and without Barium conditions and at the three dilutions were established using ADA values (2002)¹² indicating changes in consistency after adding Barium in tables. Speech pathology observations after analysis of syringe images were described in the text.

■ RESULTS

Figures 3, 4 and 5 show the average viscosity values for the three consistencies studied (N, M, P), respectively, with the seven thickening agents (E1, E2, E3, E4, E5, E6, E7) and at the two temperatures (ambient and over 40°C). For the majority of thickening agents there was a reduction in viscosity after heating in the three consistencies (as expected) with the exception of thickening agent E6 at the nectar consistency and E4 at the pudding consistency.

Table 1 demonstrates the reduction in viscosity in percentage, as the temperature increased in all conditions, with the exception of N-E6 and P-E4, when there was an increase in viscosity. Table 2 shows results from the Mann-Whitney test comparing median values in *centipoise* in the three consistencies, and two temperatures evaluated, observing that viscosity at the pudding consistency was significantly less at the temperature over 40 degrees than at room temperature.

Tables 3, 4 and 5 show average viscosities with and without Barium contrast in the three dilutions proposed, in the nectar, honey and pudding consistencies, respectively. For interpreting the changes in viscosity after adding Barium, the index suggested by the ADA (2002)¹² was used. It shows the minimum and maximum extension in centipoise (cP), where nectar is defined as liquids thickened between 51 and 350 cP; honey between 351 and 1750 cP and pudding over 1750 cP. Variations in desired consistency above the maximum value or below the minimum value were interpreted as significant changes since another substituted desired consistency. In the nectar and pudding consistencies, a variation in viscosity values suggests a change in consistency with some thickening agents, as indicated in the values in bold in Tables 3, 4 and 5. In the honey consistency, no clinically significant change was verified.

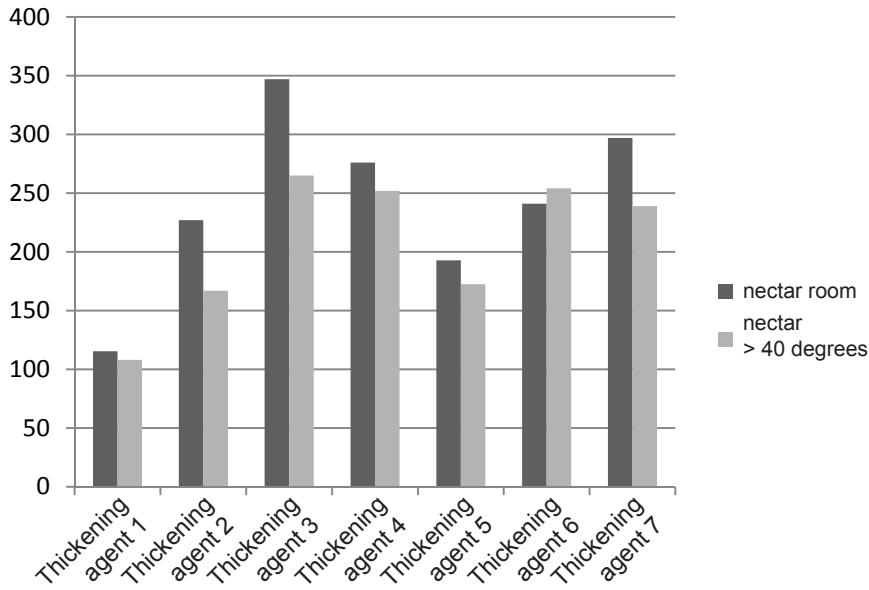


Figure 3 - Average values of viscosities in Nectar consistency at two tested temperatures (room temperature and over 40 degrees) with the seven brands of thickening agents

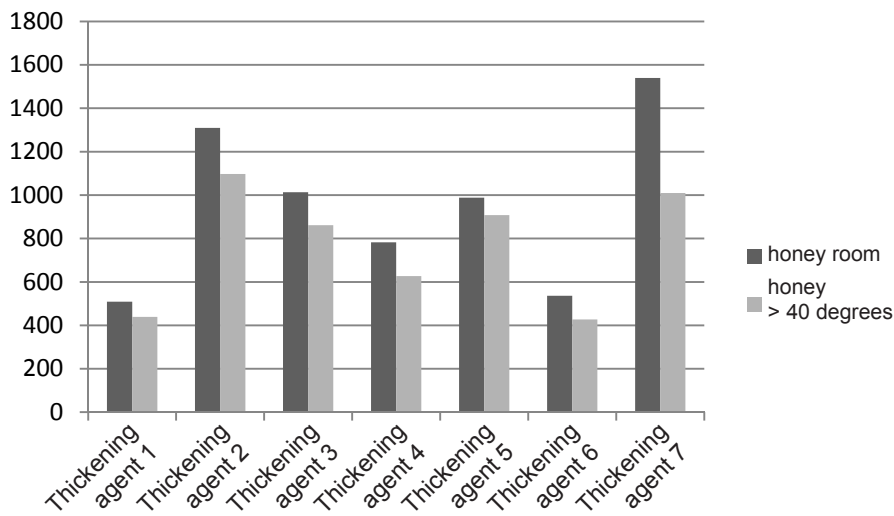


Figure 4 - Average values of viscosities in Honey consistency at two tested temperatures (room temperature and over 40 degrees) with the seven brands of thickening agents

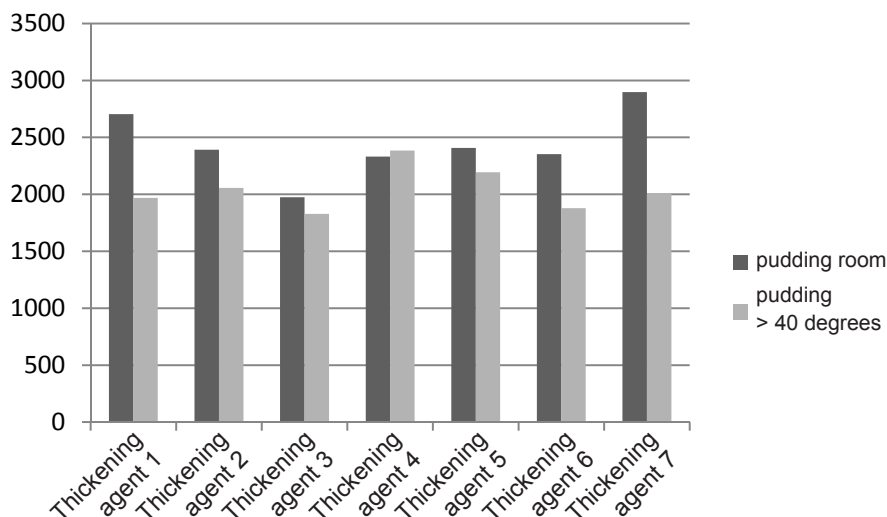


Figure 5 - Average values of viscosities in Pudding consistency at two tested temperatures (room temperature and over 40 degrees) with the seven brands of thickening agents

Table 1 - Variation of viscosity in percentage with the increase from room temperature to a temperature over 40°C with the seven thickening agents at the three consistencies

	Thickening Agent 1	Thickening Agent 2	Thickening Agent 3	Thickening Agent 4	Thickening Agent 5	Thickening Agent 6	Thickening Agent 7
Nectar	6%	26.40%	23.60%	8.70%	10.50%	5%*	19.50%
Honey	13.70%	16.20%	15%	20%	8.10%	20.20%	34.40%
Pudding	27.20%	14%	7%	2%*	8.80%	20.10%	30.50%

* The values illustrate the percentage reduction of viscosity after heating in all conditions except N-E6 and P-E4 when there was an increase in viscosity

Table 2 - Statistical comparison of average viscosities (cP) for the three consistencies at the two tested temperatures

	Room.Temp. Average	> 40° C Average	p Value
Nectar	240.9	238.9	0.383
Honey	987.9	861.5	0.383
Pudding	2391	2011.3	0.017*

Mann-Whitney Test

* p < 0.05

Table 3 - Average viscosity for the combined preparation at Nectar consistency with and without Barium contrast at 50%, 25% and 12.5% at a temperature over 40°C

NECTAR		Thickening Agent 1	Thickening Agent 2	Thickening Agent 3	Thickening Agent 4	Thickening Agent 5	Thickening Agent 6	Thickening Agent 7
Barium Contrast at 50%	W/O	106.75	113.5	161.5	284.5	268	315	309
	W/	634	794	974.5	383	366	335.25	542.75
Barium Contrast at 25%	W/O	107	118	176	319	242.5	347.5	319
	W/	214.25	181.5	225.75	443.5	273.75	375	381
Barium Contrast at 12.5%	W/O	105.5	99.75	120	329	229	373.75	315.25
	W/	255.75	158	220	490.5	256.5	431.25	369.5

Table 4 - Average viscosity for the combined preparation at Honey consistency with and without Barium contrast at 50%, 25% and 12.5% 40°C

HONEY		Thickening Agent 1	Thickening Agent 2	Thickening Agent 3	Thickening Agent 4	Thickening Agent 5	Thickening Agent 6	Thickening Agent 7
Barium Contrast at 50%	W/O	982.5	559	513	938	1084	850.5	913.5
	W/	707.25	830.25	1199	890	1085	570	809.75
Barium Contrast at 25%	W/O	647.75	730.5	638	1251	1042.5	810	1042.5
	W/	689.25	921.5	704	1296	970.5	947	989.5
Barium Contrast at 12.5%	W/O	470	981	476	1355.75	1208.5	1030	1117
	W/	440.5	1261	718	1334.25	1108.75	1027.5	1097.75

Table 5 - Average viscosity for the combined preparation at Pudding consistency with and without Barium contrast at 50%, 25% and 12.5% 40°C

PUDDING		Thickening Agent 1	Thickening Agent 2	Thickening Agent 3	Thickening Agent 4	Thickening Agent 5	Thickening Agent 6	Thickening Agent 7
Barium Contrast at 50%	W/O	1850.5	2275.5	1801.5	2577.75	2338.5	2007.5	2214
	W/	2078	2854	2329.25	1330	1981.75	1027.25	1445
Barium Contrast at 25%	W/O	1867	2230.75	2123	2532.5	2089.25	2170.25	2273.5
	W/	2013.5	1830	2155	2011.5	1956	1330.25	2112
Barium Contrast at 12.5%	W/O	2428.5	2445.75	2010.5	2225.25	2294.25	2191.5	1890.75
	W/	1710.5	1835.25	1947.5	2355.5	2125.25	1788.5	1386.25

After analysis of the syringe images in the various conditions established, the speech pathologists indicated that the visualization of the preparations diluted to 25% was very similar to that observed with the dilution at 50%. With the dilution at 12.5%, it was also possible to visualize the preparation, however, there was difficulty due to image quality (lighter tone), as reported by the speech pathologists.

■ DISCUSSION

Despite the frequent number of studies showing the importance of videofluoroscopy in studying swallowing^{4,5,10,14,17,19} the literature is limited to studies showing the standardization of the amount of Barium contrast added to baby formula used in these exams in babies. In several countries, there is already a standardization of Barium at diverse consistencies for foods used in exams on adults. The amount of Barium is important for obtaining good image resolution during scopy, but it could affect food flavor and viscosity^{10,14,15,17} This study shows viscosity values for a thickened starting formula (milk) at nectar, honey and pudding consistencies, at two temperatures and with seven thickening agents. The findings reveal there may be a change in viscosity values depending on temperature and

contrast concentration added to the milk used in the videofluoroscopy. Several factors may affect viscosity, including enzyme degradation and pH of foods, such as temperature and preparation¹⁹. One study²⁰, in particular, revealed there is a difference in food viscosity in the nectar and honey consistencies at different temperatures, proving the Arrhenius ratio, in which the increase in temperature generally causes suspensions of gelatinized starches leading to a decrease in viscosity, as in this study for the majority of thickening agents in the three consistencies. In general, the graphs in Figures 3, 4 and 5 show that, as there was an increase in temperature, viscosity decreased for most thickening agents studied. Only with thickening agent 6 at the nectar consistency (N-E6) and thickening agent 4 at the pudding consistency (P-E4) was there an increase of 5% and 2%, respectively, of viscosity with the increase in temperature. While the reduction in viscosity was expected, its increase goes against the Arrhenius ratio, since in N-E6 and P-E4 conditions, heating led to the swelling of granules of starch and they gelatinized more, differing from the expected.

Thickening agents available in Brazil (and, therefore, tested in this study) are mostly modified starch with or without the addition of maltodextrin,

where this addition may have the function of making them more stable. However, even with varied compositions (only modified starch, starch and maltodextrin, xanthan gum and maltodextrin) the tested thickening agents revealed variations in viscosity with an increase in temperature. Thickening agents E1, E3, E7 are modified starch and maltodextrin, the E2, E4 and 6 are only modified starch, and E5 is xanthan gum, the only one in the three consistencies to maintain a more constant variation in viscosity (ranging from 8.1% to 10.5%). Thickening agents E4 and E6 in this study, particularly, are made only with modified starch, without maltodextrin, and the unexpected findings of an increase in viscosity after an increase in temperature need to be better investigated in a study that allows greater control of the thickening agent composition.

In one study²¹, starch-based thickening agents were observed to have time-dependent behavior, because there is a decrease in viscosity between 1 and 4 hours after food preparation. Thickening agents with maltodextrin did not present any decrease in viscosity and the fluid becomes thicker 30 minutes after preparation. Thus, this type of thickening agent is considered more consistent and stable with time when compared to starch-based thickening agents. In another study¹⁷ thickened cow milk-based infant formula presented 1.3 times less viscosity when cooled naturally for 30 minutes. Another study²⁰ also reported that in 2% milk, thickening agents behave a little differently from other liquids tested (water and juice), because it contains fats that can interfere in starch granulation. As explained in the referred study, at low temperatures, the fat molecule is in its solid state and it can create blocks of space in the starch structure, swelling it less and reducing viscosity.

Table 2 shows the average viscosities in the three consistencies tested indicating statistical significance when comparing findings for the pudding consistency at the two temperatures. Although the increase in temperature causes a statistically significant reduction in viscosity in the pudding consistency, after heating the preparation, it still maintained the viscosity values within the extension stipulated in literature for the consistency in question¹². However, clinically, changes of up to 30% in viscosity with the change in temperature, as illustrated in Table 1, may require some care in preparing the recommended thickened diet, since the thickened liquids are part of a broad category, and that small changes in viscosity can cause changes in swallowing²².

With the addition of the Barium contrast, there was a significant increase in viscosity values for nectar, particularly for the dilution at 50%, changing

the consistency of the preparation for honey with all thickening agents, with the exception of E6. Even with the E6 thickening agent, the viscosity found was very near the maximum limit of 350 cP for the nectar category, which places the preparation with this thickening agent almost at a “*thin honey or thick nectar*” category. In the same dilutions of Barium, still in the nectar consistency, the changes in consistency occurred at a smaller number; however, always revealing an increase in viscosity, especially for E4, E6 and E7, at a dilution of 25% and 12.5%, where once again the preparation in nectar consistency became honey after adding Barium. When pudding consistency was tested, there was a sufficient reduction in viscosity to change the pudding to honey in thickening agents E4, E6 and E7 diluted at 50%, E6 diluted at 25% and E1 and E7 diluted at 12.5%. In other words, significant changes in thickened liquid consistency occur with the addition of Barium, especially diluted at 50%.

Seeking to reflect on the possibility of reducing Barium dilution in preparations for videofluoroscopy, images with the thickened liquid in various consistencies and dilutions were analyzed by two speech pathologists experienced in conducting the exam. There was no difficulty in visualizing the preparations with the Barium dilution at 25%; however, the professionals questioned whether the dilution at 12.5% could make the preparation resolution closer to the resolution of soft tissues, complicating the interpretation of the exam, particularly the identification of aspiration of small quantities of material. Considering that use of the contrast has the objective of optimizing exam interpretation, it is important to consider that reductions in Barium dilution should be studied by the team in charge of the exam, since various factors can affect the image obtained. For example, device age has a direct relation on image quality and certainly will affect the quantity of Barium used by a given team. Maintenance of thickened liquid consistency and adjustment of the best Barium dilution for a given machine can be optimized on a multidisciplinary team where the speech pathologist, the nutritionist, the physician and the radiology technician together assume the role of caring for exam quality and accuracy.

The findings of this study with the data reported in literature suggest the importance of specific care with the consistency of preparations for conducting the videofluoroscopy and for orienting caretakers, particularly after recommending modified diets. The elaboration of an instructions manual for thickening liquids with Barium can improve management of patients at risk for aspiration.

■ CONCLUSION

Analysis of findings reveal significant changes in preparing milk and Barium with the increase in nectar viscosity to the point of making it honey

and the reduction in viscosity from pudding also to honey. The most frequent changes were with Barium diluted to 50% and with some types of thickening agents. The images obtained diluting Barium to 25% provided similar quality to those obtained with the dilution at 50%.

RESUMO

Objetivos: estudar a viscosidade da fórmula de partida espessada para os exames de videofluoroscopia de deglutição após acréscimo de contraste de Bário. **Métodos:** copos de 200 ml de leite foram preparados em três consistências com sete espessantes. A viscosidade média foi verificada com viscosímetro nas temperaturas ambiente e acima de 40°C, e após acrescentar o contraste de Bário em diluições a 50%, 25% e 12,5%. Os preparados foram expostos à fluoroscopia para obtenção de imagens que foram avaliadas quanto à visualização do preparado nas diferentes consistências, diluições e espessantes. **Resultados:** comparando valores médios em *centipoise (cP)*, observou-se que a viscosidade na consistência pudim foi significativamente menor na temperatura acima de 40°C do que na temperatura ambiente. Nas consistências néctar e pudim o acréscimo de Bário resultou em mudança significativa da viscosidade para mel. Não houve mudança na qualidade das imagens entre as diluições de Bário à 50% e 25%. **Conclusão:** o acréscimo do Bário resulta em mudanças nos valores de viscosidade que afetaram a consistência do preparado espessado para néctar e pudim. Uma redução da diluição do contraste para 25% não resulta em mudança clinicamente significativa na qualidade da imagem. Os achados sugerem a importância da padronização do preparado para a fluoroscopia em relação à viscosidade e diluição do Bário visando garantir a reprodutibilidade do exame, prevenir falhas diagnósticas e otimizar as orientações para modificações da dieta na disfagia orofaríngea infantil.

DESCRIPTORIOS: Deglutição; Transtornos da Deglutição; Bário; Viscosidade; Fluoroscopia.

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Mailing address:

Camila Ribeiro Gomide Queiroz

Rua Sílvio Marchione 3-20

Bauru – SP – Brazil

CEP: 7012-900

E-mail: camilargqueiroz@gmail.com