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The behavior of lemon-based thickened fluids submitted to the IDDSI flow test as a strategy for dysphagia treatment

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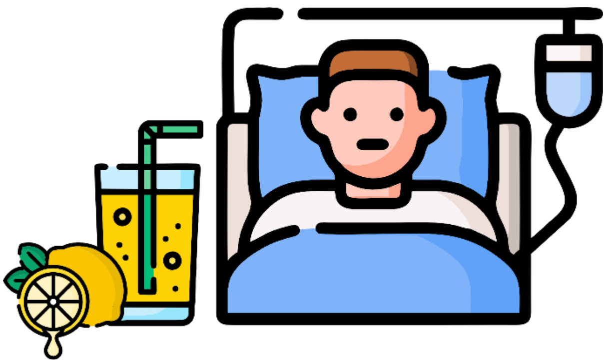
Abstract
Dysphagia is a health condition that causes swallowing difficulty, which may be treated by many techniques. Feeding modified foods should be a usual protocol for these individuals, as it will rarely be a diet of choice but a diet necessary to maintain a safe oral intake of nutrients. All people who suffer from changes in swallowing have difficulty in oral feeding, which compromises their nutritional status, mainly due to dehydration. Thickening of fluids is a well-established management strategy for oropharyngeal dysphagia. Thus, this research aimed to evaluate commercial lemon-based beverages (juices and flavored waters) with the addition of thickeners through the gravity flow test, according to the protocol established by the International Dysphagia Diet Standardization Initiative (IDDSI). Eight commercial beverage samples, categorized as flavored carbonated water (L01, L02, L03, L04), isotonic beverage (L05), liquid soft drink (L06) and powdered soft drink (L07 and L08), in addition to two thickeners based on xanthan gum were used. A 10 mL slide-tip syringe with a barrel length of 61.5 mm was employed for the flow test. Adding thickening agents to lemon-based beverages caused substantial changes in their rheological properties. Differences between samples and treatments were observed according to the type and amount of thickener. Samples L05 and L08 showed 8.55 and 8.05 mL retention in the syringe, respectively, classifying them as moderately thickened liquids, while the other samples were classified as slightly thickened liquids. The ideal treatment for the dysphagic patient aims to ensure a safe intake and a correct nutritional and water supply, in addition to the consequent improvement of the patient's general clinical condition. According to their nutritional profile, the inclusion of these beverages may be interesting in increasing some micronutrients such as sodium, potassium, calcium, phosphorus, and magnesium. The flow properties of lemon-based beverages can be a good option for patients with dysphagia when improved using low amounts of thickening agents to suit their diets.

Keywords: Swallowing disorder, IDDSI, thickened liquids, hypertension, beverages.

Graphical Abstract



Thickened lemon-based beverages may help treat dysphagia patients

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ROYALDATASET

1. Introduction

Dysphagia is a change in human swallowing, characterized by inadequate transit of the food bolus from the mouth to the stomach (Reber et al., 2019). The swallowing disorder can affect babies, the elderly, and individuals with neurological diseases, such as Parkinson's and cerebrovascular accident (CVA), among other pathologies (Bassi et al., 2014).

A recent study showed that there was a higher prevalence of perception of dysphagia in females (9.4%) and elderly individuals aged 80 years or older (12.6%) in a municipality in southern Rio Grande do Sul (Mello et al., 2021). In the study by Dias and Lombardi (2021), 100 older adults aged 60 to 90 years were evaluated in the city of Santos (Brazil), where 54% of this sample had some difficulty in swallowing, regardless of severity or frequency. According to Bassi et al. (2014), the incidence of dysphagia in patients after a stroke is 43 to 50%, even with speech therapy in the first 48 h. Furthermore, as described by Burgos et al. (2017), stroke patients are more likely to develop dehydration and malnutrition and have a higher risk of aspiration pneumonia and mortality.

In a way, dysphagia compromises the nutritional status, interfering with the patient's social interaction and the pleasure in food consumption (Bassi et al., 2014). In addition, relevant complications of dysphagia are reported through aspiration, characterized at the time of swallowing by the passage of food into the respiratory tract; it can be silent or manifested through coughing, aspiration pneumonia or malnutrition and dehydration (Burgos et al., 2017).

Body water corresponds to 60% of body weight and has many functions, such as regulating body temperature and absorbing shock, being a solvent for chemical reactions, and means of transporting and removing waste products (Reber et al., 2019). Dysphagia increases the risk of insufficient fluid intake. In the study by Streicher et al. (2018), 75% of individuals living in nursing homes showed signs of dehydration. Therefore, the consumption of thickened fluids is indicated to reduce the risk of aspiration, as the thickening promotes a longer duration of oral fluid conduction and allows more time for the closure of the upper airways to occur (Steele et al., 2015).

Given the above, the International Dysphagia Diet Standardization Initiative - IDDSI (https://iddsi.org), an organization composed of researchers from several countries, released a global standardized structure based on years of literature and research, universally using terminology to modify the texture of foods and the thickness of liquids for individuals with swallowing difficulties, through a formal and objective methodology considered safe (de Villiers et al., 2019). Thus, an eight-level diagram was proposed to classify beverages and foods according to their main flow properties (fluids and solids). Levels were identified by numbers, text labels and color codes through a quick and objective test aided by appropriate tools. Beverages are rated from 0 to 4 as follows: thin liquid (level 0), very slightly thickened (level 1), slightly thickened (level 2), moderately thickened (level 3) and extremely thickened (level 4). For moderately thickened and/or extremely thickened beverages, the drip test using a fork and spoon is recommended as a complementary method to determine consistency. The IDDSI selected this type of gravity flow test as its top recommended method for characterizing liquid flow because it is considered simple, inexpensive, and easily reproducible (Barbon & Steele, 2018).

The main strategy in treating dysphagia is to pay greater attention to swallowing, especially for liquids, avoiding early escape into the larynx through the use of foods with texture modified by thickenings, such as industrial products or domestic adaptations (Matsuo & Fujishima, 2020).

Dysphagia is a growing concern worldwide due to an aging population. Providing greater patient safety and evolution in dysphagia to promote better treatment outcomes is the main reason for the IDDSI recommendation for internationally standardized terminology. Simply following the manufacturer's guidelines when using non-aqueous thickening beverages can lead to discrepancies between the resulting and prescribed consistency. Therefore, it should be considered inappropriate to ensure safe swallowing. In addition, the type of thickener, the processing temperature and the conduction of the protocol, through the use of a syringe used to test the flow properties of the beverages, can affect the correct choice of food intended for people with dysphagia.

Thus, the present study aimed to evaluate commercial lemon-based beverages (juices and flavored waters) with the addition of thickeners through the gravity flow test, according to the protocol established by the IDDSI. These foods can be classified using this method, resulting in a table with information and standardized consistency characterization recommended by the International Dysphagia Diet Standardization Initiative.

2. Material and Methods

2.1 Materials

Eight samples of lemon-based beverages were acquired, plus two thickeners recommended for patients with dysphagia, both based on maltodextrin and xanthan gum, all commercially available (Madrid-Spain). Commercially available 10 mL BD-type syringes (Becton and Dickinson®), presenting a sliding tip with a barrel length of 61.5 mm, were used. The eight lemon-based drinks, which consisted of the thickened samples, were coded as flavored carbonated water (L01, L02, L03, L04), isotonic drink (L05), liquid ready-made soft drink (L06) and powdered soft drink (L07 and L08). In **Table 1**, it is possible to observe the list of beverage ingredients, as well as the two samples of thickeners.

Table 1 List of ingredients in lemon-based beverages

Samples	Classification	Ingredients
L01	Sparkling water	Carbonated water and natural aroma.
L02	Sparkling water	Carbonated water, lemon juice, natural flavoring, preservatives: potassium sorbate and sodium benzoate, sweeteners: aspartame (21 mg/100 mL) and acesulfame potassium (5 mg/100 mL), acidity regulator citric acid, calcium disodium EDTA sequestrant.
L03	Sparkling water	Carbonated water, clarified lemon juice concentrate, vitamins (niacin B3, calcium D- pantothenate B5, maltodextrin and pyridoxine hydrochloride B6), acidity regulator: malic acid and sodium citrate, flavorings, citric acid acidulant, preservatives: sodium benzoate sodium and potassium sorbate, stabilizers: gum arabic and ester gum, sweeteners: aspartame (31.5 mg/100 mL) and potassium acesulfame (8.1 mg/100 mL) and calcium disodium EDTA sequestrant.
L04	Sparkling water	Carbonated water, clarified lemon juice concentrate, vitamins (niacin B3, calcium D- pantothenate B5, maltodextrin and pyridoxine hydrochloride B6), flavoring, preservatives: sodium benzoate and potassium sorbate, acidulant citric acid, sweeteners: aspartame (21.5 mg/100 mL) and potassium acesulfame (5.3 mg/100 mL) and calcium disodium EDTA sequestrant.
L05	Isotonic	Water, sucrose, sodium chloride, sodium citrate, monopotassium phosphate, acidulant INS330, synthetic flavoring identical to natural lemon, preservatives INS 202 and INS211, antioxidant INS300 and artificial colors INS171 and tartrazine INS102.
L06	liquid refreshment	Water, concentrated lemon juice (1.0%), acidity regulators citric acid and sodium citrate, flavoring, sodium hexametaphosphate and calcium disodium EDTA scavengers, preservatives sodium benzoate and potassium sorbate, sweeteners acesulfame potassium, sucralose and sodium cyclamate and tartrazine artificial dye.
L07	soft drink powder	Sugar, maltodextrin, dehydrated lemon juice, vitamin C, zinc sulfate, vitamin D, citric acid acidulant, anti-wetting agent: tricalcium phosphate and silicon dioxide, aspartame (22 mg/100 mL), sodium cyclamate (16 mg/100 mL) acesulfame potassium (3.3 mg/100 mL) and sodium saccharin (1.6 mg/100 mL), acidity regulator sodium citrate, titanium dioxide and tartrazine and sparkling quaya extract.
L08	soft drink powder	Maltodextrin, vitamin C, dehydrated lemon juice, vitamin A, vitamin B6, vitamin B1, acidulant citric acid, acidity regulator sodium citrate, aspartame (44 mg/100 mL) and acesulfame potassium (5.6 g/100 mL) anti humectant: tricalcium phosphate and silicon dioxide, titanium dioxide and tartrazine.
ES.01	thickener	Maltodextrin, xanthan gum and guar gum.
ES.02	thickener	Maltodextrin, xanthan gum and potassium chloride.

2.2 Flow Test (IDDSI)

IDDSI test was used to classify the five levels of liquids according to gravity flow through a 10 mL syringe (https://iddsi.org/Food-Testing-Methods). The amount of liquid remaining after 10 s of flow was used to classify the thickness of the fluids using the detailed IDDSI structure descriptors: level 0 or liquid thin, level 1 or very slightly thickened, level 2 or slightly thickened, level 3 or moderately thickened and level 4 or extremely thick (IDDSI, 2019).

The samples were first evaluated in their original composition, without adding thickener, at room temperature (24 ± 1 °C). In a second step, the thickener was homogenized using a portable mixer (28003 – IKEA, China) for 1 min and then left to rest for 10 min until complete solubilization. There are differences in the homogenization of thickeners and beverages due to the dissolution rate in a solvent. The method briefly uses a portable blender, spraying the thickener, homogenizing for a few seconds, followed by rest for the flow test step (Rush, Bolland, & Gosa, 2021).

The temperature of food consumed in hospital environments and the mechanism of action of the thickener are crucial factors that affect sensory attributes (Cho & Yoo, 2015). For example, lemon-based beverages are refreshing drinks usually consumed under refrigeration temperatures. However, thickeners were added to beverages at room temperature (24 °C) to simulate industrial processes and storage conditions, which must be considered for patient safety and ease of swallowing.

Regarding thickeners, the manufacturer indicates the amount necessary to achieve adequate thickening (3.0 g for ES.01 and 2.4 g for ES.02 in a 200 mL portion). We emphasize that the manufacturer did not inform how long the preparation should rest after adding the thickener and complete solubilization; however, we established this time at 10 min, as it is adequate in the hospital and domestic environments (Maieves and Teixeira, 2021).

The syringe barrel was filled with fluid samples using another syringe to the 10 mL indication level with the syringe tip closed with a gloved finger to prevent leakage of fluid samples. The syringe was positioned perpendicular to the floor, and the finger closure was released. The fluid was allowed to flow for 10 s, and the tip of the syringe was closed again with a gloved finger after 10 s. The amount of liquid sample remaining in the syringe was measured, and its classification was given as follows: no content left, level 0; 1–4 mL, level 1; 4–8 mL, level 2; 8–10 mL, level 3. Syringes were not reused and were discarded after testing. Tests were performed in triplicate

The appearance was visually evaluated for 7 days, checking whether or not there were signs of deterioration during this period, such as discoloration on the surface of the food, appearance of liquids and unpleasant odor.

The methodology described by Assis and Leoni (2003) for the antifungal analysis was followed, which indicates the visual verification of colony formation during storage.

2.3 Characterization of Beverages

2.3.1 pH of beverages

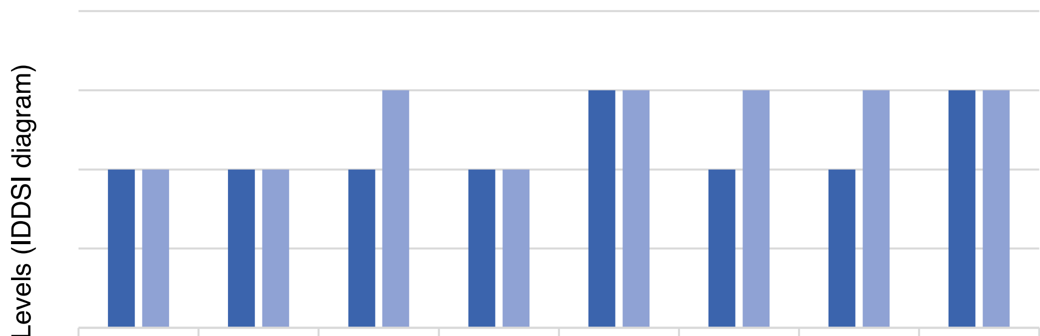
The pH was measured using a benchtop pHmeter (Gehaka, PG1800, Brazil) after proper calibration with buffer solutions (pH 4 and pH 7).

2.3.2 Nutritional survey of thickened beverages

The data contained in the nutritional tables of the beverages, as well as those contained in the thickeners, were used to further perform comparisons regarding their composition. After tabulation of the data, they were corrected to 200 mL plus the amounts of thickeners. Thus, according to the addition of thickener, the obtained result was added to the values of carbohydrates, sugars, dietary fibers and minerals (sodium, potassium, calcium, phosphorus and magnesium).

3 Results and Discussion

The results of the IDDSI flow test for each lemon-based beverage are reported in **Fig. 1**. The data were reported at the level according to the diagram proposed by the IDDSI (**Fig. 2**) after observing the milliliter content in the syringe body after 10 sec. Temperature generally affects the rheological properties of drinks, especially thick ones (Cho & Yoo, 2015; de Villiers et al., 2019). Therefore, room temperature close to 24 °C has been reported as the ideal temperature for evaluating thickened fluids in the IDDSI test because they have fewer lumps, thus facilitating their classification (de Villiers et al., 2019). All original samples, *i.e.*, without adding a thickening agent, showed level 0 (not shown) after 10 s of syringe flow.



	L01	L02	L03	L04	L05	L06	L07	L08
ES.01	2	2	2	2	3	2	2	3
ES.02	2	2	3	2	3	3	3	3

Fig. 1 Viscosity of lemon-based thickened fluids according to the flow test (IDDSI).

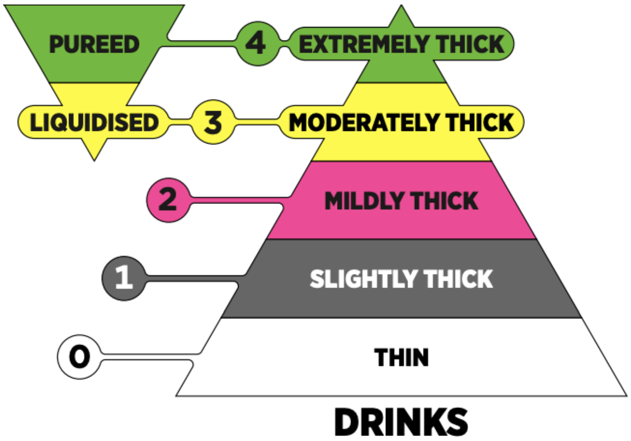


Fig. 2 Classification of drinks according to the levels obtained by the IDDSI flow test. Source: IDDSI Framework 2.0 (2020) - http://iddsi.org

Adding thickening agents to lemon-based beverages caused substantial changes in their rheological properties. Differences between samples and treatments were observed according to the type and amount of thickener (**Table 2**). For example, adding 3.0 g/200 mL of ES.01 thickener caused 8.55 and 8.05 mL retention in the syringe in samples L05 and L08, respectively, classifying them as moderately thickened liquids, while the other samples were classified as slightly thickened liquids.

On the other hand, the addition of 2.4 g/200 mL thickening agent ES.02 based on maltodextrin, xanthan gum and potassium chloride for samples L03, L06 and L07 resulted in different flow levels when compared to the use of thickener ES.01 based on maltodextrin, xanthan gum and guar gum, classifying them as moderately thickened liquids (level 3).

Table 2 Content of macro and micronutrients after addition of thickening agents (ES.01 and ES.02) in lemon-based beverages.

Samples	EV (kcal)	CHO (g/200 mL)	Sugars (g/200 mL)	Dietary Fiber (g/200 mL)	Na (mg/200 mL)	K (mg/200 mL)	Ca (mg/200 mL)	P (mg/200 mL)	Mg (mg/200 mL)
ES.01									
L01	36	1.7	0.1	0.8	52.2	0.08	0.6	1.5	0.6
L02	36	1.7	0.1	0.8	56	0.08	0.6	1.5	0.6
L03	41	1.7	0.1	0.8	152	0.08	0.6	1.5	0.6
L04	36	1.7	0.1	0.8	79	0.08	0.6	1.5	0.6
L05	88	14.7	13.1	0.8	137	24.08	0.6	1.5	0.6
L06	36	1.7	0.1	0.8	119	0.08	0.6	1.5	0.6
L07	48	3.9	2.2	0.8	66	0.08	0.6	1.5	0.6
L08	41	1.7	0.1	0.8	76	0.08	0.6	1.5	0.6
ES.02									
L01	31	1.5	0.0	0.6	32	9.6	0	0	0
L02	31	1.5	0.0	0.6	36	9.6	0	0	0
L03	36	1.5	0.0	0.6	132	9.6	0	0	0
L04	31	1.5	0.0	0.6	59	9.6	0	0	0
L05	83	14.5	13.0	0.6	117	33.6	0	0	0
L06	31	1.5	0.0	0.6	99	9.6	0	0	0
L07	43	3.7	2.1	0.6	46	9.6	0	0	0
L08	36	1.5	0.0	0.6	56	9.6	0	0	0

EV, energy value; CHO, carbohydrates; Na, sodium; K, potassium; Ca, calcium, P, phosphorus; Mg, magnesium.

Possibly, we can associate the hypothesis that potassium chloride present in the ES.01-based samples is the main driver of the thickening of lemon-based beverages, as more than 62.5% of the samples are moderately thickened. At the same time, the thickener ES.01, with guar gum as the primary thickening agent, presented 75% of the samples classified at level 2. This observation can be raised since the two thickeners have maltodextrin and xanthan gum in both commercial samples.

Undoubtedly, the composition of the beverages also influenced the levels obtained, as different thickeners and levels revealed at least 2 IDDSI levels. This means that the added thickener content for these drinks must be adjusted according to the speech therapist's recommendation for the texture of the drinks. In addition, there were two levels for the same product for different thickeners but with the same measurement (different gravimetry) for a given consistency (information on the label, according to the manufacturer).

Not surprisingly, variations in thickening technique can lead to considerable variability in the resulting consistency, depending on the type and amount of thickener used, adherence to recipe instructions, mixing method (spoon, fork, or handheld blender, for example), temperature, and the setting time allowed between the mixture and the portion of the product (Cichero et al., 2000). Moreover, individual caregivers, including speech therapists, exhibit an alarming degree of inter-individual variability in the amounts of thickener used to achieve a given range of consistency (Glassburn & Deem, 1998). Despite the theoretical simplicity of adding a thickening agent to a liquid to avoid compromising the airway during swallowing, successful clinical implementation of this compensatory strategy has proven to be challenging (Rush et al., 2021).

Fig. 3 shows that the liquids had very similar pH in their thickened state, except sample L01 (pH = 7). According to Lavoisier, Boudrag and Ramaioli (2021), food with a lower pH is relevant for individuals with difficulty in swallowing, such as dysphagia, especially for those who need more time to conduct food in the oral cavity, particularly for more than 5 s. In their study, Moriel et al. (2010) evaluated the use of a starch-based thickener (not indicated for beverages due to the interference in flavor and color) and found that such thickener can reduce the viscosity when they come into contact with saliva; this occurs due to the salivary alpha-amylase enzyme, responsible for breaking down starch granules.

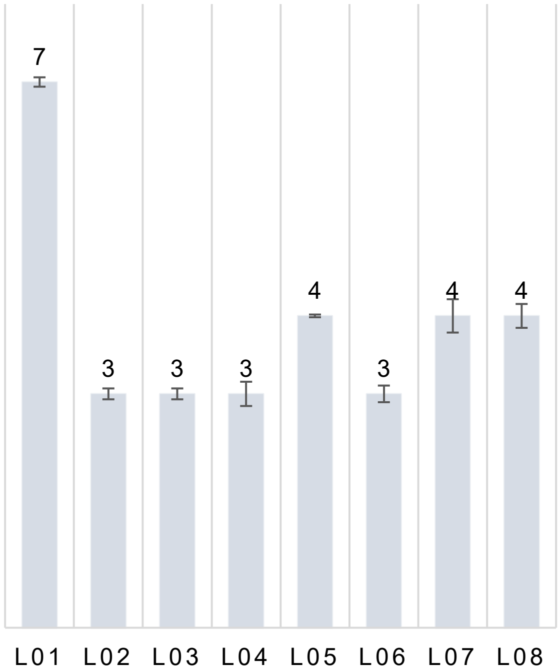


Fig. 3 pH readings obtained in different lemon-based beverages.

In this study, it was possible to observe that water thickened with corn starch had a viscosity reduction of 80% after 5 s of contact with saliva. However, in lemon (pH = 2.7) and orange (pH = 4) juices thickened with corn starch at IDDSI level 3, there was no reduction in shear viscosity. Thus, it is noticeable that the action of the alpha-amylase enzyme was inhibited in beverages with lower pH. This is due to the fact that the ideal pH for alpha-amylase to act is between 6 and 7. Therefore, at pH 4, its action is reduced by half, and at pH near 3.5, its activity is inhibited.

Barbon and Steele (2018) used four different concentrations of the same xanthan gum-based thickener (ES.02) used here to increase the viscosity properties of commercial flavored water (lemon flavoring). In addition to the flow test (IDDSI), the authors performed the line propagation test, the Bostwick consistometer test, and shear-controlled rheometry to illustrate the differences. Food thickeners containing gums are not susceptible to digestion by salivary amylase and provide a stable viscosity (Lee et al., 2016), indicating that food thickeners containing gums are more suitable thickeners, explaining the choices used in this study.

Gum-based and starch-based thickeners differ in the way they absorb water. A starch-based thickener swells, while a gum-based thickener creates a net that traps water in hydration. Dewar and Joyce (2006) report that the viscosity of the maltodextrin-based thickener increases 30 min after preparation, which is why the reading took place in 10 min, with consumption being encouraged in this first 30 min. The time of 10-30 min is considered reasonable for beverages prepared at the beginning of a meal (Garcia et al., 2005); however, for convenience, the best situation is that the preparation has an unchanged viscosity for a longer time.

The provision of modified foods should be a usual protocol for these individuals, as it will rarely be a diet of choice but a necessary diet to maintain a safe oral intake of nutrients. All people who suffer from swallowing disorders have difficulty in oral feeding, which compromises their nutritional status, mainly due to dehydration (Thibault et al., 2011).

The ideal treatment for the dysphagic patient aims to ensure a safe intake and a correct nutritional and water supply, in addition to the consequent improvement of the patient's general clinical condition. The inclusion of these drinks, according to their nutritional profile, may increase some micronutrients and caloric value. In **Table 2**, it is possible to observe the profile in energy value (kcal), in addition to carbohydrates, sugars, dietary fiber, and the minerals sodium (Na), potassium (K), calcium (Ca), phosphorus (P) and magnesium (Mg).

Despite the samples being categorized between flavored and carbonated waters, isotonic drinks and liquid and reconstituted refreshments (in powder form) are not the best options due to the high content of sugars and additives in some samples (**Table 1**). However, dehydration is a prevalent condition in individuals with dysphagia, including those affected by cerebral palsy, since they are unable to communicate the feeling of thirst and drink autonomously, depending on others to offer them fluids. In addition, many dysphagic patients are resistant to water (Sura et al., 2012). Therefore, the consequences of low water intake are severe since water is essential for correct intestinal, kidney and liver functioning and constipation due to polymedication. Some solutions to minimize this problem include flavoring water with lemon or orange (Santos et al., 2011) or even offering these drinks, especially flavored waters, and isotonic drinks.

In hypertensive people with kidney problems and cardiovascular diseases, micronutrients such as sodium should be avoided. As water has oligo-elements in its composition, it deserves attention concerning the mineral sodium since the eight samples, when thickened, presented values between 32 and 152 mg for a 200 mL portion. There was also an increase in the content of potassium, chlorine, calcium, phosphorus, and magnesium in the composition of the beverages after the change in consistency. Although the amount of sodium found in the supply of the thickened liquid is not high, this addition can compromise the total mineral intake under severe or moderate restrictions. Thus, this value should always be included in the general diet, considering the restriction minimum of 5 g of sodium chloride, *i.e.*, 2,000 mg of sodium per day (Loyolla et al., 2022). Therefore, the value of sodium added to the thickener should not be analyzed isolatedly but considering the total sodium intake throughout the day, always maintaining the patient's oral safety.

4 Conclusion

The flow properties of lemon-based beverages evaluated using the IDDSI protocol can be a good option for patients with dysphagia when improved using low amounts of thickening agents to suit their diets. Flavored waters, except for sample L01, may be suitable options, as they are refreshing drinks with low pH. Adopting easy-to-access flow tests, such as the one based on the use of BD-type syringes proposed by the IDDSI, may be an alternative method to evaluate these beverages in hospital environments, offering beverages more safely. Even if thickened, encouraging the consumption of beverages is essential for the recovery of the patient's health and stands out as an element of comfort and quality.

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Authors' Contributions
H.A.M. Conceptualization; data curation; investigation; methodology; writing – original draft; writing - proofreading and editing.
B.V.S. methodology; data curation, writing - original draft. ME. data curation; essay - original draft. U.R.C. methodology; formal analysis; essay - original draft. F.B.L. methodology; formal analysis; essay - original draft. A.N.L. methodology; formal analysis; essay - original draft. J.P.H. methodology; formal analysis; essay - original draft.

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Ethics approval and consent to participate.
Not applicable.

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Informed Consent Statement
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Conflicts of Interest
The authors declare that they have no conflict of interest.

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