Mechanical and rheological categorization of food patterns suitable for older adults with swallowing limitation

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ABSTRACT
The improvement in the nutritional status of older adults with swallowing limitations, as could happen in Alzheimer’s, has prompted modified-texture food design, including thick liquids that reduce the risk of aspiration. National Dysphagia Diet and the International Dysphagia Diet Standardization Initiative classified food accordingly with dysphagia severity level by literature sources without considering preparation and service conditions. The rheological and mechanical behavior of 34 liquid, 35 semisolid, and solid food commonly included in elderly menus was categorized by dysphagia severity level, considering preparation conditions and evaluation at service temperature. Data were fitted to the Power Law and Herschel-Bulkley models. Rheological behavior found thixotropic and pseudoplastic fluids in the range of 0.13 < n < 0.69; 0.48 < K < 62081, without elastic limit. Solid and semisolid food were classified by hardness as 4-pureed (H ≤ 15000), 5-Minced & moist, and 6-Soft & bite-sized (15000 ≤ H ≤ 40000), 7-Regular-Easy to chew (H > 40000). Analyzing the rheological and mechanical behavior attributes allowed the categorization by type of dysphagia. Outcomes for food with individualized attributes are useful for older adult caregivers at home and in professional clinical care, emphasizing people with cognitive impairment, including Alzheimer’s.

Introduction
Global trends evidenced the elderly population increase. By 2050, one in six people will be 65 and over, being expected 1.5 billion older people and 426 million people over 80 years old with a prominent level of vulnerability. Sustainable global goals, particularly zero hunger and good health & well-being, prompt new strategies to enhance the nutritional status and feeding experience even when physiological and mental limitations stand along with longevity. Recently, improving nutritional conditions of the elderly with swallowing limitations has promoted texture-modified foods and thickened liquids, which can reduce the risk of aspiration. People with Alzheimer’s disease, a degenerative neuronal disease associated with impaired cognitive learning and memory function, show limitations that interfere with daily activities; essential bodily functions such as walking; and swallowing until the person becomes dysfunctional. Swallowing is a process by which solid and liquid foods are transported by motor sequences, voluntary and involuntary, with a succession of central and peripheral neurological components responsible for transporting the already minced food from the cavity mouth to the stomach.

Swallowing involves four phases: (1) Oral preparation stage; voluntary muscles get food ready by chewing and mixing with saliva; (2) Oral phase; voluntary muscles rise the tongue and push the bolus toward the back; (3) Pharyngeal phase; involuntary muscles elevate soft palate, closure of the vocal cords and muscular movement of the pharynx toward the hypopharynx with the opening of the cricopharyngeal sphincter; (4) Esophageal phase; involuntary muscles, occurs with the relaxation of
the cricopharyngeal sphincter allowing the passage of food from the pharynx to the esophagus, entering the lower esophageal sphincter which leads to the stomach. In one or more stages of the swallowing process, dysphagia disorder was related to the severity of Alzheimer’s disease. 

The relation between Alzheimer’s, dysphagia, food, and nutrition has been interdisciplinary studied in recent years. Between 50% and 75% of older adults with Alzheimer’s present symptoms of dysphagia, which were associated with the deterioration of cognitive and motor functions. Consequently, swallowing problems were associated with malnutrition, aspiration pneumonia, and increased morbidity and mortality. 

Thus, thickened liquids and modified-texture foods have frequently solved swallowing problems. Thickened liquids refer to products such as water or thickened milk, which improve food and saliva transit during swallowing of the oral and pharyngeal phase by slowing down, promoting better coordination, making a cohesive bolus without breaking into many drops moving safely to the esophagus; hence rheological behavior characterization is essential. Modified-texture foods are products with a solid or soft solid consistency that requires low chewing during oral processing, such as puree.

Two indicators have traditionally categorized swallowing problems. One in North America, where the National Dysphagia Diet (NDD) classified by viscosity (η) acceptable liquids (0–50 mPa.s), nectar-like liquids (51–350 mPa.s), honey-like liquids (351–1750 mPa.s), and thick liquids or pudding (η > 1750 mPa.s), at a shear rate of 50 s⁻¹, which was questioned because thickened liquids for dysphagia show non-Newtonian behavior.

For the second indicator, the International Dysphagia Diet Standardization Initiative (IDDSI) developed the globally standardized terminology and definitions for textured modified food and thickened liquids in all care settings and cultures for people with dysphagia. Table 1 shows the descriptors at five levels for the rheology of liquids and six levels for foods with a modified texture that the IDDSI proposed, together with the texture analysis profile carried out by Matsuo & Fujishima. On the other hand, recent studies reveal the importance of defining the rheological and mechanical properties of liquid, semisolid, and solid foods according to the severity of dysphagia to maintain safe swallowing.

Preview research also confirmed the lack of nutritional status in thickened liquids and modified-texture food consumers. Few researchers have studied food service operation, production, and portion size associated with thickened liquids and modified-texture food for older adults in professional clinical and home care. On the other hand, consuming thickened liquids and modified-texture food requires nutritional considerations to promote healthy aging.

According to USDA, food patterns were developed to help individuals carry out the dietary guideline’s recommendations, identifying daily amounts of foods in nutrients-dense forms to eat from five major food groups and their subgroups. Therefore, it is interesting to quantify and correlate the foods’ rheological and mechanical characteristics by dysphagia severity levels to design foods suitable for older adults with Alzheimer’s or other cognitive impairments. Thus, this research

| Descriptor according to IDDSI for liquids | Viscosity defined by NDD (shear rate 50 s⁻¹) |
|------------------------------------------|---------------------------------------------|
| 0-Thin                                   | 0–2 mPa.s                                   |
| 1-Slightly thick                         | 3–50 mPa.s                                  |
| 2-Mildly thick                           | 51–350 mPa.s                                |
| 3-Moderately thick                       | 351–1750 mPa.s                              |
| 4-Extremely thick                        | 1751 mPa.s – from then on                   |

| Descriptor according to IDDSI for solid and semisolid | Analysis of texture profile (Hardness, cohesiveness, and adhesiveness) |
|-------------------------------------------------------|-----------------------------------------------------------------------|
| 3-Liquidized                                          | Matsuo & Fujishima                                                     |
| 4-Pureed                                              | Hardness (N/m²) 0–12000, Cohesiveness 0.2–0.7, Adhesiveness (J/m³) ≤ 300 |
| 5-Minced & moist                                      | Hardness (N/m²) ≤ 15000, Cohesiveness 0.2–0.9, Adhesiveness (J/m³) ≤ 1000 |
| 6-Soft & bite-sized                                   | Hardness (N/m²) ≤ 400000, Cohesiveness 0–1.0, Adhesiveness (J/m³) ≤ 1000 |
| 7-Easy to chew, regular                              | Hardness (N/m²) > 400000, Cohesiveness 0–1.0, Adhesiveness (J/m³) > 1000 |

Table 1. Level of thickening and texture descriptors for liquid, semisolid, and solid foods.
aimed to determine the parameters range for rheological and textural behavior of liquid, semisolid, and solid foods daily consumed under-controlled conditions of preparation and evaluation, which can be categorized according to dysphagia severity level. Categorizing the rheological and mechanical behavior of daily meals is essential to supply food with individualized attributes depending on swallowing limitations as a valuable tool for caregivers at home and in the professional clinical care of older adults with mental and physical limitations, including Alzheimer’s.

Methodology

Foods patterns selection

Liquid, semisolid, and solid foods were selected as suggested patterns for the elderly, highlighting nutritional recommendations to design dishes easy to prepare, with sizes adapted to the intake considering the food preferences around the world. The consumption of traditional preparations by the elderly has been associated with a healthier diet, better ability to exercise memory, and enhanced self-identity fundamental in socialization processes. Foods selected conquer the following expectations: 1) Commonly consumed by older adults with swallowing limitations; 2) Easily prepared under standard kitchen conditions with basic culinary techniques; 3) Availability at local supermarkets as traditional food; 4) A large variety of foods in order to obtain a wide range of rheological and textural properties, to be categorized according to dysphagia severity described by IDDSI, NDD, and Matsuo & Fujishima.

Food sample preparation

Patterns selected included 34 liquid foods and 35 semisolid and solid foods, elaborated with raw materials acquired at the local market and prepared by basic cooking techniques according to Rombauer et al. Sautéing, boiling, simmering, grilling, stewing, roasting. Cooking was performed by an induction heating plate (JAVA Bogotá, Colombia), with heating power between 300 W and 1700 W depending on stainless steel pan size. A food mincer with knife blades (HC3000 Black & Decker, China) acquiring pure consistency. A desiccator with silica gel pearls (SIMAX, Czech Republic) was used to maintain an 11% of relative humidity (RH) condition simulating a dehydration process due to environmental aging. Total soluble solids as saccharose were assessed by a digital refractometer and expressed as °Brix, (Saitama, Japan). Moisture was evaluated by AOAC method 950.46 using an oven (Binder oven, Germany); pH evaluation was achieved by a SevenCompact pH-meter S220 (Mettler Toledo Columbus, Ohio, USA). Food patterns were performed in triplicate at temperature service, suggested by several authors at 60°C for soups and hot beverages; juices, compote, and pure were evaluated at 20°C.

Liquid food patterns preparation detail: The 34 liquid food patterns obtained were clear, thick, and very thick, according to Table 1. Table 2 included preparation detail of the 34 liquid food patterns. Semisolid and solid food patterns preparation detail: The 35 semisolid and solid food patterns were elaborated as puree type, minced & moist, and soft & bite-sized preparations according to attributes described in Table 1. Table 3 include preparation detail of the 35 semisolid and solid food patterns.

Rheological measurements

Two methodologies evaluated the rheological behavior of food patterns. The first one with a dynamic viscosity with a digital rotational viscometer (RVDVII Brookfield Middleboro, Massachusetts, USA) with a variable strain range between 0.5 and 100 RPM. Each apparent viscosity at 50 s⁻¹ was obtained from the flow curve adjusted by K and n, besides rotational evaluation by viscosimeter. The second evaluated flow behavior under the action of a regular force with a rheometer (Anton Paar GmbH, Austria), with a strain range between 0 and 100 S⁻¹. A Peltier heating system was adapted to maintain
Table 2. Liquid food patterns preparation detail.

| Food patterns | Liquid food patterns preparation detail |
|---------------|-----------------------------------------|
| Chicken (Solanum tuberosum L) | Chicken broth |
| Bean (Phaseolus vulgaris L) | Traditional bean soup |
| Carrot (Daucus carota) | Carrot blended soup |
| Lentil (Lens culinaris) | Lentil broth |
| Mango (Mangifera indica) | Mango Pulp |
| Papaya (Carica papaya) | Papaya Pulp |
| Hot cocoa beverage | Hot cocoa beverage with lactose-free milk (75 g/ 200 ml) |
| Pumpkin (Cucurbita moschata) | Pumpkin soup |
| Tomato (Solanum lycopersicum) with onion (Allium cepa) and olive oil | Minced stew of tomato with onion and olive oil |
| White corn (Zea mays) | White corn soup |

| Liquid food patterns preparation detail | |
|----------------------------------------|--|
| Chicken broth | Chicken soup with minced chicken breast and potato |
| Traditional bean soup | Minced bean soup |
| Carrot blended soup | Carrot blended soup reconstituted 1:0.5 (pulp: water) |
| Lentil broth | Lentil soup added with potato |
| Mango Pulp | Reconstituted juice of mango at 1:1, 1:2, and 1:3 (pulp: water) |
| Papaya Pulp | Reconstituted juice of papaya at 1:1, 1:2, and 1:3 (pulp: water) |
| Hot cocoa beverage with lactose-free milk (75 g/ 200 ml) | Hot cocoa beverage with lactose-free milk and micronized cornstarch (1%, 2% and 3% w/w) |
| Pumpkin soup | Pumpkin soup with micronized cornstarch (1% and 2% w/w) |
| Minced stew of tomato with onion and olive oil | |
| White corn soup | Reconstituted white corn soup 1:0.5 (pulp: milk) |

The rheological behavior of fluid patterns was determined by modeling the relationship between viscosity (η, mPa.s) and shear stress (σ, mPa) versus shear rate (γ, s⁻¹), considering a possible elastic limit σ₀ that corresponds to the effort necessary to initiate the flow; the consistency index K (mPa.s); and the flow behavior index, n. [38] Newtonian fluids behavior was observed when σ₀ is zero and n is 1.0, following Eq. (1) [13]

$$\sigma = \eta \cdot \gamma$$  \hspace{1cm} (1)

The data were adjusted to the power-law model for non-Newtonian fluids by Eq. (2), including pseudoplastic fluids (n < 1), when lower apparent viscosities appeared at increasing shearing strain rate and diluting fluids (n > 1), when higher apparent viscosities appeared at increasing share rate (See Figure 1). Herschel-Bulkley model adjusted data for fluids with σ₀ by Eq. (3) and described some pseudoplastic fluids with an elastic limit (σ₀ > 0). [13]

$$\sigma = \sigma_0 + K \cdot \gamma^n$$  \hspace{1cm} (2)

$$\sigma = K \cdot \gamma^n$$  \hspace{1cm} (3)

Instrumental texture profile analysis evaluation

The texture profile was evaluated with a TAXT Plus texture analyzer for semisolid and solid samples by Texture Profile Analysis (Stable Micro Systems Ltd., Surrey, England) and processed with Texture Exceed software. The TPA (Texture Profile Analysis) texture tests were differentiated and set by probes,
Table 3. Semisolid and solid food patterns preparation detail.

| Food patterns                  | Semisolid and solid food patterns preparation detail |
|--------------------------------|------------------------------------------------------|
| Sweet cornbread                | Sauteing with butter at three mix conditions 1: 1, 1: 2, and 1: 3 (flour: water) |
| Tuna (Thunnus)                 | Tuna<br>Tuna Minced                                  |
| Pumpkin (Cucurbita moschata)   | Simmering in water for 20, 25, 30, and 35 minutes until the consistency of puree |
| Mango (Mangifera indica)       | Raw and pure                                         |
| Papaya (Carica papaya)         | Raw and pure                                         |
| Avocado (Persea americana)     | Raw and pure                                         |
| Banana (Musa × paradisiaca)    | Raw and pure                                         |
| Pumpkin (Cucurbita moschata)   | Pumpkin soup with micronized cornstarch (1% and 2% w/w) |
| Cornbread and cornbread with cheese | Sauteing with butter for 2, 4, 6, and 8 minutes |
| Broad beans (Vicia faba)       | Simmering in water for 15, 20, and 25 minutes until the consistency of puree |
| Squash (Sechium edule)         | Simmering in water for 20, 25, and 30 minutes until the consistency of puree |
| Caramel flan                   | Treatments 1: 1, 1: 2, 1: 3, 1: 4, and 1:5 (commercial powder: lactose-free milk) |
| Yellow cassava (Arracacia xanthorrhiza) | Simmering in water for 25, 30, and 35 minutes and minced until pure consistency |
| Sweet peas (Pismus sativum)    | Simmering in water for 15, 20, and 25 minutes and minced until pure consistency |
| Tapioca (Manihot esculenta)    | Simmering in water for 20, 25, 30, and 35 minutes until consistency of puree |
| Yellow potato (Solanum phureja) | Simmering in water for 15, 20, and 25 minutes and minced until pure consistency |
| Potato (Solanum tuberosum L)   | Grilled chicken breast with olive oil for 15 and 20 minutes |
| Chicken breast                 | Chicken breast simmering in water for 30 minutes up to internal cooking temperature of 74°C<br>Minced chicken breast simmering in water for 30 minutes up to internal cooking temperature of 74°C and crushed until pure consistency |
| Brazilian cheese bread         | Three dehydration treatments of 0, 20, and 30 minutes under controlled condition of 11% RH |
| Fresh cheese                   | Fresh cheese<br>Minced fresh cheese                |
| Sweet corn parcels             | Sweet corn parcels                                   |
| Pearl barley (Hordeum vulgare) | Simmering in water for 20, 30, and 40 minutes and minced until pure consistency |
| Beans (Phaseolus vulgaris)     | Simmering in water for 60, 70, and 80 minutes and minced until pure consistency |
| Chicken egg                    | Boiled, scrambled, and poached, each one under four cooking treatments 3, 6, 9, and 12 minutes |
| Agar-agar                      | At addition ratio of 1: 1, 1: 2, 1: 3, 1: 4, 1: 5, and 1: 6 (Agar powder: Water). |
| Oat flakes (Avena sativa)      | At addition ratio of 1: 1, 1: 2, 1: 3, 2: 1, 2: 2, and 2: 3 (Water; oat flakes) |
| Gelatin                        | Three treatments 1: 1, 1: 2, and 1: 3 (Unflavored gelatin powder: water) |
| Flavored Jelly                 | Three treatments 1: 1, 1: 2, and 1: 3 (Jelly powder: water) |
| White polished rice (Oryza sativa) | Simmering in water for 10, 15, 20, and 25 minutes |
| Wheat short pasta              | Simmering in water for 10, 15, 20, and 25 minutes |
| Sweet corn (Zeá mays)          | Simmering in water for 5, 10, 15, and 20 minutes |
| Whole meal loaf                | Roasted for 1, 2, and 3 minutes                       |
| Fresh cubic pieces of carrot   | Hydration up to 20, 60, and 90 minutes, under controlled condition of 11% RH |
| (Daucus carota)                | Simmering in water for 25, 30, 35, and 40 minutes and minced until pure consistency |
| Lentil (Lens culinaris)        | Simmering in water for 40, 60, and 70 minutes        |
| Ripe banana (Musa balbisiana)  | Simmering in water 10, 15, 20, and 25 minutes and minced until pure consistency<br>Sauteing for 2, 3, 4 minutes with sunflower oil |
| Green banana                   | Simmering in water 40, 50, 60, and 70 minutes Sauteing for 1, 3, 4, and 5 minutes with sunflower oil |

considering the maximum limit response of 6 N for a load cell of 5 Kg. The test setup was established with a cylindrical aluminum probe (P25, 25 mm diameter, 0.0019 m²) for firmness lower than 23285 N/m² and a cylindrical probe (P10, 10 mm diameter, 0.0003 m²) for firmness higher than 106060 N/m². Software displayed force (gf) data per each sample evaluated. Responses were standardized through the effort measurement by N/m², in the way that the final response integrated probes size and response force; pretest speed 2 mm/s; test speed 3 mm/s; posttest speed 5 mm/s; deformation distance 4 mm; the time between cycles of 5 s; and firing force of 25 g. Pattern samples were cut using a stainless-steel cylindrical cutter 2.54 cm diameter y 3 cm height. The texture parameters calculated by TPA were hardness (H), which is the peak of maximum force, cohesiveness (C) applying Eq. (4), elasticity (E) Eq. (5), adhesiveness (A) Eq. (6),...
adhesive force (FA) Eq. (7), gumminess (G) Eq. (8), chewiness (CH) Eq. (9), following equations proposed by Singh et al.,[40]

\[
C = \frac{\text{Area}2}{\text{Area}1} \quad (4)
\]

\[
E = \frac{\text{Distance}2}{\text{Distance}1} \quad (5)
\]

\[
A = \text{Area}3 \quad (6)
\]

\[
FA = -1 \times \text{Peak Negative} \quad (7)
\]

\[
G = H \times C \quad (8)
\]

\[
CH = G \times E \quad (9)
\]

**Food pattern categorization**

Liquid food patterns were pre-categorized according to the apparent viscosity range (mPa.s), at a shear rate of 50 s\(^{-1}\), and the descriptors according to IDDSI level with the syringe flow test\(^{[17]}\) (Table 1). After that, homogeneous subsets were grouped by flow behavior (Newtonian- (NF) or non-Newtonian - (NNF); responses to shear speed (pseudoplastic- (PsF), dilatant- (DF), plastic- (PLF)); behavior over time (Thixotropic- (TF) or rheopectic- (RF)). Solid and semisolid foods were categorized, mainly by firmness in (N/m\(^2\)), following the descriptors proposed for the IDDSI and the ranges presented by Matsuo & Fujishima\(^{[18]}\) (Table 1). The data were correlated with dysphagia severity level following Gallego et al.,\(^{[41]}\) as shown in Tables 4 and 5.

**Statistical analysis**

A completely randomized design was applied to compare rheological responses for 26 simple liquid food preparations, and texture responses for 35 semisolid and solid preparations.\(^{[42]}\) All evaluations were done by triplicate. Starch and pectin additions were analyzed as a single-factor nested design.\(^{[43]}\) Texture responses and rheological data were analyzed by ANOVA and Fisher’s tests (\(\alpha = 0.05\)). T-test or ANOVA followed by Fisher test established significant differences among thickeners and minced
Table 4. Relation among type of dysphagia, severity levels and food consistency recommended.

| Dysphagia Level | Food Consistency | Slight | Moderate | Moderate severe | Severe |
|-----------------|------------------|--------|----------|-----------------|-------|
| Preparatory oral dysphagia | Semisolids/ solids Liquids | Easy to chew, regular (7) | Soft & bite-sized (6); Minced & moist (5) | Soft & bite-sized (6); Minced & moist (5) | Pureed (4) |
| Oral phase dysphagia | Semisolids/ solids Liquids | Slightly thick (1); Mildly thick (2) | Slightly thick (1); Mildly thick (2); Moderately thick (3) | Moderately thick (3) | Extremely thick (4) |
| Pharyngeal phase dysphagia | Semisolids/ solids Liquids | Solid foods not recommended | Solid foods not recommended | Solid foods not recommended | Solid foods not recommended |
| Esophageal phase dysphagia | Semisolids/ solids Liquids | Pureed (4) | Solid foods not recommended | Thin (0) | Thin (0) |

Note: The numbers in parentheses indicate the thickenings levels according to IDDSI (IDDSI, 2019). Information about food recommendation was adapted from (Gallego et al., 2022).

Table 5. Categorization outcome considering food thickening level and dysphagia severity level. IDDSI, the International Dysphagia Diet Standardization Initiative, *IDDSI, 2019; **Gallego et al. [41].

| Food thickening level IDDSI* | Dysphagia severity level** | Liquid foods resulting category |
|-----------------------------|---------------------------|--------------------------------|
| Thin (0)                    | Esophageal phase dysphagia level moderate severe and severe | 1                              |
| Slightly thick (1); Mildly thick (2) | Preparatory oral dysphagia level slight and moderate Oral phase dysphagia level moderate severe and severe Pharyngeal phase dysphagia level slight and severe | 2                              |
| Moderately thick (3)        | Preparatory oral dysphagia level moderate and moderate severe Oral phase dysphagia level slight and moderate Pharyngeal phase dysphagia level slight and severe Esophageal phase dysphagia level slight and moderate | 3                              |
| Extremely thick (4)         | Preparatory oral dysphagia level severe Pharyngeal phase dysphagia level moderate and moderate severe | 4                              |

| Texture IDDSI* | Dysphagia severity level ** | Semisolid and solid foods category |
|----------------|----------------------------|-----------------------------------|
| Pureed (4) | Preparatory oral dysphagia level severe Oral phase dysphagia level moderate severe Esophageal phase dysphagia level moderate | 1                              |
| Soft & bite-sized (6); Minced & moist (5) | Oral phase dysphagia level moderate severe Esophageal phase dysphagia level slight and moderate | 2                              |
| Easy to chew, regular (7) | Oral phase dysphagia level slight y moderate Esophageal phase dysphagia level slight | 3                              |

effects. The correlation among evaluated variables was performed by Pearson coefficient analysis (P ≤ .01) by Minitab v.21.1.0 (Minitab INC, USA). The solver tool using Microsoft Excel software (Microsoft 365, USA) allowed model adjustment. The regression method solver performed the goodness-of-fit test by Minitab v.21.1.0 (Minitab INC, USA).
Table 6. Food patterns categorization by rheological behavior associated with dysphagia severity level and IDDSI classification. Color per road indicates level of thickening according to Table 8. η at 50s⁻¹(mPa.s), apparent viscosity. K, consistency index (mPa.s), n Flow index. M, moisture wet base (%) after cooking treatment. Data corresponds to average of n = 3 per pattern. Letters indicate significant difference (p < .05) by Fisher Test per type of preparation. S. T., Service temperature. NN F, Non-Newtonian Fluid, Ps F, pseudoplastic fluid, TF Thixotropic fluid. *Gallego et al., [41] **RIPD, Recommended intake per day; calorie level of pattern for a diet of 2000 calories[21].

| Liquid food patterns | Ingredients | S. T. (°C) | IDDSI evaluation (ml/10s)* /η at 50 s⁻¹(mPa.s) | Rheological behavior of flow | Dysphagia Level* |
|----------------------|-------------|------------|---------------------------------------------|-----------------------------|------------------|
| Chicken Broth        | Broth made: |           | K=1.14 a                                   |                             | 1                |
|                      | Water 66.4% | 60         | (0; 0 ml) / 0.18± 0.39                     |                             |                  |
|                      | 26.56%      |            |                                             |                             |                  |
|                      | Salt 0.39%  |            |                                             |                             |                  |
| Chicken broth and chicken mince soup | Same ingredient proportion at chicken broth (water, potato, chicken, and salt) 60 | K=118 b                                   |                             | 2                |
| RIPD**               | 2 cups; 500 g 25 Calories | n=0.35 a                                   |                             |                  |
|                      |                     | NN F, Ps F                                    |                             |                  |
|                      |                     | TF                                            |                             |                  |
|                      |                     | Mwb Potato 73.70%                             |                             |                  |
|                      |                     | Mwb Chicken 65.70%                            |                             |                  |
| Chicken broth and chicken mince soup | Same ingredient proportion at chicken broth (water, potato, chicken, and salt) 60 | K=930 a                                   |                             | 2                |
| RIPD**               | 2 cups; 500 g 155 Calories | n=0.35 a                                   |                             |                  |
|                      |                     | NN F, Ps F                                    |                             |                  |
|                      |                     | TF                                            |                             |                  |
|                      |                     | Mwb Carrot 90.10%                             |                             |                  |
|                      |                     | Mwb banana 78%                                |                             |                  |
|                      |                     | Mwb Red beans 62.45%                          |                             |                  |
| Traditional bean soup | Same ingredient proportion at traditional bean soup (water, carrot, banana, red beans, and salt) minced 60 | K=2306 b                                   |                             | 4                |
| RIPD**               | ½ cup; 160 g 86 Calories | n=0.42 b                                   |                             |                  |
|                      |                     | NN F, Ps F                                    |                             |                  |
|                      |                     | TF                                            |                             |                  |
|                      |                     | Mwb Carrot 90.10%                             |                             |                  |
|                      |                     | Mwb banana 78%                                |                             |                  |
|                      |                     | Mwb Red beans 62.45%                          |                             |                  |

(Continued)
| Table 6. (Continued). |
|-----------------------|
| **Carrot blended soup** | **K=395^b** |
| Salt | 99.67% |
| (3; 8.9 ml) / 387± | 60 |
| 7.09 | 0.33% |
| **RIPD** | **n=0.30^a** |
| 1 ½ cup; 400 g | NN F, Ps F |
| 190 Calories | TF |
| Carrot blended soup reconstituted 1:0.5 | Mwb Carrot 90.10% |
| Same ingredient proportion at carrot blended soup (carrot and salt) + | **K=31^a** |
| 60 | **n=0.50^b** |
| (2; 5.3 ml) / 189± | NN F, Ps F |
| 38.39 | TF |
| 55.30% | Mwb Carrot 90.10% |
| **Lentil broth** | **K=0.57^a** |
| 62.64% | **n=0.65^b** |
| 14.23% | NN F, Ps F |
| (0; 0 ml) / 0.16± | TF |
| 0.32 | Mwb Lentil: 63.15% |
| 22.78% | Mwb Potato: 73.70% |
| Sal | 0.34% |
| **Minced lentil soup added with potato** | **K=73^b** |
| Same ingredient proportion at lentil broth (water, lentil, potato, and salt) | **n=0.42^a** |
| 60 | NN F, Ps F |
| (1; 1.8 ml) / 40± | TF |
| 6.02 | Mwb Lentil: 63.15% |
| 1 | Mwb Potato: 73.70% |
| **Mango Pulp** | **K=199^d** |
| 100% | **n=0.30^b** |
| 20 | NN F, Ps F, TF |
| (3; 9 ml) / 1132± | Mwb Mango 83.72% |
| 121.54 | 20 | **RIPD** |
| **Mango pulp and reconstituted juice** | **K=113^c** |
| **Reconstituted mango pulp 1:1** | **n=0.26^e** |
| 45.34% | NN F, Ps F |
| 20 | TF |
| (2; 6.2 ml) / 232± | °Brix 15 |
| 42 | pH 4 |
| Sugar | 45.60% | **RIPD** |
| 1 ½ cup; 400 g | 232 Calories | (Continued) |
Table 6. (Continued).

| Reconstituted mango pulp 1:2 |  |  | 
|-----------------------------|---|---|---|
| **RIPD** | 1 ½ cup; 400 g | 200 Calories |  
| Sugar | 31.14% | 20 | (2; 6 ml) / 81± 8.18 |  
| K=19<sup>b</sup> |  
| n=0.40<sup>b</sup> |  
| NN F, Ps F TF |  
| °Brix 12 |  
| pH 4 |  

| Reconstituted mango pulp 1:3 |  |  | 
|-----------------------------|---|---|---|
| **RIPD** | 1 ½ cup; 400 g | 198 Calories |  
| Sugar | 23.71% | 20 | (1; 1.9 ml) / 37± 8.58 |  
| K=5<sup>a</sup> |  
| n = 0.54<sup>a</sup> |  
| NN F, Ps F TF |  
| °Brix 10 |  
| pH 5 |  

| Papaya Pulp |  |  | 
|-----------|---|---|---|
| **RIPD** | 1 ½ cup; 400 g | 156 Calories |  
| Sugar | 100% | 20 | (3; 8.5 ml) / 1209± 49.66 |  
| K=860<sup>c</sup> |  
| n=0.17<sup>bc</sup> |  
| NN F, Ps F TF |  
| Mwb Papaya 85.13% |  

| Reconstituted papaya pulp 1:1 |  |  | 
|-----------------------------|---|---|---|
| **RIPD** | 1 ½ cup; 400 g | 228 Calories |  
| Sugar | 45.45% | 20 | (2; 4.6 ml) / 299± 44.88 |  
| K=50<sup>b</sup> |  
| n=0.42<sup>b</sup> |  
| NN F, Ps F TF |  
| °Brix 15 |  
| pH 6 |  

| Reconstituted papaya pulp 1:2 |  |  | 
|-----------------------------|---|---|---|
| **RIPD** | 1 ½ cup; 400 g | 200 Calories |  
| Sugar | 31.25% | 20 | (2; 4.5 ml) / 95± 8.73 |  
| K=14<sup>a</sup> |  
| n=0.43<sup>a</sup> |  
| NN F, Ps F TF |  
| °Brix 13 |  
| pH 6 |  

| Reconstituted papaya pulp 1:3 |  |  | 
|-----------------------------|---|---|---|
| **RIPD** | 1 ½ cup; 400 g | 192 Calories |  
| Sugar | 23.81% | 20 | (1; 2.8 ml) / 25.14± 3.33 |  
| K=9.6<sup>a</sup> |  
| n=0.47<sup>a</sup> |  
| NN F, Ps F TF |  
| °Brix 10 |  
| pH 6 |  

(Continued)
| Mango compote °Brix 65, pH 3; Pectin in different proportions | 0.1 % | 29.98% | (3; 8.8 ml) / 1148± 51 | K=1202a |
|---|---|---|---|---|
| **RIPD** | Sugar | 9.99% | 20 | n=0.26a |
| 1 cup; 200 g | Citric Ac. | 49.98% | | NN F, Ps F |
| 166 Calories | | | | TF |
| 0.5 % | 29.92% | (4; 10 ml) / 1902± 80.88 | K=2344b |
| **RIPD** | Sugar | 9.95% | 20 | n=0.27a |
| 1 cup; 200 g | Citric Ac. | 49.88% | | NN F, Ps F |
| 162 Calories | | | | TF |
| 1% | 29.86% | (4; 10 ml) / 2048± 80.51 | K=44142c |
| **RIPD** | Sugar | 9.90% | 20 | n=0.23a |
| 1 cup; 200 g | Citric Ac. | 49.77% | | NN F, Ps F |
| 160 Calories | | | | TF |
| 2% | 29.70% | (4; 10 ml) / 2308± 105.77 | K=5967d |
| **RIPD** | Sugar | 9.78% | 20 | n=0.26a |
| 1 cup; 200 g | Citric Ac. | 49.50% | | NN F, Ps F, TF |
| 158 Calories | | | | |
| 0.1% | 10% | (3; 8.9 ml) / 1738± 43.09 | K=1483a |
| **RIPD** | Sugar | 6.66% | 20 | n=0.35a |
| 1 cup; 200 g | Citric Ac. | 83.33% | | NN F, Ps F |
| 148 Calories | | | | TF |
| 0.5% | 9.9% | (4; 10 ml) / 2517.37± 58.68 | K=1515b |
| **RIPD** | Sugar | 6.66% | 20 | n=0.37a |
| 1 cup; 200 g | Citric Ac. | 83.28% | | NN F, Ps F |
| 148 Calories | | | | TF |
| 1% | 9.98% | (4; 10 ml) / 2846.75± 119.87 | K=1520b |
| **RIPD** | Sugar | 6.65% | 20 | n=0.33a |
| 1 cup; 200 g | Citric Ac. | 83.21% | | NN F, Ps F |
| 145 Calories | | | | TF |

(Continued)
| Hot cocoa beverage with lactose-free milk | Weight/Volume | Calories | Total Carbohydrate | % RDI* | K | n  | Notes |
|-----------------------------------------|---------------|---------|-------------------|--------|----|----|-------|
| Micronized cornstarch (1%)              | 2 cups; 500 g  | 330     | 2%                | 1.291% | K=8.9 | n=0.36 | NN F, Ps F, TF |
| RIPv**                                  | 2 cups; 500 g  | 336     | 2%                | 1.278% | K=78 | n=0.36 | NN F, Ps F, TF |
| Micronized cornstarch (3%)              | 2 cups; 500 g  | 344     | 2%                | 1.266% | K=420 | n=0.38 | NN F, Ps F, TF |
| No micronized cornstarch                | 1 cup; 200 g   | 143     | 2%                | 1.04%  | K=0.61 | n=0.70 | NN F, Ps F, TF |
| RIPv**                                  | 2 cups; 500 g  | 314     | 2%                | 1.394% | K=62081 | n=0.32 | NN F, Ps F, TF |

*Note: RDI values and other nutritional information are approximate and may vary depending on the specific product and preparation method.

(Continued)
Table 6. (Continued).

| Micronized cornstarch | No micronized cornstarch | K = 22<sup>a</sup> |
|-----------------------|--------------------------|-------------------|
| 1 ½ cup; 400 g       | 33.16%                   | 208 Calories      |
| 180 Calories         | 66.33%                   |                   |
| Salt 0.49%           | (2; 4.4 ml) / 308±       | 57.68             |
|                       |                         |                   |
| Micronized cornstarch (1%) | 32.84%               | K = 111<sup>b</sup> |
| 1 ½ cup; 400 g       | 65.68%                   | 208 Calories      |
| 208 Calories         | 0.49%                    |                   |
| Salt 0.49%           | (3; 9 ml) / 712±        | 22.74             |
|                       |                         |                   |
| Micronized cornstarch (2%) | 32.52%               | K = 161<sup>b</sup> |
| 1 ½ cup; 400 g       | 65.04%                   | 224 Calories      |
| 224 Calories         | 0.48%                    |                   |
| Salt 0.48%           | (3; 9 ml) / 1668±       | 84.18             |
|                       |                         |                   |
| Minced stew           | 70.6%                    | K = 203<sup>3</sup> |
| 1 ½ cup; 400 g       | 28.24%                   | 292 Calories      |
| 292 Calories         | 0.70%                    |                   |
| Olive oil 0.70%      | (3; 9.2 ml) / 730±      | 82.86             |
| Salt 0.42%           |                         |                   |
|                       |                         |                   |
| White corn soup       | 33.11%                   | K = 7451<sup>b</sup> |
| ½ cup; 160 g         | 33.1%                    | 128 Calories      |
| 128 Calories         | 50                       |                   |
| Sugar 33.1%          | (2; 6.7 ml) / 223.17±   | 17.08             |
| Cinnamon 0.66%       |                         |                   |
|                       |                         |                   |
| Reconstituted white corn soup 1:0.5 | 33.1% | K = 106<sup>b</sup> |
| ½ cup; 160 g         | 50                       | 186 Calories      |
| 186 Calories         | Same ingredient proportion at white corn soup (white corn, sugar, and cinnamon) | 23.57±             |
|                       | + 50                     | 11.77             |

* The evaluation was performed by syringe flow test according to IDDSI testing methods.
| Liquid food patterns                              | Fitted line plots                                                                 | Type of fluid/Regression equation | PF at 50 S⁻¹ |
|-------------------------------------------------|------------------------------------------------------------------------------------|-----------------------------------|--------------|
| Chicken Broth                                   | ![Chicken Broth](image)                                                            | Pseudoplastic                      | 0.78 mPa*s   |
|                                                 | ![Fitted line plot](image)                                                         | $\sigma = 1.14 \cdot \dot{\gamma}^{0.54}$ | 98.52 %      |
|                                                 |                                                                                   | R-sq determination coefficient     | 98.34 %      |
|                                                 |                                                                                   | R-sq (Adj) determination coefficient adjusted | 88.95 %      |
|                                                 |                                                                                   | AE <1*10⁻⁷                        |              |
| Chicken soup with minced chicken breast and potato | ![Chicken soup with minced chicken breast and potato](image)                       | Pseudoplastic                      | 92.01 mPa*s  |
|                                                 | ![Fitted line plot](image)                                                         | $\sigma = 117.8 \cdot \dot{\gamma}^{0.36}$ | 98.03 %      |
|                                                 |                                                                                   | R-sq determination coefficient     | 97.79 %      |
|                                                 |                                                                                   | R-sq (Adj) determination coefficient adjusted | 94.22 %      |
|                                                 |                                                                                   | AE <1*10⁻⁷                        |              |
| Traditional bean soup                           | ![Traditional bean soup](image)                                                   | Pseudoplastic                      | 728.66 mPa*s |
|                                                 | ![Fitted line plot](image)                                                         | $\sigma = 930.08 \cdot \dot{\gamma}^{0.35}$ | 99.90 %      |
|                                                 |                                                                                   | R-sq determination coefficient     | 99.88 %      |
|                                                 |                                                                                   | R-sq (Adj) determination coefficient adjusted | 99.84 %      |
|                                                 |                                                                                   | AE <1*10⁻⁷                        |              |
| Minced traditional bean soup                     | ![Minced traditional bean soup](image)                                             | Pseudoplastic                      | 1721.25 mPa*s|
|                                                 | ![Fitted line plot](image)                                                         | $\sigma = 2306.1 \cdot \dot{\gamma}^{0.42}$ | 86.82 %      |
|                                                 |                                                                                   | R-sq determination coefficient     | 85.17 %      |
|                                                 |                                                                                   | R-sq (Adj) determination coefficient adjusted | 86.67 %      |
|                                                 |                                                                                   | AE <1*10⁻⁷                        |              |
| Carrot blended soup                              | ![Carrot blended soup](image)                                                      | Pseudoplastic                      | 321.59 mPa*s |
|                                                 | ![Fitted line plot](image)                                                         | $\sigma = 395.49 \cdot \dot{\gamma}^{0.30}$ | 97.67 %      |
|                                                 |                                                                                   | R-sq determination coefficient     | 97.38 %      |
|                                                 |                                                                                   | R-sq (Adj) determination coefficient adjusted | 96.54 %      |
|                                                 |                                                                                   | AE <1*10⁻⁷                        |              |
| Carrot blended soup reconstituted 1:0.5          | ![Carrot blended soup reconstituted 1:0.5](image)                                 | Pseudoplastic                      | 22.46 mPa*s  |
|                                                 | ![Fitted line plot](image)                                                         | $\sigma = 31.6 \cdot \dot{\gamma}^{0.49}$ | 99.88 %      |
|                                                 |                                                                                   | R-sq determination coefficient     | 99.86 %      |
|                                                 |                                                                                   | R-sq (Adj) determination coefficient adjusted | 99.81 %      |
|                                                 |                                                                                   | AE <1*10⁻⁷                        |              |

(Continued)
Table 7. (Continued).

| Product Description                                      | Consistency Type | Power Law Parameter | Relative Error | Absolute Error |
|-----------------------------------------------------------|------------------|---------------------|----------------|----------------|
| Lentil broth                                              | Pseudoplastic    | $\sigma = 0.57 \cdot \dot{\gamma}^{0.56}$ | 97.15%         | 0.36 mPa*s     |
| Minced lentil soup added with potato                      | Pseudoplastic    | $\sigma = 72.79 \cdot \dot{\gamma}^{0.43}$ | 98.91%         | 54.10 mPa*s    |
| Mango Pulp                                                | Pseudoplastic    | $\sigma = 198.08 \cdot \dot{\gamma}^{0.29}$ | 99.43%         | 161.49 mPa*s   |
| Reconstituted mango pulp 1:1                             | Pseudoplastic    | $\sigma = 113.79 \cdot \dot{\gamma}^{0.26}$ | 98.91%         | 94.87 mPa*s    |
| Reconstituted mango pulp 1:2                             | Pseudoplastic    | $\sigma = 19.28 \cdot \dot{\gamma}^{0.40}$  | 98.23%         | 14.56 mPa*s    |
| Reconstituted mango pulp 1:3                             | Pseudoplastic    | $\sigma = 4.72 \cdot \dot{\gamma}^{0.55}$   | 92.75%         | 3.22 mPa*s     |

(Continued)
| Papaya Pulp | 761.79 mPa*s |
|-------------|--------------|
| Pseudoplastic | \( \sigma = 860.58 \cdot \dot{\gamma}^{0.18} \) |
|             | 95.25 %     |
|             | 94.66 %     |
|             | 91.49 %     |
|             | AE <1*10^{-7} |

| Reconstituted papaya pulp 1:1 | 36.99 mPa*s |
|-------------------------------|--------------|
| Pseudoplastic                 | \( \sigma = 49.52 \cdot \dot{\gamma}^{0.42} \) |
|                               | 93.12 %     |
|                               | 94.43 %     |
|                               | 92.55 %     |
|                               | AE <1*10^{-7} |

| Reconstituted papaya pulp 1:2 | 10.79 mPa*s |
|-------------------------------|--------------|
| Pseudoplastic                 | \( \sigma = 14.59 \cdot \dot{\gamma}^{0.43} \) |
|                               | 97.47 %     |
|                               | 97.16 %     |
|                               | 98.20 %     |
|                               | AE <1*10^{-7} |

| Reconstituted papaya pulp 1:3 | 6.93 mPa*s |
|-------------------------------|--------------|
| Pseudoplastic                 | \( \sigma = 9.63 \cdot \dot{\gamma}^{0.47} \) |
|                               | 97.56 %     |
|                               | 97.25 %     |
|                               | 95.98 %     |
|                               | AE <1*10^{-7} |

| Mango compost, Brix 65, pH 3, in different proportions |  |
|--------------------------------------------------------|-------------------|
| 0.1%                                                   | 1001.64 mPa*s     |
| Pseudoplastic                                          | \( \sigma = 1202.1 \cdot \dot{\gamma}^{0.26} \) |
|                                                       | 93.08 %           |
|                                                       | 92.21 %           |
|                                                       | 88.05 %           |
|                                                       | AE <1*10^{-7}     |

| 0.5%                                                   | 1942.76 mPa*s     |
| Pseudoplastic                                          | \( \sigma = 2343.9 \cdot \dot{\gamma}^{0.27} \) |
|                                                       | 96.83 %           |
|                                                       | 96.43 %           |
|                                                       | 95.56 %           |
|                                                       | AE <1*10^{-7}     |

| 1%                                                     | 37379.6 mPa*s     |
| Pseudoplastic                                          | \( \sigma = 4414.2 \cdot \dot{\gamma}^{0.24} \) |
|                                                       | 99.28 %           |
|                                                       | 99.19 %           |
|                                                       | 99.03 %           |
|                                                       | AE <1*10^{-7}     |

| 2%                                                     | 49656.2 mPa*s     |
| Pseudoplastic                                          | \( \sigma = 59677 \cdot \dot{\gamma}^{0.27} \) |
|                                                       | 97.12 %           |
|                                                       | 96.76 %           |
|                                                       | 91.44 %           |
|                                                       | AE <1*10^{-7}     |
Papaya compote, 65°Brix, pH 3. Pectin at different proportions

| Concentration | Rheological Model | Pseudoplastic Parameters | % Recovery | AE
|---------------|------------------|--------------------------|------------|---|
| 0.1%          | Pseudoplastic    | $\sigma = 1483.8 \cdot \dot{\gamma}^{0.35}$ | 99.42%     | $<1 \times 10^{-7}$ |
|               |                  |                          | 99.34%     |               |
|               |                  |                          | 98.26%     |               |
| 0.5%          | Pseudoplastic    | $\sigma = 1515.9 \cdot \dot{\gamma}^{0.37}$ | 99.82%     | $<1 \times 10^{-7}$ |
|               |                  |                          | 99.79%     |               |
|               |                  |                          | 99.75%     |               |
| 1%            | Pseudoplastic    | $\sigma = 1520.9 \cdot \dot{\gamma}^{0.34}$ | 99.49%     | $<1 \times 10^{-7}$ |
|               |                  |                          | 99.43%     |               |
|               |                  |                          | 99.28%     |               |
| 2%            | Pseudoplastic    | $\sigma = 62081 \cdot \dot{\gamma}^{0.32}$ | 97.25%     | $<1 \times 10^{-7}$ |
|               |                  |                          | 96.90%     |               |
|               |                  |                          | 96.07%     |               |

No micronized cornstarch

| Concentration | Rheological Model | Pseudoplastic Parameters | % Recovery | AE
|---------------|------------------|--------------------------|------------|---|
|               | Pseudoplastic    | $\sigma = 0.61 \cdot \dot{\gamma}^{0.71}$ | 98.04%     | $<1 \times 10^{-7}$ |
|               |                  |                          | 97.80%     |               |
|               |                  |                          | 83.48%     |               |

Micronized cornstarch (1%)

| Concentration | Rheological Model | Pseudoplastic Parameters | % Recovery | AE
|---------------|------------------|--------------------------|------------|---|
|               | Pseudoplastic    | $\sigma = 8.89 \cdot \dot{\gamma}^{0.37}$ | 98.24%     | $<1 \times 10^{-7}$ |
|               |                  |                          | 98.01%     |               |
|               |                  |                          | 86.07%     |               |

Micronized cornstarch (2%)

| Concentration | Rheological Model | Pseudoplastic Parameters | % Recovery | AE
|---------------|------------------|--------------------------|------------|---|
|               | Pseudoplastic    | $\sigma = 77.88 \cdot \dot{\gamma}^{0.37}$ | 99.54%     | $<1 \times 10^{-7}$ |
|               |                  |                          | 99.49%     |               |
|               |                  |                          | 98.51%     |               |

Micronized cornstarch (3%)

| Concentration | Rheological Model | Pseudoplastic Parameters | % Recovery | AE
|---------------|------------------|--------------------------|------------|---|
|               | Pseudoplastic    | $\sigma = 420.68 \cdot \dot{\gamma}^{0.38}$ | 99.85%     | $<1 \times 10^{-7}$ |
|               |                  |                          | 99.83%     |               |
|               |                  |                          | 99.78%     |               |
| Table 7. (Continued). |
|-----------------------|
| Pumpkin soup with no micronized cornstarch and micronized cornstarch |
| No micronized cornstarch | 14.08 mPa*s |
| Pseudoplastic | 99.50 % |
| $\sigma = 22.36 \times \dot{\gamma}^{0.66}$ | 99.44 % |
| | 98.71 % |
| AE $<1 \times 10^{-7}$ |  |
| Micronized cornstarch (1%) | 73.08 mPa*s |
| Pseudoplastic | 99.16 % |
| $\sigma = 111.69 \times \dot{\gamma}^{0.61}$ | 99.05 % |
| | 97.04 % |
| AE $<1 \times 10^{-7}$ |  |
| Micronized cornstarch (2%) | 113.05 mPa*s |
| Pseudoplastic | 99.57 % |
| $\sigma = 161.84 \times \dot{\gamma}^{0.52}$ | 99.52 % |
| | 99.31 % |
| AE $<1 \times 10^{-7}$ |  |
| Minced stew | 159.9 mPa*s |
| Pseudoplastic | 97.65 % |
| $\sigma = 203.78 \times \dot{\gamma}^{0.35}$ | 97.36 % |
| | 92.03 % |
| AE $<1 \times 10^{-7}$ |  |
| White corn soup | 6631.95 mPa*s |
| Pseudoplastic | 98.20 % |
| $\sigma = 7451 \times \dot{\gamma}^{0.17}$ | 97.97 % |
| | 96.14 % |
| AE $<1 \times 10^{-7}$ |  |
| White corn soup and white corn soup reconstituted |  |
| Reconstituted white corn soup 1:0.5 | 79.86 mPa*s |
| Pseudoplastic | 97.86 % |
| $\sigma = 105.81 \times \dot{\gamma}^{0.41}$ | 97.59 % |
| | 96.52 % |
| AE $<1 \times 10^{-7}$ |  |

*AE: adjustment error
Results and analysis

The 34 liquid and 35 solid and semisolid food patterns of daily consumption were evaluated under controlled conditions of preparation and service, classifying five categories for liquids and four for solids and semisolids considering the quantitative values of the rheological behavior and texture attributes, as detailed in sections 3.1 and 3.2. Additionally, unifying previous categories with the information traditionally used from the IDDSI and other authors generated a simplified proposal that facilitates offering foods according to swallowing limitations, as shown in Tables 6 and 8. Cooking techniques, preparation such as blending and minced, the addition of thickeners, and service conditions affect the mechanical behavior of foods, as shown in Tables 4 and 7, each detailed in section food sample preparation. Current results showed that texture and rheological patterns vary between specific ranges for every parameter, which is not well described in other studies for thickened liquids or modified-texture food. Therefore, intrinsic variation entails contradictions when applying qualitative descriptors to denote differences among categories, risking the safety of those who use these patterns. It is essential to replace qualitative descriptors for considering correlations among parameter and quantitative ranges. Moreover, thickened liquids and modified-texture food should be included among food choices with enough information to increase food choices variability. Additionally, previous studies showed the research gap around the association between rheological and texture behavior, older adult dietary requirements, and food service temperature.

Texture and rheology results were associated with portion size, caloric density, dietary requirements, and food service temperature providing a better and broader food choice variability. In addition, recent studies discourage food choices where the nutrition suitability is unsuccessful in meeting all recommendations because of improper portion sizes. Some studies recommend using IDDSI color-coded levels similar to the current result to avoid confusion. Besides, different colored dishes could help *mise en place* for each IDDSI level. Service temperature substantially impacts the texture and rheological properties of thickened liquids and modified-texture food. Soup and hot beverages could be classified as non-Newtonian with pseudoplastic characteristics with a food service temperature of 60°C. However, pseudoplasticity could change in other temperature ranges. Current results suggested specific food service temperatures for every pattern, useful for caregivers at home and in the professional clinical care of older adults.

Rheological categorization

Gallegos et al. established the need for rheological characterization under standardized conditions for different dysphagia severity levels. Barbon & Steele also recognized that straightforward definitions are not yet given for the several degrees of thickening of liquid foods. Current results adjusted and normalized provided a precise idea of the thickening categories described in Tables 6, 7, and 8.

Table 6 shows the rheological behavior of standardized food patterns categorization by rheological behavior associated with dysphagia severity levels described by Gallego et al. IDDSI and NDD considered the apparent viscosity at 50 s⁻¹ (Table 1). The IDDSI syringe flow test outcomes were similar to other reports. Although categorized food patterns were within the expected ranges, some methodological elements must be considered to achieve reliable results by following IDDSI flow test instructions, such as syringe dimensions, sample volume, and evaluation time. Even the IDDSI qualitative method approached low differences by service temperature; evaluation was restrained to low viscous fluids. Nozzle diameter, bubble presence, or particle content could affect highly viscous fluids, which must be sifted in a mesh of 4 mm. Moreover, the IDDSI test is based only on visual qualitative observation, and non-numerical data is involved. Colors indicate thickening categorization within the range of 0.18 mPa.s and 3023 mPa.s in the way that the lookup table comes from blue to red. Each pattern showed a specific behavior described by K (Consistency index) and n (flow index) as no Newtonian fluids, depending on time and share rate as thixotropic and pseudoplastic, respectively, for all cases.
Table 2646

Table 8. Summary of rheological behavior categorization for liquid food patterns by IDDSI descriptor. *Gallego et al., [41].

| IDDSI Descriptor | Average-viscosity at 50 s⁻¹ (mPa.s) | NDD Own | Patterns by descriptor type (%) | Dysphagia level* | n – Flow index | K – Consistency index (mPa.s) |
|------------------|------------------------------------|---------|-------------------------------|-----------------|---------------|-------------------------------|
| 0-Thin           | 0.16–0.18                          | 5.8     | 1                             | 0.63–0.71b      | 0.57–0.61a     |
| 1–Slightly thick | 3–50                               | 9.68–40 | 17.64                         | 0.13–0.51ab     | 0.48–143b      |
| 2 – Mildly thick | 51–350                             | 36–142  | 29.41                         | 0.16–0.69ab     | 6–946b         |
| 3 – Moderately   | 351–378                            | 26.47   | 3                             | 0.30–0.49ab     | 172–1483b      |
| thick            | 1750                               | 20.58   | 4                             | 0.36–0.42a      | 1515–62081c    |
| 4 – Extremely    | >1751                               | 1902–3023 | 20.58 | 4 | 0.36–0.42a | 1515–62081c |
| thick            |                                    |         |                               |                 |               |

Values correspond to the average among patterns in the same category described in Table 6. Different letters indicate significant differences by ANOVA and Fisher test (p < 0.05).

Fluids too thin can cause aspiration pneumonia, and too thick fluids can cause suffocation. [15,19] Kerwood et al. [50] developed a patent for a pregelatinized hydroxypropylated starch, which acts as a thickener in beverages, with an approximate viscosity between 400 mPa.s and 3500 mPa.s, corresponding to moderately thick (3) and extremely thick (4). Likewise, Gallegos Montes et al. [51] patented an instant powder as a thickener in food preparations. Talens et al. [32] evaluated the pea creams flow, viscoelasticity, and chewing properties using different hydrocolloids as thickeners, the viscosity ranges in products Honey-like and pudding were classified. Stading [52] established that the deformation speed depended on the viscoelasticity and consistency of the food.

When comparing the effect of preparation, several differences emerged. Lentil or chicken broth without vegetables or any thickening agent was included in the category 0-thin, with a flow index n between 0.54 and 0.65 and consistency index K between 0.57 and 1.14 mPa.s. Under the standard, minced and reconstituted preparation, some soups, juices, and chocolate beverages were included among 1–4 categories depending on thickener addition, natural starch or pectin presence in raw ingredients, and preparation type. At a higher level of starch or pectin, a higher category level, associating a flow index n between 0.13 and 0.69 and consistency index K between 0.48 and 62081 mPa.s. The preparation type with the same ingredients and temperature service, in some cases, presented a significant difference (p < .05), as shown in Table 6. For instance, minced traditional bean soups displayed a higher of n, 0.42 and viscosity of 2968 mPa.s included in level 4- Extremely thick. However, standard preparation displayed a 17% lower n value and around two times thicker when minced preparation, pointing out that ordinary solution of blending food could be unsafe. Moreover, liquifying by adding water after mincing, as in Carrot blended soup, yielded two times lower viscosity and ten times lower K. Hence, to enhance the swallowing experience, adhesivity, and cohesivity balance should be considered to avoid suffocation.

The preparations with wheat, sweet corn, potato, and banana, the amylose/amylopectin ratio modified the flow properties. Amylose generates gelatinous textures associated with the gelling process, while amylopectin shows cohesive textures. [53] Adding milk in hot cocoa beverages and white corn soup generated gelatious textures associated with milk carbohydrates and cooking process temperature. [54] Also, preparations with wheat, sweet corn, potato, and banana required moist heat for gelatinization generating viscous pastes or strong gels. [54] Dry heat promotes amylose linear chains attached by hydrogen connections making them less available for hydrolysis along with digestion. [55] The starch interaction during the cooking process fostered non-covalent binding with proteins, as happened in chicken & potato soup, beans, plantain & carrot soup, lentil & potato soup, and white corn soup with milk. [56] Due to electrostatic attraction, chicken, bean, lentil, and milk proteins also allowed physical bonds with starches by hydrophilic groups, [57] and hydrogen bonding. [58] Yang et al. [59] and López-Barón et al. [60] reported those interactions in corn starch, whey protein, wheat starch, and hydrolyzed pea protein.
Table 9. Solid and semi-solid foods patterns categorization by Mechanical behavior associated with dysphagia severity level and IDDSI classification. Color per roads indicates level of consistency accordingly to described in Table 10. Data corresponds to average of n = 3 per pattern. Letters indicate significant difference (p < .05) by Fisher Test per type of preparation. *Gallego et al, **Recommended Intake Amounts per day, calorie level of pattern for a diet of 2000 calories.

| Texture profile (TPA) | Semi-solid and solid food patterns | Recommended Intake per day** | Hardness (N/m²) | Cohesiveness | Adhesiveness (J/m²) | Chewiness (N/m²) | IDDSI classification | Dysphagia level* |
|-----------------------|------------------------------------|-------------------------------|-----------------|--------------|---------------------|-----------------|----------------------|----------------|
| Sweet                 | flour: water 1:1                    | 2 oz; 65 g                    | 17800 ± 274a    | 0.78 ± 0.02b | 0.13 ± 0.25a        | 13791.44 ± 249c | 6                     | 2               |
| Cornbread             | flour: water 1:2                    | 195 Calories                  | 14463 ± 672b    | 0.8 ± 0.016a | 2.29 ± 0.51b        | 11569.02 ± 755b | 6                     | 2               |
| Tuna                  | flour: water 1:3                    | 9269 ± 435a                  | 7.6 ± 0.046a    | 2.15 ± 1.41b | 6919.06 ± 339a      | 6               | 2                    |
| Tuna                  | Tuna loin                           | 4 oz; 125 g                   | 1323 ± 127a     | 0.69 ± 0.018a | 10.06 ± 5.67a       | 910.63 ± 318b  | 5                     | 2               |
| Tuna                  | Tuna minced                         | 145 Calories                  | 513 ± 108b      | 0.49 ± 0.03b  | 23.5 ± 6.38b        | 252 ± 40.21a   | 5                     | 2               |
| Pumpkin               | 20 min simmering                   | 3 oz; 100 g                   | 7342 ± 194a     | 0.16 ± 0.02a  | 182.34 ± 35a        | 1530.31 ± 94a  | 5                     | 2               |
| Pumpkin               | 25 min simmering                   | 104 Calories                  | 7199 ± 59b      | 0.18 ± 0.015b | 234.41 ± 21c        | 1454.88 ± 113d | 5                     | 2               |
| Pumpkin               | 30 min simmering                   | 6758 ± 226bc                 | 0.22 ± 0.083b   | 170.24 ± 76b  | 1240.88 ± 178c      | 5               | 2                    |
| Pumpkin               | 35 min simmering                   | 6001 ± 195bc                 | 0.22 ± 0.019b   | 111.22 ± 88b  | 974.12 ± 66b        | 5               | 2                    |
| Pumpkin               | 35 min simmering & minced          | 213 ± 30b                    | 0.59 ± 0.07c    | 127.86 ± 16c  | 126.8 ± 51c         | 4               | 1                    |
| Mango                 | Raw                                 | 3 oz; 100 g                   | 274 ± 248b      | 0.53 ± 0.073a | 189 ± 17b           | 1459.73 ± 63b  | 4                     | 1               |
| Mango                 | Pure                               | 68 Calories                   | 206 ± 75a       | 0.66 ± 0.04b  | 129.09 ± 95c        | 137.35 ± 37a   | 4                     | 1               |
| Cornbread             | 2 min sauteing                      | 2 oz; 65 g                    | 36420 ± 578a    | 1.03 ± 0.16d  | 30572.08 ± 796b     | 37661.12 ± 543a | 7                     | 3               |
| Cornbread             | 4 min sauteing                      | 165 Calories                  | 35382 ± 718a    | 1.13 ± 0.12c  | 25309.6 ± 215a      | 39594.59 ± 720a | 7                     | 3               |
| Cornbread             | 6 min sauteing                      | 83337 ± 733b                 | 1.10 ± 0.046b   | 70820.5 ± 113c | 79848.01 ± 637b     | 7               | 3                    |
| Cornbread             | 8 min sauteing                      | 79259 ± 752b                 | 0.94 ± 0.42a    | 63032.06 ± 287a | 74515.36 ± 705b    | 7               | 3                    |
| Cornbread with cheese | 2 min sauteing                      | 2 oz; 65 g                    | 23285 ± 126a    | 0.68 ± 0.098b | 1.67 ± 0.29a        | 15797.23 ± 405b | 6                     | 2               |
| Cornbread with cheese | 4 min sauteing                      | 212 Calories                  | 19716 ± 223a    | 0.69 ± 0.073a | 13616.45 ± 287b     | 13502.22 ± 350a | 6                     | 2               |
| Cornbread with cheese | 6 min sauteing                      | 20121 ± 590a                 | 0.69 ± 0.051b   | 30493.86 ± 348b | 13538.35 ± 442a     | 6               | 2                    |
| Cornbread with cheese | 8 min sauteing                      | 28595 ± 577b                 | 0.68 ± 0.032b   | 54186.4 ± 58d  | 19535.13 ± 551c     | 6               | 2                    |
| Broad beans           | 15 min simmering                   | 2 oz; 65 g                    | 10800 ± 224a    | 0.33 ± 0.011c | 17.84 ± 0.52a       | 3811.64 ± 48.1f | 5                     | 2               |
| Broad beans           | 20 min simmering                   | 73 Calories                   | 10447 ± 201b    | 0.18 ± 0.047a | 36.18 ± 3.05b       | 1932.33 ± 96.6f | 5                     | 2               |
| Broad beans           | 25 min simmering                   | 9426 ± 361b                  | 0.2 ± 0.066a    | 62.49 ± 7.22a  | 1902.92 ± 83.47f    | 5               | 2                    |
| Broad beans           | 25 min simmering & minced          | 9275 ± 281b                  | 0.28 ± 0.016b   | 55.23 ± 9.82d  | 2641.22 ± 44.35f    | 4               | 1                    |
| Squash                | 20 min simmering                   | 3 oz; 100 g                   | 13891 ± 498d    | 0.17 ± 0.051b | 167.25 ± 1.37d      | 2440.22 ± 61.60d | 5                     | 2               |
| Squash                | 25 min simmering                   | 140 Calories                  | 9117 ± 361a     | 0.11 ± 0.073a | 90.69 ± 4.58a       | 1016.17 ± 73.02 | 5                     | 2               |
| Squash                | 30 min simmering                   | 6874 ± 661b                  | 0.09 ± 0.082a   | 49.84 ± 4.01b  | 624.13 ± 99.41b     | 5               | 2                    |
| Squash                | 30 min simmering & minced          | 6030 ± 395b                  | 0.11 ± 0.013a   | 37.73 ± 6.19a  | 446.57 ± 54.37a     | 4               | 1                    |

(Continued)
Table 9. (Continued).

Texture profile analysis (TPA)

| Semi-solid and solid food patterns | Recommended Intake per day**[21] | Hardness (N/m³) | Cohesiveness (J/m³) | Adhesiveness (N/m²) | Chewiness (N/m²) | IDDSI classification | Dysphagia level³ |
|------------------------------------|----------------------------------|------------------|---------------------|---------------------|------------------|-----------------------|-----------------|
| Caramel flan                        | 4 oz; 125 g 135 Calories         | 3907 ± 106.5⁵    | 0.41 ± 0.02⁶        | 103.2 ± 40⁴         | 1585.8 ± 107.8⁶  | 4                     | 1               |
| commercial powder: lactose-free    |                                  |                  |                     |                     |                  |                       |                 |
| milk 1:1                           |                                  |                  |                     |                     |                  |                       |                 |
| commercial powder: lactose-free    |                                  |                  |                     |                     |                  |                       |                 |
| milk 1:2                           |                                  |                  |                     |                     |                  |                       |                 |
| commercial powder: lactose-free    |                                  |                  |                     |                     |                  |                       |                 |
| milk 1:3                           |                                  |                  |                     |                     |                  |                       |                 |
| commercial powder: lactose-free    |                                  |                  |                     |                     |                  |                       |                 |
| milk 1:4                           |                                  |                  |                     |                     |                  |                       |                 |
| commercial powder: lactose-free    |                                  |                  |                     |                     |                  |                       |                 |
| milk 1:5                           |                                  |                  |                     |                     |                  |                       |                 |

| Yellow cassava                     | 4 oz; 100 g 104 Calories         | 162424 ± 740⁴     | 0.47 ± 0.01⁵        | 812.27 ± 72.56⁶     | 75386.2 ± 474.55⁷  | 7                     | 3               |
| 25 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 30 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 35 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 35 min simmering & minced         |                                  |                  |                     |                     |                  |                       |                 |
| Sweet pea                         | 2 oz; 65 g 38 Calories           | 3899 ± 126.57⁴   | 0.68 ± 0.00⁷        | 0.1 ± 0.17⁸         | 264.36 ± 106⁷      | 5                     | 2               |
| 15 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 20 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 25 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 25 min simmering & minced         |                                  |                  |                     |                     |                  |                       |                 |
| Tapioca                           | 4 oz; 100 g 173 Calories          | 83669 ± 322.1³    | 0.37 ± 0.03⁴        | 531.27 ± 56.78⁵     | 30939.72 ± 496.2⁶  | 7                     | 3               |
| 20 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 25 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 30 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 35 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 35 min simmering & minced         |                                  |                  |                     |                     |                  |                       |                 |
| Yellow potato                      | 4 oz; 100 g 86 Calories           | 7240 ± 556.09⁵   | 0.47 ± 0.01⁴        | 223.34 ± 32.06⁶     | 338.48 ± 61.73⁵    | 6                     | 2               |
| 15 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 20 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 25 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |
| 25 min simmering & minced         |                                  |                  |                     |                     |                  |                       |                 |
| Chicken breast                     | 4 oz; 125 g 138 Calories          | 5559 ± 85.18⁴    | 0.77 ± 0.06⁵        | 15.51 ± 0.32⁶       | 429.17 ± 38.71⁷    | 5                     | 2               |
| Grilled                            |                                  |                  |                     |                     |                  |                       |                 |
| 15 min                            |                                  |                  |                     |                     |                  |                       |                 |
| 20 min                            |                                  |                  |                     |                     |                  |                       |                 |
| 30 min                            |                                  |                  |                     |                     |                  |                       |                 |
| 30 min simmering                  |                                  |                  |                     |                     |                  |                       |                 |

(Continued)
Table 9. (Continued).

| Texture profile analysis (TPA) | Semi-solid and solid food patterns | Recommended Intake per day**[21] | Hardness (N/m²) | Cohesiveness (J/m²) | Adhesiveness (J/m²) | Chewiness (N/m²) | IDDSI classification | Dysphagia level* |
|-------------------------------|------------------------------------|-----------------------------------|-----------------|---------------------|--------------------|-----------------|----------------------|-----------------|
| Brazilian cheese bread       | 0 minutes dehydration             | 3 oz; 80 g                        | 230 Calories    | 4859 ± 213.64a      | 0.92 ± 0.061a      | 1835.25 ± 78.99a | 4468.39 ± 55.13a   | 6               | 2               |
|                              | (surface)                          |                                   |                  | 2015 ± 114.56b      | 0.96 ± 0.054a      | 1798.84±           | 2140.15 ± 67.01b   | 5               | 2               |
|                              | 20 min dehydration (surface)      |                                   |                  | 1489 ± 156.78a      | 0.96 ± 0.077a      | 1259.83±           | 1434.68 ± 66.24a   | 5               | 2               |
|                              | 30 min dehydration (surface)      |                                   |                  | 1619 ± 207.41a      | 0.88 ± 0.018b      | 996.64±            | 1409.12 ± 54.03a   | 6               | 2               |
|                              | 0 min dehydration (inside)        |                                   |                  | 3618 ± 284.16b      | 0.76 ± 0.027a      | 1.17 ± 0.39a       | 2762.28 ± 50.81b   | 5               | 2               |
|                              | 20 min dehydration (inside)       |                                   |                  | 3438 ± 205.11c      | 0.74 ± 0.052a      | 1.61 ± 0.11a       | 2561.82 ± 53.92a   | 5               | 2               |
| Fresh cheese                 | Fresh cheese complete             | 4 oz; 125 g                       | 181 Calories     | 5529 ± 13.31b       | 0.9 ± 0.07a        | 59.01 ± 4.5b       | 4997.83 ± 221.74b  | 5               | 2               |
|                              | Fresh cheese minced               |                                   |                  | 495 ± 48.92a        | 0.82 ± 0.021a      | 882.17 ± 39.52a    | 409.2 ± 50.94a     | 4               | 1               |
| Papaya                       | raw                                | 4 oz; 100 g                       | 39 Calories      | 2975 ± 58.04b       | 0.3 ± 0.017a       | 192.99 ± 19.21h    | 805.09 ± 44.21h    | 4               | 1               |
|                              | pure                              |                                   |                  | 1029 ± 20.76a       | 0.31 ± 0.001a      | 138.58 ± 10.83a    | 328.01 ± 67.02a    | 4               | 1               |
| Avocado                      | raw                                | 4 oz; 100 g                       | 160 Calories     | 6031 ± 30.26b       | 0.32 ± 0.053a      | 207.17 ± 22.98a    | 1854.07±           | 4               | 1               |
|                              | pure                              |                                   |                  | 2431 ± 47.05a       | 0.46 ± 0.017b      | 134.39 ± 30.04a    | 1102.82 ± 64.61a   | 4               | 1               |
| Sweet corn                    | Sweet corn parcels                | 4 oz; 100 g                       | 155 Calories     | 4934 ± 119.82       | 0.92 ± 0.063       | 361.27 ± 56.04     | 4552.61 ± 128.63a  | 5               | 2               |
| Pearl barley                 | 20 min simmering                  | 4 oz; 100 g                       | 123 Calories     | 3281 ± 177.03c      | 0.55 ± 0.014c      | 0.04 ± 0.003a      | 1802.67 ± 17.52c   | 5               | 2               |
| Beans                        | 60 min simmering                  | 4 oz; 100 g                       | 151 Calories     | 3179 ± 63.51c       | 0.68 ± 0.016c      | 0.57 ± 0.045b      | 2202.34 ± 40.77c   | 5               | 2               |
|                              | 70 min simmering                  |                                   |                  | 2599 ± 58.44b       | 0.68 ± 0.011c      | 0.04 ± 0.002a      | 1757.55 ± 54.31b   | 5               | 2               |
|                              | 80 min simmering                  |                                   |                  | 2797 ± 45.76b       | 0.65 ± 0.026b      | 0.03 ± 0.014c      | 1845.21 ± 25.62c   | 5               | 2               |
|                              | 80 min simmering and minced       |                                   |                  | 1543 ± 28.9a        | 0.59 ± 0.088a      | 0.03 ± 0.007a      | 1027.63 ± 10.95a   | 4               | 1               |
| Textural Property | Semi-solid and solid food patterns | Recommended Intake per day | Hardness (N/m²) | Cohesiveness | Adhesiveness (J/m²) | Chewiness (N/m²) | IDDSI classification | Dysphagia level |
|-------------------|-----------------------------------|-----------------------------|----------------|-------------|---------------------|----------------|----------------------|-----------------|
| Chicken egg       | Boiled 3 min (surface) 4 oz; 100 g | 1228 ± 38.16ab             | 0.96 ± 0.05ab  | 4.62 ± 0.16c | 1052.14 ± 68.03d   | 6              | 2                    |                 |
|                   | Boiled 6 min (surface) 155 Calories | 1314 ± 46.78ab             | 0.82 ± 0.014ab | 5.15 ± 0.82d | 1231.92 ± 72.38e   | 6              | 2                    |                 |
|                   | Boiled 9 min (surface) 156 Calories | 1526 ± 40.66ab             | 0.92 ± 0.02b   | 1.95 ± 0.06b | 1527.87 ± 58.42g   | 6              | 2                    |                 |
|                   | Boiled 12 min (surface) 1628 ± 36.11c | 0.94 ± 0.03b       | 1.61 ± 0.09s   | 1538.29 ± 43s | 6                | 2                    |                     |                 |
|                   | Boiled 3 min (Inside) 4 oz; 100 g | 1513 ± 48.96a             | 0.87 ± 0.05b   | 1.4 ± 0.17a  | 1310.63 ± 88.06f   | 6              | 2                    |                 |
|                   | Boiled 6 min (Inside) 155 Calories | 1751 ± 67.03b             | 0.78 ± 0.049c  | 2.57 ± 0.76c | 1559.52 ± 76.38b   | 6              | 2                    |                 |
|                   | Boiled 9 min (Inside) 1861 ± 55.83c | 0.87 ± 0.05b        | 1.75 ± 0.64b   | 1802.75 ± 65.17e | 6 | 2                     |                     |                 |
|                   | Boiled 12 min (Inside) 2039 ± 64.32d | 0.85 ± 0.023d    | 3.61 ± 0.47d   | 1909.46 ± 62.05f | 6 | 2                     |                     |                 |
|                   | Scrambled 3 min 4 oz; 100 g       | 2482 ± 56.69a           | 0.95 ± 0.046b  | 4392.84 ± 78.03d | 2301 ± 40.69d   | 6              | 2                    |                 |
|                   | Scrambled 6 min 212 Calories      | 2685 ± 40.18b           | 0.91 ± 0.019b  | 3631.26 ± 60.28 | 2433.68 ± 38.07  | 6              | 2                    |                 |
|                   | Scrambled 9 min 3069 ± 57.93c     | 0.88 ± 0.074a           | 4210.29 ± 56.78b | 2698.54 ± 78.67 | 6              | 2                    |                     |                 |
|                   | Scrambled 12 min 3457 ± 67.93d    | 0.93 ± 0.03b            | 1637.62 ± 43.86 | 2995.92 ± 59.16 | 6              | 2                    |                     |                 |
|                   | Poached 3 min 4 oz; 100 g         | 380 ± 12.79a            | 1.38 ± 0.25e   | 787.95 ± 43.84 | 525.92 ± 58.16e   | 5              | 2                    |                 |
|                   | Poached 6 min 146 Calories        | 422 ± 25.68b            | 1.02 ± 0.65s   | 1335.54 ± 67.81 | 428.19 ± 60.27c  | 7              | 3                    |                 |
|                   | Poached 9 min 775 ± 30.55         | 1.21 ± 0.28h            | 2359.27 ± 44.43 | 936.68 ± 23.18c | 7              | 3                    |                     |                 |
|                   | Poached 12 min 890 ± 17.73d       | 1.3 ± 0.18f             | 2189.19 ± 61.92 | 996.87 ± 30.08c | 7              | 3                    |                     |                 |
| Banana             | raw 4 oz; 100 g 5933 ± 81.64b     | 0.41 ± 0.061a           | 506.96 ± 64.99 | 2418.68 ± 83.02 | 5              | 2                    |                     |                 |
|                   | pure 89 Calories 307 ± 27.86a      | 0.55 ± 0.077b           | 211.05 ± 51.68 | 167.47 ± 57.43 | 4              | 1                    |                     |                 |
|                   | Agar: Water 1:1 4 oz; 125 g        | 3225 ± 81.67c           | 0.48 ± 0.06p   | 67.31 ± 12.06 | 1656.85 ± 57.50d  | 4              | 1                    |                 |
|                   | Agar: Water 1:2 33 Calories        | 4958 ± 55.92d           | 0.56 ± 0.01c   | 87.67 ± 16.84 | 2754.69 ± 67.30c  | 4              | 1                    |                 |
|                   | Agar: Water 1:3 1957 ± 47.03b      | 0.54 ± 0.05f            | 92.78 ± 17.44d | 1056.08 ± 52.44 | 4              | 1                    |                     |                 |
|                   | Agar: Water 1:4 3592 ± 70.30c      | 0.47 ± 0.041b           | 10.43 ± 20.70c | 1705.90 ± 50.17d   | 4 | 1                     |                     |                 |
|                   | Agar: Water 1:5 1523 ± 61.27b      | 0.57 ± 0.033c           | 80.14 ± 14.99c | 872.99 ± 43.06b | 4              | 1                    |                     |                 |
|                   | Agar: Water 1:6 1038 ± 50.03a      | 0.63 ± 0.029h           | 61.79 ± 16.35b | 652.14 ± 47.02a | 4              | 1                    |                     |                 |
| Oat flake          | Water: oat flakes 1:1 4 oz; 100 g  | 165± ± 0.26b           | 1.26 ± 0.31b   | 13.79± ± 5.2d | 207.67 ± 2.52c   | 5              | 2                    |                 |
|                   | Water: oat flakes 1:2 8.5b          | 345 ± 15.6c             | 0.6 ± 0.067a   | 93.34± ± 59.0c | 205.99 ± 9.7c   | 5              | 2                    |                 |
|                   | Water: oat flakes 1:3 295 ± 54.8d   | 0.62 ± 0.071a           | 111.62 ± 54.04d | 182.82 ± 46.11b | 5              | 2                    |                     |                 |
|                   | Water: oat flakes 2:1 255 ± 28.9c   | 0.63 ± 0.016a           | 159.34 ± 30.88d | 161.31 ± 22.16c | 5              | 2                    |                     |                 |
|                   | Water: oat flakes 2:2 617 ± 67.2c   | 0.6 ± 0.054a            | 80.28± ± 20.16c | 372.56 ± 30.27d | 5              | 2                    |                     |                 |
|                   | Water: oat flakes 2:3 1295 ± 98.5f  | 0.69 ± 0.022d           | 86.48± ± 16.75c | 896.6 ± 10.06c | 5              | 2                    |                     |                 |

(Continued)
| Semi-solid and solid food patterns | Recommended Intake per day**[^1] | Hardness (N/m²) | Cohesiveness | Adhesiveness (N/m) | Chewiness (N/m²) | IDDSI classification | Dysphagia level* |
|-----------------------------------|---------------------------------|----------------|--------------|-------------------|-----------------|----------------------|-----------------|
| Gelatin and Jelly                |                                |                |              |                   |                 |                      |                 |
| Gelatin: water 1:1              | 4 oz; 125 g                    | 1688 ± 72.59   | 1.24 ± 0.25  | 55.32.49 ± 43.75^5| 2085.71 ± 68.66^4| 7                     | 3               |
| Gelatin: water 1:2              | 8 Calories                      | 1145 ± 45.66^b| 1.31 ± 0.67^b| 3849.44 ± 67.90^b| 1501.59 ± 73.2^b| 7                     | 3               |
| Gelatin: water 1:3              |                                | 817 ± 10.87^a  | 1.5 ± 0.52^b | 2881.24 ± 77.30^a | 1221.81 ± 56.88^a| 7                     | 3               |
| Jelly: water 1:1                | 4 oz; 125 g                    | 2835 ± 60.16^e | 1.11 ± 0.36^b| 918.57 ± 76.9^b   | 313.51 ± 18.6^c  | 7                     | 3               |
| Jelly: water 1:2                | 54 Calories                     | 1961 ± 67.2^c  | 1.18 ± 0.41^a | 6482.52 ± 81.65^c | 2344.2 ± 52.17^a  | 7                     | 3               |
| Jelly: water 1:3                |                                | 1468 ± 47.3^c  | 1.27 ± 0.77^b | 4894.31 ± 1861.42 | 48.91^a          | 7                     | 3               |
| Potato                           |                                |                |              |                   |                 |                      |                 |
| 25 min simmering                | 4 oz; 100 g                     | 16977 ± 513.09^d| 0.19 ± 0.01^a | 153.21 ± 2.51^b  | 3217.6 ± 59.93^c | 6                     | 2               |
| 30 min simmering                | 86 Calories                     | 16238 ± 452.17^d| 0.35 ± 0.06^c | 123.68 ± 5.68^a  | 5896.5 ± 77.82^d | 6                     | 2               |
| 35 min simmering                |                                | 9118 ± 52.63^e | 0.21 ± 0.01^c | 305.38 ± 9.98^d   | 1994.3 ± 44.10^a | 6                     | 2               |
| 40 min simmering                |                                | 1351 ± 44.95^b | 0.25 ± 0.04^c | 196.81 ± 8.12^c   | 3245.86 ± 67.32^c| 6                     | 2               |
| 40 min simmering and minced     |                                | 887 ± 3.51^c   | 0.26 ± 0.02^c | 382.63 ± 4.19^c   | 2875.67 ± 40.54^a| 4                     | 1               |
| Wheat short pasta               |                                |                |              |                   |                 |                      |                 |
| 10 min simmering                | 4 oz; 100 g                     | 2336 ± 44.76^d| 0.78 ± 0.05^a | 19.84 ± 0.56^a    | 1832.66 ± 94.69^d| 5                     | 2               |
| 15 min simmering                | 131 Calories                    | 1688 ± 38.94^f | 0.9 ± 0.01^a  | 1517.6 ± 47.63^b  | 1511.99 ± 67.02^c| 7                     | 3               |
| 20 min simmering                | 182 Calories                    | 1251 ± 56.75^b | 1.09 ± 0.69^b | 3678.76 ± 101.3^d | 1364.8 ± 44.69^d | 7                     | 3               |
| 25 min simmering                |                                | 946 ± 25.97^a  | 1.21 ± 0.74^c | 2998.02 ± 98.26^e | 1143.93 ± 67.31^e| 7                     | 3               |
| White polished rice             |                                |                |              |                   |                 |                      |                 |
| 10 min simmering                | 4 oz; 100 g                     | 1457 ± 76.11^c | 0.38 ± 0.06^c | 1.79 ± 0.71^b     | 554.82 ± 3.11^a  | 5                     | 2               |
| 15 min simmering                | 182 Calories                    | 1235 ± 50.18^b | 0.47 ± 0.05^c | 1.58 ± 0.17^b     | 582.74 ± 17.43^c | 5                     | 2               |
| 20 min simmering                | 1437 ± 60.82^c                  | 0.58 ± 0.04^c  | 4.48 ± 0.42^c | 840.51 ± 10.99^f  | 7                     | 3               |
| 25 min simmering                |                                | 1117 ± 54.16^d | 0.54 ± 0.11^c | 44.33 ± 0.58^d    | 604.6 ± 18.53^b  | 5                     | 2               |
| Sweet Corn                      |                                |                |              |                   |                 |                      |                 |
| 5 min simmering                 | 4 oz; 100 g                     | 1517 ± 52.93^a | 0.59 ± 0.03^c | 2.12 ± 0.43^c     | 889.79 ± 4.5^a   | 5                     | 2               |
| 10 min simmering                | 81 Calories                     | 1895 ± 66.81^b | 0.59 ± 0.01^c | 8.16 ± 0.67^c     | 1126.33 ± 46.31^b| 5                     | 2               |
| 15 min simmering                |                                | 3302 ± 71.2^c  | 0.58 ± 0.01^c | 3.29 ± 0.32^b     | 19243.37 ± 51.08^f| 5                     | 2               |
| 20 min simmering                |                                | 3437 ± 70.17^c | 0.5 ± 0.03^a  | 10.8 ± 2.6^d      | 1765.5 ± 50.62^b | 5                     | 2               |
| Wholesome loaf                  |                                |                |              |                   |                 |                      |                 |
| Roasted 1 min                   | 2 oz; 42 g                      | 4312 ± 54.02^c | 0.72 ± 0.05^c | 0.04 ± 0.01^c     | 3007.46 ± 47.14^a| 7                     | 3               |
| Roasted 2 min                   | 128 Calories                    | 4903 ± 61.03^b | 0.65 ± 0.07^c | 0.04 ± 0.00^d     | 3151.39 ± 41.26^a| 7                     | 3               |
| Roasted 3 min                   |                                | 10090 ± 180.31^c| 0.65 ± 0.01^c | 0.02 ± 0.00^c     | 6589.09 ± 51.96^b| 7                     | 3               |
| Hydration 20 min                | 2 oz; 42 g                      | 5232 ± 78.66^b | 0.65 ± 0.07^c | 0.3 ± 0.02^d     | 3417.18 ± 30.78^c| 5                     | 2               |
| Hydration 60 min                | 128 Calories                    | 3947 ± 54.33^a | 0.67 ± 0.04^c | 0.06 ± 0.01^d     | 2631.01 ± 40.22^a| 7                     | 3               |
| Hydration 90 min                |                                | 3657 ± 50.16^a | 0.7 ± 0.02^c  | 0.02 ± 0.00^d     | 2557.67 ± 48.92^a| 7                     | 3               |

(Continued)
Table 9. (Continued).
Texture profile analysis (TPA)

| Semi-solid and solid food patterns | Recommended Intake per day**(1)** | Hardness (N/m²) | Cohesiveness (J/m²) | Adhesiveness (N/m²) | Chewiness (N/m²) | IDDSI classification | Dysphagia level |
|-----------------------------------|----------------------------------|-----------------|----------------------|---------------------|-----------------|---------------------|------------------|
| Carrot                            | 25 min simmering                 | 1 oz; 30 g      | 10606 ± 680.17b     | 0.37 ± 0.043c       | 413.4±          | 38008.22 ± 358.61e  | 7                |
|                                  | 30 min simmering                 |                 |                      |                     |                 |                     |                  |
|                                  |                                  | 30 Calories     | 70473 ± 249.5d      | 0.3 ± 0.017b        | 257.96 ± 56.08b | 21082.34 ± 466.18d | 7                |
|                                  |                                  | 35 min simmering | 55823 ± 532.89c    | 0.31 ± 0.03b        | 339.78 ± 67.31c | 18934.28 ± 478.34c | 7                |
|                                  |                                  | 40 min simmering | 48397 ± 310.06b    | 0.26 ± 0.077a       | 262.77 ± 40.62c | 12519.26 ± 437.10b | 7                |
|                                  |                                  | 40 min simmering & minced | 23305 ± 225.6a     | 0.3 ± 0.031b        | 131.99 ± 39.88b | 6786.74 ± 339.a   | 5                |
|                                  |                                  | 4 oz; 100 g     | 16969 ± 517.61c    | 0.37 ± 0.057b       | 66.14 ± 1.69c   | 6081.31 ± 47.05c  | 5                |
|                                  |                                  | 60 min simmering | 11275 ± 488.1b     | 0.3 ± 0.082a        | 41.27 ± 2.22a   | 3373.17 ± 40.12c  | 5                |
|                                  |                                  | 70 min simmering | 7331 ± 509.3a      | 0.31 ± 0.071a       | 54.36 ± 4.52b   | 2069.48 ± 48.56b  | 5                |
| Ripe Banana chips                | 10 min simmering                 | 4 oz; 100 g     | 26529 ± 317.46c    | 0.68 ± 0.078a       | 164.8±          | 17897.55±         | 6                |
|                                  |                                  | 116 Calories    | 33.82d             |                      | 466.94d         |                     |                  |
|                                  |                                  | 15 min simmering | 25204 ± 409.1d     | 0.7 ± 0.016b        | 64.93±          | 1760.12±          | 6                |
|                                  |                                  | 20 min simmering | 21799 ± 338.17c    | 0.67 ± 0.043a       | 123.1±          | 14600.04 ± 302.8a | 6                |
|                                  |                                  | 25 min simmering | 14624 ± 304.66b    | 0.67 ± 0.033a       | 55.61±          | 9699.47 ± 46.87b  | 6                |
|                                  |                                  | 25 min simmering & minced | 9559 ± 283.19c    | 0.65 ± 0.015b       | 22.99±          | 7611.38 ± 50.18a  | 4                |
|                                  |                                  |                   | 2.51±              |                      |                 |                     |                  |
|                                  |                                  | 4 oz; 100 g     | 10997 ± 488.77c    | 0.6 ± 0.087a        | 185.85±         | 6451.04 ± 51.66a  | 6                |
|                                  |                                  | 254 Calories    | 38.74±             |                      |                 |                     |                  |
|                                  |                                  | 4 oz; 100 g     | 12090 ± 492.15b    | 0.6 ± 0.012a        | 212.07±         | 7208.44 ± 48.92b  | 6                |
|                                  |                                  | 4 oz; 100 g     | 18733 ± 390.50c    | 0.59 ± 0.01a        | 220.35±         | 8247.49 ± 69.08c  | 6                |
| Green Banana chips              | 40 min simmering                 | 4 oz; 100 g     | 26543 ± 276.07c    | 0.74 ± 0.081b       | 47377.9 ± 152.75d | 19799.45 ± 312.24c | 7                |
|                                  | 50 min simmering                 | 116 Calories    | 27200 ± 337.82d    | 0.72 ± 0.016c       | 16491.63 ± 220.13a | 19625.8 ± 415.67c | 7                |
|                                  |                                  | 60 min simmering | 19765 ± 306.43b    | 0.72 ± 0.019b       | 3751.82 ± 76.38c | 14197.99 ± 407.55b | 7                |
|                                  |                                  | 70 min simmering | 18905 ± 315.18a    | 0.67 ± 0.011b       | 27047.29 ± 198.25b | 13359.24 ± 418.38c | 7                |
|                                  |                                  |                   | 7.36±              |                      |                 |                     |                  |
|                                  |                                  | 4 oz; 100 g     | 77963 ± 493.12c    | 0.73 ± 0.056d       | 0.72 ± 0.38b    | 64884.66 ± 490.03a | 7                |
|                                  |                                  | 254 Calories    | 86670 ± 512.76c    | 0.69 ± 0.023c       | 1.62 ± 0.87c   | 70213.92 ± 335.11b | 7                |
|                                  |                                  | 4 oz; 100 g     | 80337 ± 551.61b    | 0.61 ± 0.082b       | 0.4 ± 0.013a   | 71152.7 ± 380.17c  | 7                |
|                                  |                                  | 254 Calories    | 88616 ± 507.65c    | 0.57 ± 0.017a       | 0.35 ± 0.096b  | 71705.63 ± 411.84c | 7                |

**Notes:**
- Values with different superscript letters (a, b, c, d) indicate significant differences.
Adding salt ions can impact the interactions of liquid food patterns with starch through electrostatic shielding.\textsuperscript{[61]} As in formulations of liquid food patterns of Table 6, column B, low salt concentrations favor protein dissolution, which can help protein interactions with starch, improving such pattern’s quality.\textsuperscript{[62]}

Food with high methoxyl pectin promoted different textures due to the hydrophobic interactions essential for gelling Yang et al. \textsuperscript{[63]} In compotes, the combination of papaya and mango with high methoxyl pectin increased the methoxyl content enhancing the gelling capacity;\textsuperscript{[64]} the gelling capacity of high methoxyl content could indicate strong cohesive and adhesive forces, increasing the firmness of food products.\textsuperscript{[65]} The decrease in pH with the addition of citric acid enabled pectin yield due to the number of hydrogen ions boosted, resulting in carboxyl group neutralization.\textsuperscript{[66]} Furthermore, sugar content between 40° and 60° Brix improved the chain–chain relation in gelatin gel networks.\textsuperscript{[67]}

Kim et al.\textsuperscript{[68]} developed drinks and soups thickened with different concentrations of xanthan gum to the ranges recommended by the NDD generating pudding-like viscosity (4 – extremely thick), considering the future categorization according to the IDDSI. Dick, Bhandari, & Prakash\textsuperscript{[69]} evaluated the printability and texture of cooked beef pasta for older adults with dysphagia, using different gums as thickeners and classifying them according to the IDDSI.

Table 7 summarizes the rheological behavior of liquid food patterns classified by dysphagia severity level described by IDDSI and NDD. Column A describes each liquid food pattern evaluated; Column B shows the fitted line plot of each pattern; Column C presents the regression equation; Column D displays the error, and Column E indicates prediction fit, R-squared, adjusted R-squared, and Predicted R-square. The pseudoplastic behavior for all liquid food patterns had a better fit under power-law than Herschel-Bulkley model, as observed in the regression equation (Column C), the fitted line plot (Column B), low error (Column D), and R-squared over 83.85% (Column E). Additionally, a higher thickening level, a higher viscosity value at 50s-1, for example, 0- thin had values between 0.36 and 0.78 mPa*s-1, while 4–extremely thick showed values between 1520 to 49731 mPa*s-1.

Table 8 outlines the rheological behavior categorization for liquid food patterns by IDDSI related to dysphagia severity. The lookup table shows a clear, direct relation between thickeners and addition level, so the higher percentage of thickeners in liquid food patterns were associated with the higher levels of dysphagia according to the IDDSI and the NDD.\textsuperscript{[32,47,68]}

| Table 10. Summary mechanical parameters categorization for semisolid and solid food patterns by IDDSI descriptor. H, Hardness (N/m²); C, Cohesiveness (0–1); A, Adhesiveness (J/m²). *Gallego et al.\textsuperscript{[41]} |
| --- |
| **Descriptor IDDSI** | **Parameters** | **Matsuo & Fujishima\textsuperscript{[1]}** | **Own** | **Patterns by descriptor type (%)** | **Dysphagia level** |
| 4- Pureed | Hardness (N/m²) | H ≤ 15000 | H ≤ 15000 | 25.60 | 1 |
| | Cohesiveness | 0.2 ≤ C ≤ 0.9 | 0.2 ≤ C ≤ 0.9 |
| | Adhesiveness (J/m²) | A ≤ 1000 | A ≤ 900 |
| 5-Minced & moist | Hardness (N/m²) | 15000 ≤ H ≤ 40000 | 15000 ≤ H ≤ 37000 | 33.7 | 2 |
| | Cohesiveness | 0 ≤ C ≤ 1.0 | 0 ≤ C ≤ 1.0 |
| | Adhesiveness (J/m²) | A ≤ 1000 | A ≤ 900 |
| | 4 – Extremely thick liquid | 4 – Extremely thick liquid |
| 6-Soft & bite-sized | Hardness (N/m²) | 15000 ≤ H ≤ 40000 | 15000 ≤ H ≤ 37000 | 23.5 | 2 |
| | Cohesiveness | 0 ≤ C ≤ 1.0 | 0 ≤ C ≤ 1.0 |
| | Adhesiveness (J/m²) | A ≤ 1000 | A ≤ 900 |
| 7-Regular-Easy to chew | Hardness (N/m²) | H > 40000 | H > 40000 | 17.19 | 3 |
| | Cohesiveness | 0 ≤ C ≤ 1.0 | 0 ≤ C ≤ 1.0 |
| | Adhesiveness (J/m²) | A > 1000 | A > 1000 |

Values correspond to the average patterns in the same category described in Table 9
Liquid food patterns evaluated under controlled preparation and service temperature conditions generated a non-Newtonian, thinning, pseudoplastic, and thixotropic flow behavior. Moreover, the characteristics found in current patterns were suitable for safe swallowing, according to Hadde, Nicholson, & Cichero.\textsuperscript{[16]} with a cohesive bolus without fracturing it into many drops and passing safely to the esophagus.\textsuperscript{[13]} Sating\textsuperscript{[52]} evaluated the rheology of solid food regularly supplied to patients with dysphagia, finding that boluses depended on the power law. Talens et al.\textsuperscript{[32]} determined the rheological behavior of pea cream with different thickeners to people with swallowing problems, showing a shear-thinning flow behavior, non-Newtonian, pseudoplastic properties, and flow behavior indices $n$ less than one. The consistency coefficient $K$ and Viscosity at 50 s$^{-1}$ were directly correlated to thickener addition in both cases of pectin and corn starch ($p < .05$). Additionally, Vieira et al.\textsuperscript{[15]} evaluated liquid thickeners, such as linseed gum, xanthan gum, and modified starch, pointed out that flow index $n$ values were linked to the thickness perceived by consumers, and liquids with pseudoplastic characteristics, provide a pleasant and light mouthfeel. Suebsaen et al.\textsuperscript{[70]} stated that the rheological properties of foods for the elderly with dysphagia before oral processing should be like those of the bolus since this reduces chewing effort, making them more suitable.

Particle reduction and cooking process played a significant role in the matrix structure and lubricant properties of the oral processing, particularly in the minced stew, white corn, pumpkin, and carrot soup. Lubricating or tribological properties were associated with food gliding quickly over the tongue.\textsuperscript{[71]} Minced stew, pumpkin, and carrot soup had a homogeneous texture because of particle reduction that could not be a risk for the elderly population.\textsuperscript{[72]} Hence, associating rheology and tribology was essential to categorize food patterns. Several studies reported starch, pectin, gellan gum, xanthan gum, locust bean gum, and carrageenan as dysphagia thickeners in food matrices improved lubrication properties during oral processing.\textsuperscript{[13,73,74]} However, saliva has been recognized as an essential factor when applying dysphagia thickeners- $\alpha$-amylase-induced hydrolysis with starch-based thickeners affecting rheology during oral processing, case not observed in gellan or xanthan gum thickeners.\textsuperscript{[73]}

Finally, the design strategies guaranteed the thinning pseudoplastic behavior by applying repulsive agents such as pectins, binding agents such as starches, and avoiding non-connectivity agents such as diluted emulsions. These design characteristics were related to food structure and the interactions of gelling agents. It is necessary to incorporate into the design analysis of hydrophobic interactions, in this case, the effect of starch gelation that depends on the amylose/amylopectin ratio, in addition to ionic interactions that could impact pectin’s structure depending on their type, pH, and ° Brix.\textsuperscript{[75]}

\textbf{Texture profile categorization}

Tables 9 and 10 show the mechanical behavior of prepared solid and semisolid foods, associated with the classification of thickening defined by the IDDSI indicated by colors between the range of hardness ≤15000 N/m$^2$ and >40000 N/m$^2$ in the way that the lookup table comes from blue to red, with the different texture ranges proposed by Matsuo & Fujishima,\textsuperscript{[18]} and with the dysphagia severity levels described by Gallego et al.\textsuperscript{[41]}

According to Hadde & Chen,\textsuperscript{[14]} the mechanical parameters considered for safe swallowing were divided into two factors: (1) degree of structure that evaluates the parameters of hardness, cohesion, and adhesiveness and (2) degree of lubrication that combines the properties of the food surface with the perception of moisture and juiciness of the bolus. On the other hand, the mechanical parameters evaluated in current research included those of factor 1. Table 9 shows each food pattern evaluated related to mechanical behavior classification by Matsuo & Fujishima.\textsuperscript{[18]} The parameters of hardness, cohesiveness, or adhesiveness, in addition to viscosity, should be carefully considered in clinical care.\textsuperscript{[20]}
Sungsinchai et al.\cite{76} reported similar values for level 4 – (Pure) within the ranges of hardness, cohesiveness, and adhesiveness (Table 9), indicating that pure foods could be easily pressed between the tongue and the palate, allowing easy swallowing without chewing, thus facilitating the intake of nutrients by older adults with swallowing problems.

Suebsaen et al.\cite{70} evaluated the texture of banana gels with three thickeners, agar, carrageenan, and gelatin, identifying that those with agar gels had less adhesiveness, indicating a shorter time to be removed from the teeth and palate, contributing to safe swallowing. Sticky foods should be avoided as they have been associated with a high risk of suffocation and increased tongue work-induced into and through the pharynx. Banana gels with gelatin presented high cohesion because of the stronger internal bonds of gelatin when compared with other thickeners. So, cohesive foods keep the bolus together, preventing fragmenting during swallowing.

Villanueva et al.\cite{77} patented an adapted and ready-to-eat food product for the elderly with dysphagia, made with raw foods of plant origin and a thickening agent. The National Patient Safety Agency of the United Kingdom (2011) standardization applied was: Texture A (liquid puree with a smooth and uniform consistency), B (Pure uniform liquid eaten with a spoon), and C (thick moldable puree that does not require chewing). Merino et al.\cite{3} designed suitable menus for dysphagia using various gums as thickeners, selecting the maximum (F_{max}) and minimum (F_{min}) extrusion force.

Finally, results pointed out textures of levels 4-pure, 5-Minced & moist, and 6-soft & bite-sized for swallowing problems at looking forward to soft and non-adhesive food\cite{76,78,79}. Furthermore, foods with hardness (F_{max} > 40000 N/m^2), adhesiveness (A > 1000 J/m^3), and high adhesive force (AF > 1200 N/m^2) were categorized as level 7-Regular, being not able to supply for elderly with swallowing limitations due to the effect over the number of chews and slowed down the oral swallowing time, increasing the risk of pharyngeal residues, that cause suffocation.\cite{14,80}

**Conclusion**

Liquid, semisolid and solid foods that can usually be part of a suitable diet for older adults who may present with Alzheimer’s disease were categorized as liquid food patterns according to IDDSI, NDD, and dysphagia severity level; semisolid and solid patterns according to the IDDSI, Matsuo & Fujishima\cite{18} classification, and dysphagia severity level. The correlation with the rheological and mechanical behavior indicators is fundamental for designing new food products based on thickening agents. Liquid foods parameters indicated better opportunities for the elderly to improve swallowing limitations when behaving as pseudoplastic, thinning, and thixotropic fluids to avoid aspiration pneumonia and suffocation. Semisolid and solid foods categorized at levels 4-pure, 5-Minced & moist, and 6-soft & bite-sized had a better performance for swallowing problems at looking forward to soft and non-adhesive foods (F_{max} > 40000 N/m^2, A > 1000 J/m^3, AF > 1200 N/m^2), but foods categorized at level 7-Regular could increase the risk of pharyngeal residues, that cause suffocation.\cite{14,80} On the other hand, the particle reduction and the cooking process facilitate the intake of nutrients in older adults and people with swallowing limitations but should always be considered a proper balance between desirable cohesiveness and avoiding adhesiveness. Moreover, rheological and texture results associated with portion size, caloric density, dietary requirements, and food service temperature provide a better and broader food choice variability.

Finally, research outcomes open opportunities to harmonize foods’ rheological and mechanical attributes with the IDDSI classification, where thickeners must be added at a proper quantity by dysphagia severity level. On the other hand, the effect of starches, pectins, gums, or other thickeners should also be standardized on the sensory appreciation.
### Equations

| Equation number | Equations |
|-----------------|-----------|
| Eq. 1           | \( \sigma = \eta \dot{y} \) |
| Eq. 2           | \( \sigma = \sigma_0 K \dot{y}^n \) |
| Eq. 3           | \( \sigma = K \dot{y}^n \) |
| Eq. 4           | \( C = \frac{\text{Area}_2}{\text{Area}_1} \) |
| Eq. 5           | \( E = \frac{\text{Distance}_2}{\text{Distance}_1} \) |
| Eq. 6           | \( A = \frac{\text{NegativeArea} + 1}{\text{Distance}_1} \) |
| Eq. 7           | \( FA = -1 	imes \text{PeakNegative} \) |
| Eq. 8           | \( G = F + C \) |
| Eq. 9           | \( CH = G + E \) |

### List of variables

| Symbology | Meaning                      |
|-----------|------------------------------|
| \( \eta \) | Viscosity                    |
| \( \sigma \) | shear stress                 |
| \( \dot{y} \) | Shear rate                   |
| \( \sigma_0 \) | Elastic limit                |
| \( K \) | Consistency index            |
| \( n \) | Flow behavior index          |
| NF        | Newtonian                    |
| NNF       | Non-Newtonian                |
| PsF       | Pseudoplastic                |
| DF        | Dilatant                     |
| PLF       | Plastic                      |
| TF        | Thixotropic                  |
| RF        | Rheopectic                   |
| H         | Hardness                     |
| C         | Cohesiveness                 |
| E         | Elasticity                   |
| A         | Adhesiveness                 |
| AF        | Adhesive force               |
| G         | Gumminess                    |
| CH        | Chewiness                    |

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