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Natural Hydrocolloids in Texture-Modified Foods and Thickened Liquids for Dysphagia Management: Functional Characteristics, Clinical Perspectives and Future Directions

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Abstract:

Dysphagia is one of the most common swallowing disorders, affecting millions of people around the world, especially elderly and patients with neurological diseases such as stroke, Parkinson disease and dementia. Aspiration pneumonia, malnutrition, dehydration and an impaired quality of life are serious complications associated with the condition. Texture-modified foods (TMF) and thickened liquids are still a mainstay in dietary dysphagia management, with the goal to enhance bolus control and swallowing safety. Due to such properties, hydrocolloids are essential components of these formulations since they are able to control viscosity, cohesiveness and stability. For example, commercially available hydrocolloids such as xanthan gum and modified starches are in widespread use; however, there is a growing interest towards natural hydrocolloids due to their characteristics such as clean-label nature, health benefits, eco-friendliness in manufacturing processes and suitability for low-resource settings. This review aims to provides an overview of the current knowledge on natural hydrocolloids used in texture-modified foods and thickened liquids for dysphagia treatment. The physicochemical and rheological aspects of natural hydrocolloids are emphasized, such as okra mucilage, konjac glucomannan, chia seed mucilage, basil seed gum, flaxseed mucilage, psyllium husk and aloe vera gel. The relevance of the discussed mechanisms to swallowing safety and bolus control is discussed in terms of thickening, gel formation, water-binding capacity and behavior under physiological swallowing conditions. The review also provides an overview of the potential clinical applications of employing natural hydrocolloids such as improved visco-stability, nutrition enrichment, dietary fibre load and consumer acceptability. Critical review of existing evidence on their role in aspiration risk, hydration status, sensory perception, and patient compliance. Standardisation, extraction methods, shelf stability, regulatory approval and the limited amount of clinical trials are also examined.
The paper also covers emerging trends such as multifunctional hydrocolloid systems, personalized dysphagia nutrition, and new scientifically promising food structuring technologies (especially 3D food printing). These results indicate that natural hydrocolloids represent potential substitutes or adjuncts to traditional commercial thickeners, but further research is needed for standardized recipes and clinical proven indications. Interdisciplinary work integrating topics in food science, rheology, nutrition, and clinical dysphagia management is needed in the future to fully achieve the potential of natural hydrocolloids to improve dysphagia management by enhancing safety, acceptability and nutritional quality of texture-modified diets.

Keywords: Dysphagia, Natural hydrocolloids, Texture-modified foods, Thickened liquids, Rheology, Swallowing safety, Okra mucilage, Konjac glucomannan, Patient compliance, Functional foods.

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1. Introduction

1.1 Dysphagia: A Clinical Challenge

Dysphagia is a swallowing disorder defined by impaired safe and effective transport of food and fluids from the oral cavity to the stomach. Swallowing is a complex coordinated neuromuscular process with oral, pharyngeal and esophageal phases, and anything that impairs any part of this continuum will put the patient at risk for compromised swallowing safety. Dysphagia is a frequent sequela of aging, stroke, Parkinsons disease, dementia, amyotrophic lateral sclerosis (ALS), multiple sclerosis and in some cases of traumatic brain injury and head and neck cancer. With the world population ageing and dysphagia being a key challenge in social medicine, its increasing prevalence is of public health relevance[1]. Dysphagia is a disorder not only of swallowing but also one with significant clinical implications. That is that aspiration, the passing of material into the airway decreasing bolus control and compromising airway protection increases risk for aspiration pneumonia and thus accounts for a very high incidence in morbidity and mortality amongst our most vulnerable populations thus older adults as well as those with neurological impairment. Dysphagia is also associated with malnutrition, specific hydration shortage, incidental weight loss, length of hospitalization and a low quality of life. As a result, diet management has become an integral part of dysphagia management[2].

1.2 Texture-Modified Foods and Thickened Liquids

TMFs and thickened liquids are the basis of dysphagia management without medicine. They are mainly used to alter the physical properties of food and drinks in order to achieve swallowing safety, while ensuring adequate dietary intake. If liquids are thickened, the bolus flow in the oral cavity and pharynx is slowed sufficiently to give adequate time for closure of the airway therefore reducing aspiration. Similarly, changing food texture enhances bolus formation, control in the oral phase of swallowing, and swallowing efficiency. To promote consistency in clinical practice, this framework is based on the International Dysphagia Diet Standardisation Initiative (IDDSI), which verifiably classifies foods and drinks into specified texture and consistency stages using objective testing methods, worldwide standards. IDDSI has posts the global standard for developing (design) and describing/ prescribing texture-modified diets, making communication between Clinicians involved in care of these patients easier alongside researchers and food manufacturers as well.

Texture-modified diets improve the safety of swallowing, but their long-term acceptance still presents a challenge to clinicians. Poor sensory appeal and nutritional quality of many commercially available food paced products may result in reduced patient adherence and contribute to insufficient food and fluid consumption. These drawbacks have prompted the search for alternative functional ingredients with potential to yield a notable improvement of both product quality and nutritional functionality[3].

1.3 Hydrocolloids in Dysphagia Management

Hydrocolloids are hydrophilic biopolymers widely used in the food industry due to their ability to bind water, increase viscosity, gel formation, and stabilization of food systems. These functional characteristics provide the opportunity for precise control of food texture and rheological behavior, making hydrocolloids essential ingredients in both texture-modified foods and thickened liquids. Commonly used hydrocolloids in commercial dysphagia products include xanthan gum, modified starch, guar gum, carrageenan and alginate. These ingredients allow for consistent thickening and assure compliance with IDDSI consistency levels. Conversely, several commercial thickeners are limited by low nutritional value, poor sensory properties, susceptibility to enzymatic degradation or high production costs[4].

However, swallowing safety, as we made abundantly clear in our article regarding mechanisms and effects of foods become more complex and not only depend on viscosity†—ultimate advances in dysphagia research have resulted. Rheological properties including shear-thinning behavior, yield stress, viscoelasticity and bolus cohesiveness have gained increased attention in terms of their role as determinants of bolus control and swallowing function. Hence, an in-depth knowledge of both food rheology and swallowing physiology are essential for the appropriate selection of hydrocolloids[5].

1.4 Natural Hydrocolloids: Emerging Opportunities

The search for natural, sustainable and clean-label ingredients has led to the increasing demand for plant-based hydrocolloids as substitutes for traditional commercial thickeners. 0.2 Natural hydrocolloids formed from okra, konjac, chia and/or basil seeds, flaxseed, psyllium husk, and aloe vera have a great capability of water-binding [7], thickening and gelation [8], and are an excellent source of soluble/insoluble dietary fiber [9] as well as other significant bioactive components. In contrast to many of the contemporary thinkening agents, natural hydrocolloids combined rheological property and nutrition quality may be enhanced at the same time. As such, their inclusion within texture-modified diets provides opportunities to improve the safety of swallowing while facilitating hydration, supporting gut health, and improving nutritional status. In addition, many of those materials are renewable, locally available and align perfectly with the more recent trends to establish a more sustainable food production system[6].

Research on natural hydrocolloids, despite growing scientific interest, continues to be disorganized. While most published studies primarily deal with extraction methods, physicochemical characterization or generalized food applications, very few studies in fact assessed their specific role in dysphagia-relevant foods and/or compared the performance of these types of thickeners to commercial offerings.

1.5 Research Gap and Objectives

If we mainly focus on hydrocolloids then they got a good research in food science but the compiled reviews of natural hydrocolloids for texture-modified foods and thickened liquids are relatively sparse. To date, these publications have focused primarily on individual hydrocolloids or isolated rheological properties without holistic integration of swallowing physiology, nutritional value, sensory quality and clinical applicability. The yield, bolus cohesiveness, stability in the process of mouth processing and adherence to IDDSI standards also need to be a larger area of focus.

Thus, this review systemically assesses the available data on the implementation of natural hydrocolloids for texture-modified foods and thickened liquids in dysphagia care. This review provides an overview of their potential sources, biochemical composition, functional properties and rheological properties, nutritional aspects and clinical implications and compares the performance of these novel bio-thermoplastic agents with conventional commercial thickeners. It additionally recognizes the existing voids in research, reviews the challenges we currently face and reflects on potential opportunities related to food design of safer, more nutrient-grown and patient-centric dysphagia foods based on natural hydrocolloids[7].

Figure 1. Conceptual framework illustrating the role of natural hydrocolloids in texture-modified foods and thickened liquids for dysphagia management.

2. Methodology

2.1 Literature Search Strategy

This structured narrative literature review critically assessed the currently available evidence on the use of natural hydrocolloids used in texture-modified foods and thickened liquids within dysphagia management. Four major scientific electronic databases — Pubmed, Scopus, Web of Science, and Google Scholar were searched to retrieve relevant publications. They comprise databases that yield coverage of research across the fields of food science, nutrition, rheology, biomaterials and clinical dysphagia[8].
The literature search included studies published in English until December 2025. The search was maximised using a combination of Medical Subject

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Headings (MeSH), keywords and Boolean operators (AND, OR) to optimize sensitivity as well as specificity. The main key words were "dysphagia", "texture-modified foods", "thickened liquids", "natural hydrocolloids", “okra mucilage”, “konjac glucomannan”, “chia mucilage”, “basil seed gum”; flaxseed mucilage"; psyllium husk; aloe vera gel; food rheology; viscosity, swallow safety and IDDSI[9].

2.2 Study Selection Criteria

The literature was chosen for its relevance to the objectives of this review. Eligibility criteria: Original research studies, review papers and clinical investigations in texture-modified foods and thickened liquids that described the physicochemical properties, rheological characteristics, nutritional quality, sensory functionality or clinical utilization of natural hydrocolloids. [10]
We excluded studies that only addressed non-food industrial applications, duplicate publications, conference abstracts without full text, editorials and articles not providing sufficient scientific information. Quality is based on peer-reviewed publications with well-described experimental methodologies and studies directly relevant to swallowing physiology, food texture modification or dysphagia management. [11]

2.3 Data Extraction and Synthesis

Data on the relevant information from the selected studies were critically reviewed and synthesized to provide a comprehensive overview of current knowledge. Data from each publication included type and source of hydrocolloid, chemical compositions, extraction methods, rheological properties, thickening and gelling mechanisms along with nutritional characteristics, sensory properties, and applications in dysphagia-directed food systems.
Instead of performing a quantitative meta-analysis, the results were synthesized in a thematic way. The literature was summarized on the basis of five major areas including classification and functional mechanisms of hydrocolloids, rheological behavior and application as individual natural hydrocolloids, nutrition and health benefits in regards to dysphagia management, clinical implications for the management of dysphagia patients, and current issues along with future research perspectives. This reasonably identified knowledge gaps and opportunities to combine data strands from food science, nutrition, rheology, and clinical practice[12].

Table 1. Scope and thematic coverage of literature included in the review.

Theme	**Key Aspects Reviewed**	**Relevance to Dysphagia Management**
Hydrocolloid Chemistry	Chemical composition, molecular structure, polysaccharide characteristics, extraction methods	Determines hydration behavior, thickening capacity, and gel formation
Functional Mechanisms	Water binding, swelling, viscosity development, network formation, gelation mechanisms	Influences texture modification and bolus stability
Rheological Properties	Viscosity, shear-thinning behavior, yield stress, extensional viscosity, cohesiveness	Critical for swallowing safety and bolus control
Natural Hydrocolloids	Okra mucilage, konjac glucomannan, chia mucilage, flaxseed mucilage, basil seed gum, psyllium husk, aloe vera gel	Potential alternatives to commercial thickening agents
Food Formulation Applications	Texture-modified foods, thickened liquids, gel-based systems, hydrocolloid blends	Supports development of dysphagia-friendly foods
Clinical Relevance	Swallowing safety, aspiration prevention, oral and pharyngeal bolus transit	Evaluates practical effectiveness in dysphagia care

Nutritional Implications	Dietary fiber, bioactive compounds, hydration potential, nutritional enrichment	Addresses malnutrition and dehydration risks
Sensory Properties and Compliance	Taste, mouthfeel, appearance, texture acceptance	Influences long-term adherence to dysphagia diets
Challenges and Limitations	Standardization, extraction variability, stability, regulatory issues	Identifies barriers to clinical implementation
Future Research Directions	Clinical validation, personalized nutrition, advanced food structuring, 3D food printing	Highlights opportunities for innovation and future development

Table 1. Scope and thematic coverage of literature included in the review, highlighting the major scientific areas considered in evaluating the potential application of natural hydrocolloids in texture-modified foods and thickened liquids for dysphagia management.

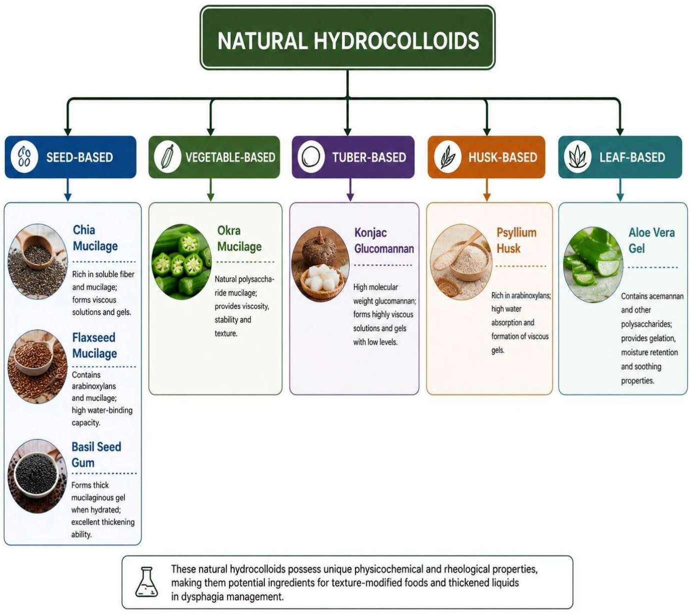

Figure 2. Classification of Natural Hydrocolloids Used in Dysphagia Management.

3. Hydrocolloids: Definition, Classification and Functional Mechanisms

Introduction Hydrocolloids because of their fascinating ability to alter texture, modulate rheological behaviour and trap complex food matrices are one of the most important functional ingredients utilized in modern food systems. These properties are especially important in dysphagia management, as they define the viscosity, cohesiveness and rheological properties of texture-modified foods and thickened liquids. The performance of a hydrocolloid is influenced not only by its capacity to modify viscosity but also by several other factors such as its molecular structure, hydration behavior, gel-forming ability and ability to interact with other food compounds. Knowledge of these properties is critical for the formulation of swallow-safe, nutrition/healthy products to serve patients with swallowing disorders[13].

3.1 Definition and Characteristics of Hydrocolloids

Hydrocolloids are polished, high-molecular-weight hydrophilic biopolymers that quickly interact with aqueous mediums to obtain viscous dispersions or gel systems. Most food hydrocolloids are polysaccharides derived from plants, microbes or marine sources, although some proteins can also display some hydrocolloid properties. Their functionality is mainly depending upon molecular weight, chain architecture, branch degree, electrical charge and hydrophilic functional group such as -OH or ─COOH. Hydrocolloid molecules, when dispersed in water, absorb water, hydrate and expand to produce three-dimensional polymeric networks. They are networks that create greater flow resistance, better water retention, and more stable food structures. Based on concentration and environmental conditions, hydrocolloids can form low-viscosity solutions, pseudoplastic fluids or elastic gels[14-16].

In contrast to conventional ingredients that primarily contribute to flavor or nutritional composition, hydrocolloids act mainly on the physical behavior of food. Due to their viscosity, ability to stabilize suspensions and emulsions, and the capacity to form gels at spoon-thick liquid or semi-solid food formulations intended for patients with swallowing disorders.

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3.2 Classification of Hydrocolloids

Natural hydrocolloids are classified into three base categories according to their biological origin, chemical composition and functional behaviour. Classification based on their botanical source is particularly useful from a food formulation perspective because structural characteristics relevant to potential applications are likely to correlate.

- Natural Hydrocolloids: Principal hydrocolloids discussed in this review are:
- Vegetable-derived: Okra mucilage
- Tuber-derived: Konjac glucomannan
- Food ingredients (derived from seeds)
- Seed husk-derived: Psyllium husk
- Leaf-derived: Aloe vera gel

With diverse origins through various plant tissues, these hydrocolloids yet retain the property of moisture retention and ultimately change the rheological properties of food systems. Nevertheless, their molecular structure is quite different which leads to significant divergence in fattening effectiveness, gelation behavior together with water-holding talent as well as sensory properties[17-20].

Table 2. Classification, composition, and functional characteristics of natural hydrocolloids relevant to dysphagia management.

Hydrocolloid	**Source**	**Major Polysaccharides / Components**	**Key Functional Properties**	**Potential Application in Dysphagia Management**
Okra Mucilage	Okra pods (*Abelmoschus esculentus*)	Galactose, rhamnose, galacturonic acid	Thickening, water retention, stabilization	Improves viscosity and bolus cohesiveness in texture-modified foods
Konjac Glucomannan	Konjac tuber (*Amorphophallus konjac*)	Glucomannan	Extremely high viscosity, gel formation, water binding	Suitable for thickened liquids and gel-based dysphagia foods
Chia Mucilage	Chia seeds (*Salvia hispanica*)	Soluble dietary fiber, mucilage polysaccharides	Thickening, emulsification, moisture retention	Potential natural thickener with added nutritional benefits
Flaxseed Mucilage	Flaxseed (*Linum usitatissimum*)	Arabinoxylans, rhamnogalacturonans	Water absorption, stabilization, viscosity enhancement	May improve bolus stability and hydration properties
Basil Seed Gum	Basil seeds (*Ocimum basilicum*)	Heteropolysaccharides	High viscosity, gel formation, water holding capacity	Promising ingredient for texture-modified beverages
Psyllium Husk	Psyllium (*Plantago ovata*)	Arabinoxylans	Exceptional water absorption and gel	Supports thickening and improved

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			development	swallowing control
Aloe Vera Gel	Aloe vera leaves	Acemannan and related polysaccharides	Gelation, moisture retention, stabilization	Potential use in soft-texture and gel-based dysphagia products

3.3 Physicochemical Properties

Several physicochemical properties influence the functional performance of natural hydrocolloids that further affects their sensory applicability for texture-modified foods.

Hydration Capacity: Hydration Hydrocolloid functionality starts with hydration. Polymer chains absorb water and swell on contact with moisture, forming hydrated systems that can increase viscosity and promote better moisture retention.

Water-Holding Capacity: Water-holding capacity describes the capacity of different hydrocolloids to retain water between their polymer network (Fauzi et al. Mizu(2015) noted that high water retention can lead to product stability, syneresis inhibition during storage and a better consistency of texture-modified foods after consumption.

Viscosity Development: Hydrated polymer chains become relatively long expanding into a network which in turn produces viscosity because the chains interact. High polymer concentration enhances resistance to flow since the effects vary with hydrocolloids arising from molecular weight and structural features.

Gel Formation: This category includes a group of hydrocolloids that form three-dimensional networks of gel via intermolecular interactions. Development of a protein gel has been shown to increase the overall structural rigidity and forming a more cohesive bolus for safe swallowing.

Stability: Hydrocolloids should show relatively stable functional behaviour under variable processing and storage conditions. Viscosity, gelation and product stability may be affected through temperature, pH, ionic strength or other ingredients that are mixed with food[21-24].

3.4 Functional Mechanisms in Food Systems

Hydrocolloids facilitate texture profiles which in turn also contribute to the functionality of food and this is created through hydrocolloid-water and hydrocolloid-food component interactions. Post-hydration, polymer chains expand / overlap leading to increased intermolecular entanglement and decreased molecular mobility. These interactions viscometrically increase viscosity, excel emulsion stabilization, and induce gel formation. Hydrocolloids further affect water distribution in food matrices, minimizing migration and preventing mix collapse. Over time, this leads to improved consistency of the product and a longer period of stability during storage.

Hydrocolloids can interact synergistically with proteins, starches and other polysaccharides within mixed food systems. These interactions can strengthen thickening, change gel rigidity in addition to boost sensory top quality. So the combinations of hydrocolloids are often used to achieve a synergistic effect on the performance of texture-modified foods[25].

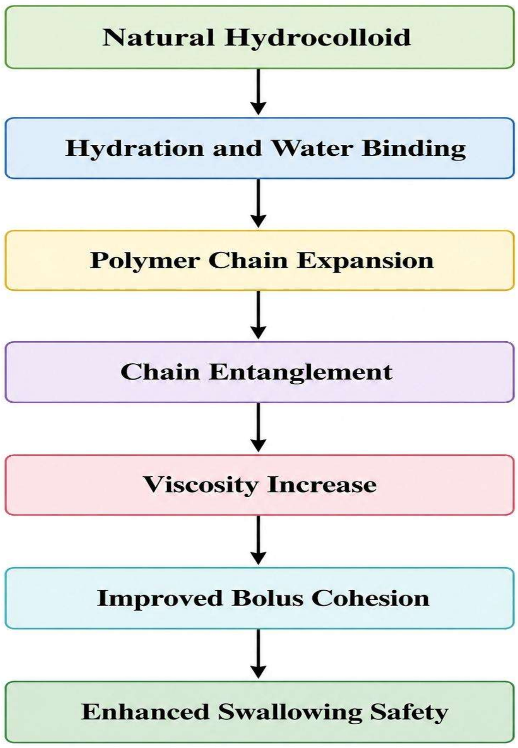

Figure 3. Mechanism of Hydrocolloid Action in Texture-Modified Foods

3.5 Relevance to Texture-Modified Foods and Dysphagia Management

Hydrocolloids exert an influence on the safety and effectiveness of texture-modified foods through their functional properties. They can increase viscosity, improve water retention, stabilize food structure and enhance bolus cohe- siveness thereby slowing bolus flow, and as such which contributes to safer swallowing by reducing the incidence. Recent research has shown that viscosity alone is insufficient to predict swallowing performance. In addition to those outlined above, other rheological properties such as shear-thinning behaviour, yield stress, viscoelasticity and bolus cohesiveness are also critical in determining swallowing safety. This indicates that a choice of hydrocolloid must be based on the overall rheological profile and not for one single property.

Among natural hydrocolloids, many of them not only exhibit certain rheological properties which are appealing for their potential use as fat replacers but also nutritional benefits like dietary fiber and bioactive compounds, thus providing simultaneous health-benefit functions. This multifunctional potential facilitates the creation of texture-modified foods that enhance not only swallowing safety but also improve nutritional quality and consensus among patients. Based on their utility, the subsequent section discusses the most important natural hydrocolloids in detail, describing their compositions and functional properties so as to select a suitable agent for management of dysphagia[26-28].

4. Natural Hydrocolloids Used in Texture-Modified Foods for Dysphagia Management

Because hydrocolloids have the ability to not only alter rheological properties but also improve nutritional quality, natural hydrocolloids have rightly attracted significant attention as functional ingredients in texture-modified food and thickened liquids developement. In contrast to traditional commercial thickeners, many hydrocolloids obtained from plants also have important additional physiological benefits (e. g., enrichment with dietary fiber, antioxidant activity, better hydration and even prebiotic potential). The multifunctional properties have enhanced interest in their use as clean-label alternatives within dysphagia movements of food systems.Natural hydrocolloids performance is inherently dependent on the structural molecular composition, interactions and capacity of hydration with water and in combination with other food components. Despite the fact that all hydrocolloids contribute to viscosity generation, each has its own distinctive functional traits in relation to gelling ability, water holding capacity, shear-thinning characteristics, bolus cohesiveness and sensory attributes. Thus, in the selection of suitable hydrocolloid would need to not only take into consideration the efficiency on thickening but also supplement with nutrition, profile stability of product availability to consumer acceptance and IDDSI texture level appropriateness.

Currently, a few plant-based hydrocolloids have been shown to have potential applications in texture-modified foods such as okra mucilage (OM), konjac glucomannan (KGM), chia seed mucilage (CSM), basil seed gum (BSG), flaxseed mucilage (FM), psyllium husk and aloe vera gel. Although these materials vary in their botanical source and chemical composition, they all contain hydrophilic polysaccharides with the ability to improve texture properties and swallowing safety when used in food. Nonetheless, the differences in terms of molecular structure and this results in wide variations with respect to rheological behaviour, hydration etc.Each hydrocolloid is discussed through critical analysis in reference to its source, chemical composition, physicochemical properties, rheological behaviours, nutritional characteristics and potential function in dysphagia. A brief overview of the current evidence, limitations and future research directions are also presented to determine their suitability in developing novel food processing techniques for texture-modified foods[29].

4.1 Okra Mucilage

Okra (*Abelmoschus esculentus L.*) is one of the recent and widely studied natural sources of plant mucilage gaining popularity as a new hydrocolloid for texture-modified foods. Okra contains a viscous texture from the complex polysaccharide-rich mucilage located primarily in pod tissues. Okra mucilage, a natural thickening agent used in soups and sauces for long time, has been studied as thickeners in dysphagia-oriented food systems by virtue of its better hydration capacity nutrient composition rheological properties.

4.1.1 Chemical Composition

The mucilage from okra mainly contains high-molecular-weight heteropolysaccharides including galacturonic acid, glucose, rhamnose, arabinose and mannose with varying proportions of galactose [19]. The ratios of these monosaccharides are dependent on cultivar, maturity, growing conditions and/or extraction methods. Okra mucilage not only consist polysaccharides but also small amounts of proteins, minerals, phenolic compounds and soluble dietary fiber which are relevant to its functional and nutritional properties.

These polysaccharides have plenty of hydrophilic functional groups that create strong interaction with water molecules, leading to rapid hydration and considerable viscosity build-up. This molecular structure is what gives it a natural thickening and stabilizing function[30].

4.1.2 Functional and Rheological Properties

One of the key properties of okra mucilage is its ability to produce high viscosity while retaining desirable flow behavior. Rheology studies have consistently shown that okra mucilage exhibits shear-thinning non-Newtonian behavior and viscosity decreases with increasing shear rate. This is a positive feature for dysphagia management, as products stay so viscous when at rest that they maintain bolus structure while reducing the ease of transport during oral processing and swallowing. Okra mucilage possesses good water holding capacity, also retains high moisture content along with moderate gel forming ability. These characteristics lead to increased stability of the product, reduced syneresis and increased cohesiveness in the bolus. The viscosity characteristics of okra mucilage and its unique properties for water retention makes it an appropriate candidate in the formulation of thickened beverages, pureed foods, soup, sauce and other texture-modified products[31].

4.1.3 Nutritional and Health Benefits

Unlike many commercially thickening agents, okra mucilage delivers have a nutritional advantage and technological functionality. The high soluble dietary fiber content may promote digestive health, increased stool frequency and improved glycemic control. Additionally, the concentration of phenolic compounds and flavonoids offers antioxidant activity which may be beneficial, however their clinical significance in dysphagic populations needs to be further explored.

Dietary quality may be augmented without increasing the risk of swallowing disorders by adding okra mucilage to texture-modified foods. This multipurpose role provides a substantial benefit over conventional thickeners that act on food texture modification[32].

4.1.4 Potential Applications in Dysphagia Management

Okra mucilage is promising as a mucoadhesive emulsifier biomaterial due to its physicochemical and rheological properties relevant for dysphagia-oriented food systems. Its high water-holding capacity and shear-thinning nature promote the formation of cohesive boluses that can be moved more easily through the oral cavity and pharynx. These characteristics are especially important for people who have delayed swallowing reflexes or diminished oral motor control.

Examples of potential strainers are food products to thicken thickened beverages, purees and solids/meals, nutritional supplements in gel form or hydrocolloid blends targeting specific IDDSI levels. Okra mucilage can also be incorporated with other natural hydrocolloids to optimize its viscosity and improve sensory properties, in addition to increasing the stability of the product[33-35].

4.1.5 Current Challenges and Future Perspectives

However, several challenges have limited the broad use of okra mucilage in dysphagia management despite the fact that this polysaccharide shows high potential. Chemical (composition and rheological, processing method) differences between botanical origin, cultivation condition, preparation method can also affect chemical formation of the study that results inheterogeneouschemicalandrheologicalperformancesbetweenstudies. Moreover, the majority of evidence is derived from laboratory-scale studies, while clinical trials assessing swallowing safety, subjective acceptability and long-term nutritional efficacy are still scarce.Ongoing explorations should leverage standardized extraction protocols, detailed rheological characterization under physiological conditions, and carefully controlled clinical studies in persons living with dysphagia. Sensory evaluation, formulation optimization and development of multifunctional hydrocolloid blends providing improved swallowing safety and nutritional quality should also be prioritized in this context.

In summary, there is currently growing evidence that identifies okra mucilage as a major natural hydrocolloid with high potential in the generation of next-generation texture-modified foods. The combination of the desirable rheological properties, nutritional benefits and s sustainable availability render it a good candidate for clinical and industrial application in the future[36-38].

4.2 Konjac Glucomannan

Konjac glucomannan (KGM) is a water-soluble polysaccharide isolated from the tuber of *Amorphophallus konjac*. It is one of the most studied natural hydrocolloids, due to its excellent water-holding capacity, high polymer weight and strong thickening capabilities. Of the plant hydrocolloids, KGM is unique in its highly viscous solutions and stable gel networks produced with relatively low concentrations, especially and particularly appropriate for texture-modified foods and thickened liquids consuming dysphagia.
KGM has attracted considerable attention beyond its technological-related applications as a functional food ingredient for the potential physiological benefits, such as dietary fiber enrichment, glycemic regulation, cholesterol reduction and prebiotic activity. KGM, with the strong combined rheological performance and nutritional functionality from unique cellulose structure endow it a canvas for possible one of the most potential natural substitutes on existing commercial thickeners.

4.2.1 Chemical Structure and Functional Characteristics

Konjac glucomannan consists predominantly of β-(1→4)-linked D-mannose and D-glucose units with a mannose-to-glucose molar ratio of about 1.6:1. The polymer is a high molecular weight polymer with many hydroxyl groups that can lipid and hydrogen bond to water molecules. This special molecular architecture facilitates fast hydration, large swelling and high viscosity formation.
In contrast to many other natural hydrocolloids, KGM is capable of achieving high viscosity at low concentrations. KGM can also form strong thermo-irreversible gels under appropriate conditions, such as alkaline treatment or interaction with other hydrocolloids. These traits confer very good structural stability and versatility of KGM in food applications[39].

4.2.2 Rheological Properties

The ability of KGM to alter the rheological behaviour is one of the most significant advantages of its use in dysphagia-oriented food formulation. KGM solutions under hydrated conditions demonstrate strong non-Newtonian shear-thinning behavior, decreasing viscosity under shear while remaining adequately viscous at rest to hold bolus form. Such a rheological response enables oral processing and swallowing and minimizes loss of the bolus into the airway before a swallow reflex is achieved (compensating physiological adaptation).
As the viscosity of KGM is also relatively high, it affects yield stress, water-holding capacity and gel strength. The properties which enhance bolus cohesiveness and structural stability are both critical for swallowing safety. Many rheological studies have shown that KGM-based formulations are more viscous stable than starch-based systems under conditions of oral processing when salivary α-amylase rapidly degrades starch thickeners.
Concentration, temperature, pH, ionic strength and protein or other polysaccharide interactions also affect KGM functional performance. Food formulation optimization is needed to develop consistency and sensory properties corresponding to the different IDDSI texture levels[40].

4.2.3 Nutritional and Physiological Benefits

KGM is not only as a thickener and stabilizer but also has many health benefits because KGM is one of the richest natural sources of soluble dietary fiber. Many studies have demonstrated efficacy in regard to gastrointestinal function, glycaemic control, reduction of serum cholesterol and body weight control. Most of these effects are linked to its high viscosity and fermentability in the gastrointestinal tract.
KGM exhibits some prebiotic property in boosting beneficial gut microorganisms, to produce more short-chain fatty acids that contribute intestinal health. These physiological advantages are especially meaningful to the elderly and those suffering from chronic neurological conditions who often also have constipation and metabolic imbalances with their dysphagia. The use of KGM in texture-modified foods thus offers synergy towards the simultaneous enhancement of both swallowing risk and nutritional quality[41].

4.2.4 Applications in Texture-Modified Foods

It has been well incorporated into various foods such as beverages, pureed and dairy products, gel-based desserts, nutritional supplements, and functional food. Its outstanding thickening efficiency means that it is

often used in lower amounts to reach the necessary dysphagia stage.
KGM is often blended with many other hydrocolloids such as xanthan gum, carrageenan, locust bean gum and plant mucilages, to enhance the gel strength, slow down or minimize syneresis and maintain the sensory properties. This type of synergistic interaction opens up a way for the development of texture-modified foods with better stability, improved mouthfeel and higher consumer acceptability[42].

4.2.5 Limitations and Future Research

Although KGM has many advantages, it also has some limitations. Overly high concentrations may yield gels with excessive firmness or elasticity that are inappropriate for some dysphagic patients. Additionally, formulation variables (pH and processing conditions) and/or storage time may affect its rheological behaviour and sensory characteristics disadvantageously.While many laboratory studies have described the physicochemical properties of KGM, further clinical studies are needed to assess swallowing biomechanics, aspiration risk, patient acceptability and nutritional adaptation. Preliminary studies on the synergistic mixtures of KGM with other natural hydrocolloids have been also applied to prepare various multifunctional texture-modified foods that could meet the expectations from both clinical and consumers in terms of sensory, processing properties, and coverage functionality in future studies.
In summary, konjac glucomannan is one of the most scientifically evidence based natural hydrocolloids currently available for dysphagia management. Due to its remarkable thickening emulsifying capacity, pseudoplastic rheological behavior, documented potential physiological benefits, it is now important landmark for the development of novel and presumably healthier gluten-free structurally texturised food products[43].

4.3 Chia Seed Mucilage

Chia (*Salvia hispanica L.*) is in the spotlight as a superfood due to its favorable nutritional composition and special hydration properties. An initial study conducted between 2009 and 2010 analysed the properties of chia seeds, showing that upon contact with water, its outer epidermal layer very quickly exudes a transparent mucilage of soluble polysaccharides. This hydrated mucilage results in a viscid layer surrounding the seeds and behaves as a hydrocolloid, which has been increasingly attracting interest for food formulation, specifically clean-label/health-oriented products.
Chia seed mucilage has recently attracted attention as a potential natural thickener for texture-modified foods due to its positive rheological properties and nutritional functionality. In contrast to various commercial hydrocolloids that mainly serve as consistency modifiers, chia mucilage is a source of dietary fiber, omega-3 fatty acids, proteins (valuable amino acid profiles), antioxidants, vitamins and minerals. This multifunctional property of chia offers the potential as a functional ingredient in the preparation of dysphagia oriented foods that can improve both swallowing safety and nutritional quality in patients[44].

4.3.1 Chemical Composition and Structure

The functional attributes of chia mucilage are derived from its polysaccharide composition. Mucilage is primarily composed of highly branched heteropolysaccharide species such as xylose, glucan, arabinose, galactose, glucuronic acid and other minor monosugars. Such polysaccharides have abundant hydrophilic function groups with the ability to bind large amounts of water.
Aside from the soluble polysaccharides, chia seeds contain around 30–35% dietary fiber, 15–25% protein, 30–35% lipid and are one of the richest plant sources of α-linolenic acid (ALA), an essential omega-3 fatty acid. In addittion, they are a source of calcium, magnesium, phosphorus, potassium and multiple antioxidant substances such as polyphenols and flavonoids.
The unique combination of dietary-fiber polysaccharides and bioactive components makes chia different from many other hydrocolloids that primarily act as thickening agents.

4.3.2 Rheological and Functional Properties

Chia mucilage has a high hydration capacity and provides viscosity immediately after absorption of water. When hydrated, these chains swell and form a continuous structure capable of holding large amounts of water. These dispersions normally show non-Newtonian shear-thinning characteristics, a feature particularly deleterious in the management of dysphagia.
In the case of shear-thinning systems, there is an adequate level of stiffness at rest in order to retain bolus

structure yet lose viscosity with the mechanical forces imposed on the material during chewing and swallowing. This results in more effortless transportation of the bolus while minimizing the risk of uncontrolled airway penetration. Apart from increasing viscosity, chia mucilage also aids to bind moisture as it acts in conjunction with water through emulsion stabilization and retention, moderate gel formation and moisture preservation [9]. These give properties that stabilize the products and can enhance the sensory characteristics of texture-modified foods.

On the other hand, chia mucilage generically has lower viscosity than konjac glucomannan at comparable concentrations. Thus, manipulation of formulation variables or combination with complementary hydrocolloids should be performed to achieve targeted IDDSI textures[45].

4.3.3 Nutritional Significance

The exceptional nutritional profile of chia mucilage is one of its major benefits. Patients with dysphagia often have inadequate nutrient intake (through low food consumption, limited dietary variety). The addition of dietary chia to texture-modified foods offers a unique opportunity to fortify these products with significant amounts of dietary fibers, protein (with a higher biological value than proteins from other plant sources), omega-3 fatty acids, minerals and antioxidant compounds.

Chia is also high in soluble fiber, which may improve gastrointestinal function, bowel regularity and postprandial glucose modulation. These compounds are also known for their cardiovascular protection and antioxidant activity, but whether they provide distinct clinical benefits in people with dysphagia requires further study.From the point of view of nutrition, chia mucilage has benefits that go beyond modifying texture towards potentially supporting multi-functional dysphagia foods, too.

4.3.4 Potential Applications in Dysphagia-Oriented Foods

Since chia mucilage has both rheological functions and nutritional value, it can be added to all kinds of texture-modified food products. Possible applications are viscous liquids, fruit semi-gels, pureed foods, dairy food products and functional high-fiber food supplements for people with swallowing disorders.

Additionally, chias mucilage can be incorporated with other natural hydrocolloids including konjac glucomannan, psyllium husk or okra mucilage to increase viscosity and gel strength and the stability of solid-in-solids emulsions without compromising on sensory properties. These combinations can help create well-balanced formulations which meet both the rheological needs and nutritional ones[46].

4.3.5 Current Challenges and Future Perspectives

Although the biomarker has favorable characteristics, it still has some limitations worthy of consideration before its clinical use becomes widespread. Chia mucilage rheological behavior is affected by the seed variety and cultivation conditions, extraction methods, hydration time, and concentration. This requires standardized protocols for GAN extraction and formulation in order to obtain a consistent product quality.

Moreover, there is a notable lack of direct evidence evaluating clinical efficacy and safety for chia-based texture-modified foods within dysphagic populations. A majority of the studies currently available have focused on physicochemical characterization or general food applications rather than swallowing biomechanics or aspiration prevention.

Further studies need to test the function of chia mucilage under physiologic swallowing conditions, establish suitable doses for targeted IDDSI levels and conduct characterized clinical trials on acceptability with patients. Research investigating synergistic structures with various other natural hydrocolloids may continue to improve the functional efficiency of chia-based systems.

In conclusion, chia seed mucilage is a potential multi-functional hydrocolloid with appropriate rheological properties and high nutritional value. The addition of inulin to texture-modified foods may not only make them safer for swallowing, but also better quality food from a dietary standpoint, and therefore an attractive ingredient for food development targeting dysphagia in the future.

4.4 Basil Seed Gum

Basil seed gum (BSG) is an all-natural hydrocolloid derived from the outer mucilaginous layer of basil seeds (*Ocimum basilicum L*). In the last several years that it has garnered great attention in food science because of its superior thickening efficiency, large water-holding capacity and suitable rheological characteristics. Basil seed gum demonstrates excellent functionality at low

concentrations relative to many conventional plant gums, implying its potential in the development of clean-label and texture-modified food products.
The rising interest in basil seed gum is not merely due to its techno-functional performance but also the fact that it derives from a renewable plant-based source, and combine with consumer demand for natural food ingredients. Despite its limited application in the management of dysphagia, its physicochemical properties indicate significant potential as a means to enhance consistency, stability and sensory properties of texture-modified foods[47].

4.4.1 Chemical Composition and Structural Characteristics

They are essentially large-molecular-weight hetero-polysaccharides have been reported to be composed of xylose, arabinose and uronic acids like rhamnose, galacturonic acid and glucose. The relatively high density of hydrophilic hydroxyl and carboxyl groups in the structure allows to hydrate quickly, leading to a considerable increase in swelling and viscosity upon hydration.
Polysaccharide structure of basil seed gum contributes to a highly hydrated polymer network, which leads to good thickening performance and moisture retention. This structural feature also reinforces its stability at various processing processes, which include temperature and pH changes, expending in a diverse group of food formulations.

4.4.2 Rheological and Functional Properties

Basil seed gum is known for its excellent rheological properties among plant- derived hydrocolloids. Hydrated dispersions show a high apparent viscosity, pronounced shear-thinning behavior and substantial water-binding capacity. These properties are beneficial for dysphagia-targeted foods as they enable the bolus to be cohesive while at rest and more easily transportable during swallowing.

- Basil seed gum also demonstrates:
- Excellent moisture retention
- High emulsion stability
- Moderate gel-forming ability
- Reduced syneresis
- Improved freeze–thaw stability

These functional properties account for producing stable food systems with a firm texture during processing as well as storage. Moreover, the gum exhibits synergistic interactions with proteins and other hydrocolloids, enabling food formulators to tailor viscosity and enhance product stability. Basil seed gum is mostly effective at low dosage compared with some other natural hydrocolloids due to relatively high viscosity produced by these gums[49].

4.4.3 Nutritional and Functional Significance

In addition to the technological functionality of basil seed gum in the food, it may also provide added nutritional values from its soluble dietary fiber. High dietary fiber intake has been linked to better gastrointestinal health, bowel function, and postprandial glucose metabolism.
The gum has fewer bioactive compounds than chia or flaxseed; however, its clean-label source and fiber content continue to be desirable qualities for functional foods. Basil seed gum gives manufacturers an efficient texture enhancer while allowing the finished product to maintain a relatively clean label which has gained importance among consumers and health care providers.

4.4.4 Potential Applications in Dysphagia Management

The rheological properties of the gum revealed its potential use in texture-modified foods and thickened liquids. Its high viscosity, water-holding capacity and shear-thinning behavior favor cohesive bolus formation that may enhance swallow safety.

- Potential applications include:
- Thickened beverages
- Pureed foods
- Dairy-based nutritional products
- Functional desserts
- Gel-based formulations
- Blends of hydrocolloids formulated with IDDSI texture levels

Since basil seed gum is effective at relatively low concentrations, it could improve some aspects of the sensory characteristics of texture-modified foods such as excessive gumminess or undesirable mouthfeel that occur with higher levels of other thickening agents.

4.4.5 Current Limitations and Future Perspectives

Although basil seed gum shows potential as a technological agent, the number of studies on its use specifically for dysphagia treatment is still sparse. The majority of published investigations have only ranged from rheological profiling, extraction optimization or traditional food applications rather than swallowing physiology and clinical utility.

More studies are warranted to study this during oral processing, interactions with saliva, bolus formation, and aspiration reduction. Clinical studies in humans dysphagic individuals are especially crucial to determine ideal concentrations, tolerance and chronic safety.

Furthermore, the application of synergistic combinations of basil seed gum with another natural hydrocolloid (e.g. konjac glucomannan, chia mucilage or psyllium husk) in order to obtain multifunctional texture-modified foods with superior rheological profile, nutritional value and sensory acceptance should be investigated in future studies.

In summary, basil seed gum is a highly promising yet underutilised natural hydrocolloid. It has favourable rheological behaviour, clean-label characterisation and excellent thickening efficiency which makes it a promising potential agent for dysphagia-targeted foods with clinical evidence being a limiting factor of mainstream application.

4.5 Flaxseed Mucilage

Flaxseed (*Linum usitatissimum L.*) is an essential functional food and has been well studied due to its high content of fibre, antioxidant lignans and bioactive phytochemicals, especially of ω-3 fatty acids. When hydrated, the outer layer of the flaxseed releases a mucilage Bouaziz (1998), which mainly consists of polysaccharides soluble in water. In fact, this mucilage has drawn more attention as a natural hydrocolloid due to its ability to thicken, emulsify, retain moisture and nutritional value.

Flaxseed mucilage offers a well-balanced mixture of technological functionality and health-promoting properties in comparison with other natural hydrocolloids. Despite its lower thickening efficiency overall relative to konjac glucomannan or basil seed gum, its high dietary fiber content and multifunctional properties render it a desirable ingredient for the development of nutritionally improved texture-modified foods.

4.5.1 Chemical Composition and Structural Characteristics

Flaxseed mucilage is composed mainly of two polysaccharides fractions: a neutral arabinoxylan-rich fraction and an acidic rhamnogalacturonan-rich to intermediate glucoronoxylan rich fractions. The numerous hydrophilic functional groups of such polysaccharides induce molecular hydration and viscosity promoting effects [10].

Flaxseed contains high proportions of soluble polysaccharides, dietary fiber, proteins, lignans and α-linolenic acid (an essential omega-3 fatty acid). These factors set flaxseed apart from standard hydrocolloids that primarily serve as rheological modifiers. As a result, flaxseed mucilage offers both technological function and nutritional augmentation in food systems.

4.5.2 Rheological and Functional Properties

Flaxseed mucilage also has some degree of desirable rheological properties for food including its water-binding capacity, viscosity enhancing potentiality, emulsion stabilizing and moisture-retaining abilities. Hydrated dispersions exhibit typically some non-Newtonian shear-thinning behavior, leading to the decrease of viscosity during oral processing and maintaining adequate structural stability at rest.

Even if the viscosity created by flaxseed mucilage is lower than from konjac glucomannan or basil seed gum, it still normally has enough for most texture-modified food applications. The mucilage also helps to improve emulsion stability and moisture retention which results in more consistent products during storage and consumption. Flaxseed mucilage rheology is strongly dependent on extraction approach, concentration, temperature pH and co-interaction (with proteins and other polysaccharides, fibres) [24]. These factors should be taken into account when developing formulations designed to adhere to IDDSI framework.

4.5.3 Nutritional Significance

Flaxseed mucilage has one major benefit — its high nutritional value. Flaxseed contains soluble dietary fiber which may improve GI function, support bowels regularity and help regulation of glycemia. In addition, the antioxidant activity of lignan compounds and omega-3 fatty acids properties implicated in cardiovascular health and anti-inflammatory effects.

Because patients with dysphagia often consume insufficient quantities of food and suffer from nutritional deficiencies, the addition of flaxseed mucilage in texture-modified foods could provide benefits other than improved swallowing safety. Its wide composition provides the potential to improve dysphagia diets regarding its nutritional quality and physiological value.

4.5.4 Applications in Texture-Modified Foods

Flaxseed mucilage has been developed in many food products such as bakery products, dairy alternatives, beverages and sauces but also functional foods. It is already known for its outstanding water holding and stabilizing characteristics, which facilitate the design of smooth and homogeneous food matrices aimed to modify texture.
Flaxseed mucilage shows promising applications through dysphagia-oriented food systems in:

- Thickened beverages
- Pureed fruit and vegetable products
- Nutritional supplements
- High-fiber texture-modified meals
- Blends of hydrocolloids that are engineered to maximize their rheological attributes

The viscosity is likely to be improved by the dominant hydrocolloid such as konjac glucomannan or psyllium husk, which provides increased gel elasticity and simultaneously improves nutritional quality by binding with flaxseed mucilage in a complex form.

4.5.5 Current Limitations and Future Perspectives

Research of flaxseed mucilage for dysphagia remains limited but shows promise. The majority of published studies have examined food formulation, physicochemical characterization or nutritional applications rather than clinical swallowing performance. Future studies need to examine the rheology of flaxseed mucilage under swallow-simulating conditions, identify best-mimicking concentrations for each of the IDDSI levels of texture and confirm patient acceptance through clinical trials. Future exploration of specific interplay with other natural hydrocolloids may also help developing multi-functional texture-modified foods enhanced with more desired sensory/chemical properties and higher nutritional value.

In summary, this review provides an assessment of the flaxseed mucilage as a new and potential rheological stable source of natural hydrocolloid with a balanced viscous performance and many nutritional advantages. Further clinical evidence is needed, but its multifunctional attributes position it well for development as a next-generation food ingredient targeting dysphagia, producing efficacy by simultaneously improving safety of swallowing whilst also enhancing overall nutritional status.

4.6 Psyllium Husk

Psyllium husk finds its origin in the outer seed coat of *Plantago ovata* and is considered as one of the most concentrated sources of naturally occurring soluble dietary fiber. Great absorption capacity in water, gel formation, and physiological health advantages, has led to frequent use by the sector of pharmaceuticals and food. Psyllium husk as a natural hydrocolloid for texture-modified foods has attracted much interest in recent years, due to its capacity of producing stable highly hydrated gel systems that can increase food consistency while simultaneously improving the nutritional quality.
Psyllium husk not only combines very good rheological properties with established health benefits, it also presents some unique advantages over many common thickening agents. Such multifunctionality makes it a potential ingredient to formulate foods targeted at dysphagia, addressing the immediate safety of swallowing as well as nutritional wellbeing in the long-term.

4.6.1 Chemical Composition and Structural Characteristics

Research has pointed to the soluble arabinoxylan polysaccharides in psyllium husk, which are responsible for many of its functional properties. Such highly branched polymers have high density of hydrophilic groups and can easily trap water which leads to large swelling and gel formation when hydrated.
Psyllium is composed of high amounts of soluble fiber, with smaller quantities of insoluble fiber, proteins, minerals and trace phytochemicals. Contrary to it, its techno-functional performance is mainly attributed to the soluble polysaccharide fraction which can create very well hydrated three-dimensional networks that immobilize high amounts of water.

The impressive ability to hold water gives psyllium a unique property, especially among plant-derived hydrocolloids, and this property helps explain why it is effective as natural thickener / stabilizer.

4.6.2 Rheological and Functional Properties

Psyllium husk has great rheological properties that are particularly important for texture-modified foods. When hydrated, the polysaccharide chains quickly take up water and swell to form very viscous dispersions with pronounced non-Newtonian shear-thinning characteristics. The properties of the product are designed for mechanical effects (eg, friction between teeth when chewing), or dissolution to preserve structural stability during storage but facilitate manipulation and swallowing under stress during oral processing.
The main functional properties of psyllium husk are as follows:

- Exceptional water-holding capacity
- Rapid viscosity development
- Shear-thinning flow behavior
- High moisture retention
- Improved bolus cohesiveness
- Enhanced product stability

These attributes enhance the formation of cohesive boluses that are more resistant to disintegration during swallowing and ultimately result in safer transportation of bolus through the oral cavity and pharynx.
In comparison with starch-based thickeners, psyllium-based systems usually showed higher viscosity stability and less sensitivity to viscosity loss in the mouth. This stability is beneficial to facilitate reliable swallowing behaviour.

4.6.3 Nutritional and Physiological Benefits

Psyllium husk is a common natural remedy with many of its health benefits backed by clinical evidence. The big soluble fiber factor facilitates higher gastrointestinal operation, better bowel regularity and increased stool water content, therefore psyllium is one of the most frequently claimed dietary fibers used for managing constipation.
Over the years, a huge amount of studies also shows that improved glycemic control is associated through psyllium supplementation due to slowed carbohydrate absorption and reduced postprandial blood glucose responses. Moreover, habitual ingestion is linked to decreased serum low-density lipoprotein (LDL) cholesterol levels and cardiovascular health.
Such physiological impacts are especially significant since patients with dysphagia tend to be older adults with many concomitant chronic conditions (diabetes mellitus, cardiovascular disease, and disordered eating) which can compound its detrimental effects on health status. Hence, the addition of psyllium to texture modified foods could result in health benefits that go deeper than safe swallowing.

4.6.4 Potential Applications in Texture-Modified Foods

The rheological and nutritional properties of psyllium husk can transform the characteristics in a variety of dysphagia-oriented food products. Applications can be variegated including thickened beverages, pureed food items, high fiber dietary supplements, functional dessert products and gel-based formulations.
Likewise, the use of psyllium husk associated with hydrocolloids such as konjac glucomannan, chia mucilage or basil seed gum can be performed aiming to optimize viscosity and moisture retention while improving sensory quality. The innovation in food systems presented by such combinations may make it possible to develop texture-modified foods that meet IDDSI consistency requirements while enhancing nutritional value. But due to its thickening properties, concentrations of psyllium need to be carefully optimized as too much can result in products that are too thick or difficult to swallow.

4.6.5 Current Limitations and Future Perspectives

While the nutritional aspects of psyllium husk are well documented, specific investigations of its use in treating dysphagia have been sparce. Published investigations predominantly focused on gastrointestinal physiology or functional food development rather than swallowing biomechanics and aspiration prevention.
In future studies, the effect of psyllium on bolus formation, oral processing, pharyngeal transit and patient acceptance in a clinical setting should be evaluated. Standardized rheological characterization in conjunction with instrumental swallowing evaluation will be required to establish its appropriateness at various IDDSI texture levels.

In summary, psyllium husk appears as one of the most promising natural hydrocolloids for texture-modified foods due to its high water-holding capacity, low/medium viscosity, and significant nutritional effects. Ongoing research will continue to identify the ideal role of this functional food/plant-based ingredient in the production of safe, nutritionally-optimised and patient-centric dysphagia diets.

4.7 Aloe Vera Gel

Aloe vera (*Aloe barbadensis* Miller) is complex succulent plant known for several medicinal, pharmacological as well food uses. The clear gel extracted from inner leaf parenchyma consists of a complex association of water soluble polysaccharide, vitamins, minerals, amino acids, enzymes and phenolic compounds. Aloe vera traditionally reflects its therapeutic properties but natural hydrocolloid could be the potential application in a functional food system.
Aloe vera gel has a significantly lower thickening capability than some of the other plant hydrocolloids being emphasized in this review. However, despite being an excellent hydrating agent and possessing a pleasant mouthfeel and bioactive-rich composition, it seems to have more appropriate possible uses as an adjunct in texture-modified foods rather than as a main thickening ingredient. These traits are of course relevant to dysphagia, with swallowing safety and patient uptake both key factors[50].

4.7.1 Chemical Composition and Structural Characteristics

Aloe vera gel is made up of about 98–99% water, with the solid component consisting of polysaccharides, proteins, amino acids, vitamins, minerals, organic acids and a wide range of phytochemicals. The main polysaccharide is acemannan, an acetylated glucomannan essential for the gel's functional characteristics. Acemannan has several hydrophilic functional groups who can connect with water and make hydrated polymer diluted systems. Analytically, it also includes minor amounts of pectic substances, hemicelluloses and additional carbohydrate polymers to moisturize the firm capacity and elastic properties.
Due to its relatively high water content and polysaccharide composition, aloe vera gel are effective as a moisture-retaining agent in products, and help produce smooth homogeneous food textures.

4.7.2 Rheological and Functional Properties

Foundations of the rheological behavior of aloe vera gel differ from those demonstrated by highly viscous hydrocolloids (but not within the similar group), for instance, konjac glucomannan or psyllium husk. Generally speaking, hydrated aloe vera formulations are moderately viscous and non-Newtonian shear-thinning. While its gelling functionality is not as effective in comparison, aloe vera gel has several functional benefits that are advantageous for the formulation of texture modified food systems.
Important functional properties include:

- Excellent moisture retention
- Moderate viscosity enhancement
- Smooth gel texture
- Good emulsion stabilization
- Improved mouthfeel
- High hydration capacity

These characteristics help to create gentle and cohesive food matrices, while also enhancing sensory quality. As a result, aloe vera gel is usually referred to as more of a secondary hydrocolloid that will support the texture and hydration properties of products than it would if used alone as an emulsifying thickener.

4.7.3 Nutritional and Physiological Benefits

It is primarily used in the texture-modifying action of aloe gel, however, it possesses numerous health-beneficial properties owing to its bioactive constituents. Acemannan is known for antioxidant, anti-inflammatory, immunomodulatory and wound healing activities. Moreover, aloe vera also provides vitamins C and E, minerals, amino acids, and phenolic compounds that contribute to nutritional value.
While these physiological effects have mainly been studied within the fields of pharmaceutical and biomedicine, they may potentially confer added benefits when included in texture modified foods containing aloe vera. The increased hydration from aloe vera gel may also be due, in part, to its high moisture content which is an even more critical factor for dysphagic individuals who often consume less fluid than necessary.
Nevertheless, more clinical studies are still needed to quantify the stability and health relevance of these bioactive compounds in dysphagic subjects following food processing.

4.7.4 Potential Applications in Texture-Modified Foods

Aloe vera gel has a mild flavour, translucent texture and smooth consistency therefore it can be used in many types of food product without causing much change on their sensory properties. Its possible use would vary from thickened beverages and fruit gels to pureed desserts, dairy and moisture-enhanced texture-modified foods.
It can also be valuable in conjunction with other stronger hydrocoids such as konjac glucomannan, basil seed gum or psyllium husk rather than performing the function alone. The combinations may improve hydration, mouthfeel and consumer acceptance while preserving tha rheological properties for safe swallowability.
Multi-functional hydrocolloid blends containing aloe vera is a new emerging research field with great potential for the future of dysphagia-specific food products.

4.7.5 Current Limitations and Future Perspectives

Objectives: 1 to report the utilization of aloe vera as a functional food ingredient, 2 list the potential application of Aloe Vera in dysphagia, and 3 explore if evidence exist-supporting them. Most of the studies available have either examined its medicinal properties or food in terms of general applications rather than swallowing physiology and texture-modified foods.
Further studies are required to explore the rheological behaviour of aloe-vera containing formulations under physiologically-relevant swallowing conditions, defining ideal formulation strategies, including patient experience via clinical trials. Synergistic interactions with other natural hydrocolloids should also be investigated future work, helping to increase both functional performance and sensory quality.
In conclusion, aloe vera gel may be considered a valuable complementary hydrocolloid instead of the main thickening agent. Due to its good hydrating properties, smooth mouthfeel and bioactive composition, it emerges as an ingredient for developing multifunctional texture-modified foods that can be beneficial in swallowing safety, hydration and nutrition.

Table 3. Comparison of Natural Hydrocolloids Used in Dysphagia Management

Hydrocolloid	**Source**	**Main Components**	**Thickening Ability**	**Nutritional Value**	**Dysphagia Potential**
Okra Mucilage	Okra pods	Polysaccharides	High	High	High
Konjac Glucomannan	Konjac tuber	Glucomannan	Very High	Moderate	Very High
Chia Mucilage	Chia seeds	Soluble fiber, polysaccharides	High	Very High	High
Basil Seed Gum	Basil seeds	Heteropolysaccharides	Very High	Moderate	High
Flaxseed Mucilage	Flaxseed	Arabinoxylans, rhamnogalacturonans	Moderate–High	Very High	High
Psyllium Husk	Psyllium seed husk	Arabinoxylans	High	High	High
Aloe Vera Gel	Aloe vera leaves	Acemannan and polysaccharides	Moderate	Moderate	Emerging

5. Rheological Properties of Natural Hydrocolloids and Their Role in Swallowing Safety

Rheological properties are one of the most important parameters for texture-modified foods and thickened liquids when used by patients with dysphagia. The response of food in the mouth and in the act of swallowing is related not only to its compositional properties but also to its flow resistance, structure stability, deformability under the mechanical force created by tongue weight and paratonic activity. Therefore, choosing the right hydrocolloids in dysphagia related foods requires full consideration to food rheology and swallowing physiology.

Natural hydrocolloids act to modify the texture of food through hydration, polymer swelling, and above all network formation which in turn affect viscosity, yield stress viscoelasticity, and bolus cohesiveness [1]. They integrate together to characterize bolus flow rate, oral control, pharyngeal transit and the final swallowing safety. Though regarded as the primary variable when defining dysphagia diets, traditional thinking states viscosity alone has not resulted in safe swallowing, whilst newer data suggest that optimal swallowing is a multi-rheological outcome (rather than a single measurement).

5.1 Importance of Rheology in Dysphagia Management

Coordinating swallowing involves careful timing of bolus formation, oral propulsion, airway protection, and esophageal transport. In fact, this coordination is often disrupted in patients with dysphagia due to impaired neuromuscular function, compromising their airway protection and increasing the risk of aspiration and pharyngeal residue. Texture modification addresses such shortcomings by modifying the rheological properties of food and beverage products.

The central role of hydrocolloids in this aspect is that they are responsible for controlling the gum system consistency and stability when subjected to exogenous forces from food handling. Indeed, suitable rheological behaviour permits the coalescence of cohesive boluses that can remain stable during oral processing when propelled through the pharynx at a defined flow rate. On the other hand, products with unsuitable rheological behaviours can flow too quickly, disintegrate on swallowing or have excess pharyngeal residue which could increase aspiration risk.

Due to such factors, rheological characterization has become a key component of developing and assessing the appropriateness of texture-modified foods within the IDDSI framework.

5.2 Viscosity and Flow Behavior

Viscosity defines the internal flow resistance of material and is still the most common parameter used to characterize thickened liquid. Higher viscosities slow down the bolus transit times through the oral cavity and pharynx, gives additional time for airway closure which can prevent aspiration due to delayed swallowing reflexes. Natural hydrocolloids increase viscosity by absorbing water and forming networks of hydrated polymers. At higher polymer concentrations, entanglement of the polymers restricts flow and produces a greater resistance to molecular motion. Nevertheless, the extent of viscosity formation from hydrocolloids contrast greatly based on differences in molecular weight, chain flexing and chemical make-up.

While konjac glucomannan is usually demonstrated as the hydrocolloid with highest thickening effectiveness, psyllium husk and basil seed gum similarly yield ultra–high viscosity systems at comparably low concentrations. They produce medium to high viscosities and also have nutraceutical effects [29]. While inputting comparatively lower-natured viscosity as compared to other thickeners, Aloe vera gel increases skin moisture retention and product flowiness. As a compensatory strategy, thicker consistencies typically improve swallowing safety but products that are too thick could increase oral effort, slow bolus transport and enhance pharyngeal residue. Hence, it is the optimal viscosity that should be targeted rather than maximum viscosity for achieving success in dysphagia therapy.

5.3 Shear-Thinning Behavior

Most hydrocolloids derived from natural sources are thixotropic, in which viscosity decreases as shear rate increases (non-Newtonian). This is of special interest in swallowing since the mechanical force applied by the tongue can temporarily lower viscosity, and allow easier transport of a bolus while remaining structurally intact prior to swallowing.

Hydrocolloids like konjac glucomannan, basil seed gum, psyllium husk and okra mucilage have significant shear-thinning properties whereby foods remain stable during serving but lose viscosity when processed orally. Both of these dynamic responses help contribute to the safety and sensory acceptance throughout swallowing. Shear-thinning degree largely depends on polymer concentration, molecular weight, temperature and interactions with other food components. Thus, careful formulation of the consumable product is required to maximize both clinical performance and consumer acceptability.

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5.4 Yield Stress and Bolus Cohesiveness

Yield stress is defined as the minimum opposite force needed to initiate flow of a material, whilst bolus cohesiveness is used to describe whether food remains in a unitary cohesive mass when being swallowed. Both properties are tightly coupled and interact synergistically in mitigating the introduction of prematurely spilled or fragmented bolus. The cluster of hydrocolloids with the desired yield stress allows for boluses to remain intact when stationed in the oral cavity. Sufficient cohesiveness simultaneously prevents transport fragmentation as the morsel traverses the pharynx, providing a low risk of aspiration and post-swallow residue.
Konjac glucomannan and basil seed gum typically generate more robust gel networks and greater yield stress than aloe vera gel or flaxseed mucilage. Psyllium husk and okra mucilage are also important bolus-binding agents due to their high-water retention capacities. On the other hand, over yield stress may increase swallowing effort and this indicate a walk of balance in development process.

5.5 Stability During Oral Processing

Texture-modified foods should provide a consistent set of rheological properties across preparation, service and ingestion. In the mouth, foods undergo contact with saliva and solids, temperature fluctuations, mechanical deformation and enzymatic digestion that can change viscosity and structural integrity.
Because of the susceptibility of starch-based thickeners to hydrolysis by salivary α-amylase, a high viscosity loss occurs during oral processing. In comparison, most of the naturally derived polysaccharide hydrocolloids are more resistant to enzymatic degradation and will ensure a more stable rheological behaviour during swallowing.
Stable rheological behaviour provides predictability over the flow of a bolus, thus enhancing swallowing safety and greater consistency in clinical practice. Against this backdrop, resistance to physical changes would also be an important criterion for hydrocolloid selection in dysphagia-dedicated foods.

5.6 Relationship Between Rheological Properties and Swallowing Safety

No single rheological parameter could be linked to safe swallowing. Rather, viscosity, shear-thinning behaviour, yield stress, bolus cohesiveness and oral processing stability together modulate performance across swallowing. Food that exhibits a balance of rheological properties is more likely to generate boluses that can form and flow in controlled ways, transit pharynx efficiently, and pose less aspiration risk.
Natural hydrocolloids supply a wide range of rheological properties which can be adapted to different swallowing difficulties, and IDDSI texture degrees. Thus, multidimensional rheological design strategies should be adopted in future formulation approaches instead of viscosity measurements as a stand-alone parameter. This multidisciplinary approach will enable the development of texture-modified foods that are safer, more palatable, and nutritionally enhanced for people with dysphagia by integrating instrumental rheology with clinical swallowing assessment.

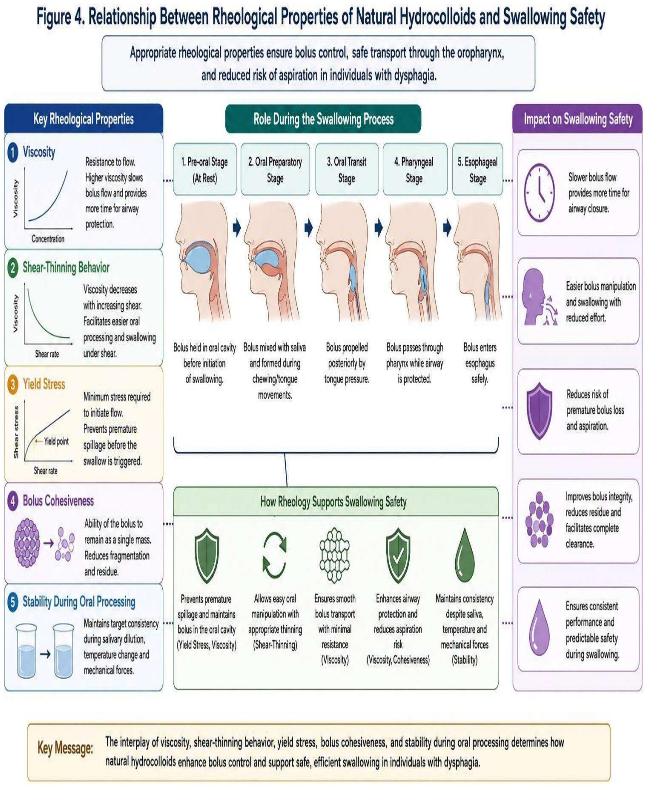

Figure 4. Relationship between the key rheological properties of natural hydrocolloids

6. Clinical Applications of Natural Hydrocolloids in Dysphagia Management

Not only are the goals of texture-modified foods to modify food consistency, but they also aid in the safety of swallowing while helping maintain nutritional adequacy and promoting well-being for patients who live with dysphagia. While laboratory studies can give some insight into the physicochemical and rheological properties of natural hydrocolloids, they can be most meaningful in their ability to address the clinical problems caused by dysphagia.

The natural hydrocolloids have several advantages over the normal thickening agents. In addition to modifying food texture, many plant-based hydrocolloids also provide added dietary fibre, bioactive components and better hydration properties thus leading to the possibility of creating multi-functional foods that can confer both a functional and nutritional benefit in terms of swallowing function. With rising interest in personalized nutrition and clean-label food ingredients, natural hydrocolloids could provide attractive candidates for next-generation dysphagia diets.

6.1 Improving Swallowing Safety

The management of dysphagia is focused primarily on aspiration prevention whilst ensuring efficiency in bolus transport. Hydrocolloids enhance bolus flow and oral control where it increasingly augments the oral swallow tract, thus assisting in swallowing safety by modifying cutting points or rheological properties [9].

Recommended changes: Natural hydrocolloids increase viscosity and improve bolus cohesiveness in such a way that patients with tardive triggering of the airway can be given more time to close the airway before the pharyngeal loop captures the bolus. The ability to maintain structural integrity (before swallowing) but be shear-thinning will also facilitate easier swallowing, by reducing resistance during oral propulsion.

In comparison to thin liquids, adequately thickened formulations have been demonstrated to decrease penetration and aspiration events in numerous patients with oropharyngeal dysphagia. Too high concentration may also result in greater oral effort and pharyngeal residue, thus suggesting that selecting proper hydrocolloids and optimizing the level according to each individual swallowing ability and IDDSI recommendations should be evaluated.

6.2 Supporting Nutritional Status

Malnutrition is therefore one of the frequent complications of dysphagia, which occurs due to a reduction in food intake caused by poor chewing ability, prolonged eating time and loss of appetite. Traditional thickeners typically enhance food texture, whilst giving minimal in the way of nutritional benefit.

More information Abstract: Natural hydrocolloids can be utilized to formulate texture-modified foods that are nutritionally enriched. Chia, flaxseed psyllium and okra mucilage are sources of soluble dietary fiber, while chia and flaxseed supplementation adds omega-3 fatty acids and antioxidant compounds to a wide variety of dishes. While aloe vera adds moisture and bioactive polysaccharides, konjac glucomanna acts as a fermentable fiber that aids in gastrointestinal health.

The combination of such ingredients at levels tested so far has the potential to improve nutrient density in texture-modified diets while controlling properties relevant to swallowing function. Such multi-action formulations may represent options especially for the ageing population and patients with chronic neurological diseases who are likely to be malnourished and suffer micronutrient deficiencies.

6.3 Hydration and Gastrointestinal Health

Non fluid consumption is another major challenge in dysphagia management since most people with swallowing difficulties are frightened to drink safe amounts of fluids or due to poor acceptance of thickened drinks. Many natural hydrocolloids have an extraordinary water absorption capacity, thus, allowing the elaboration of products maintaining moisture and with the adequate consistence. Hydrocolloids like konjac glucomannan, psyllium husk, basil seed;) gum and okra mucilage are associated with the benefit of increased hydration through gel formation by trapping water inside food matrices. Also, many of these hydrocolloids contain soluble dietary fiber that can help with bowel regularity and also support good gut microbiota and reduce constipation which is a common complaint in older adults and those with lower mobility.

Thus, the clinical usefulness of natural hydrocolloids surpasses dysphagia safety and offers benefits in gastrointestinal function and comprehensive nutrition.

6.4 Patient Acceptance and Quality of Life

Effective dysphagia management requires both clinical safety and patient compliance. Currently available commercial thickened liquids are found in many cases to have poor sensory properties, including undesirable mouthfeel, altered flavor and lowered palatability which contribute to lack of compliance with fluid management programs ultimately resulting in inadequate food or fluid intake. Natural hydrocolloids provide various opportunities for enhancing the sensory quality of texture-modified foods by regulating textural properties, moisture content and incorporation of the more natural ingredient profile. The more attractive and appealing a product is to consume, the more likely patients are to adopt diets as prescribed for long-term adherence.

Greater adherence with dietary protocols can result in better nutritional status, hydration, eating out as well as better social participation and satisfaction which lead to higher quality of life eventually. However, sensory is highly subjective and varies significantly among individuals; thus, patient-centered formulation of final product inclusive of sensory evaluation needs to be performed.

6.5 Current Evidence and Clinical Translation

Introduction: Despite the functional properties of natural hydrocolloids having been extensively studied, limited research has examined their swallowing capability in individuals with dysphagia. The majority of the available evidence is obtained from laboratory studies, rheological profiling or industrial applications as a functional food ingredient.

Instrumental swallowing assessments, such as videofluoroscopic swallowing studies and fiberoptic endoscopic evaluation of swallowing, combined with standardized rheological measurements and patient-reported outcomes should be integrated into future clinical research. These multidisciplinary schemes will bolster the evidence base supporting clinical implementation of natural hydrocolloids.

The existing evidence supports the potential of natural hydrocolloids to enhance dysphagia management. Considering these properties together with nutritional and sensory advantages can support their applications as multifunctional ingredients for next-generation texture-modified foods. Collaboration among food scientists, clinicians, dietitians and speech-language pathologists will be necessary to facilitate the translation of these exciting materials into everyday clinical practice.

7. Challenges, Limitations, and Future Perspectives

There is significant potential for using naturally sourced hydrocolloids to improve the quality of texture modified foods and thickened liquids through targeting rheological properties while at the same time maximising nutrition. However, issues related to science, technology and healthcare still constrain the broad application of these systems in managing dysphagia. These limitations need to be addressed before the use of natural hydrocolloids can be adopted as a standard therapy in evidence-based dietary interventions.

7.1 Variability of Natural Hydrocolloids

Despite the fact that they are economically beneficial, great variety of unique challenges come along with plant derived hydrocolloids such as inconsistencies in their physicochemical properties. Unlike the hydrocolloids manufactured by industry under specific conditions, natural ones respond to many variables, including the plant genotype, geographic origin, climatic condition, soil composition, cultivation method of harvesting time and post-harvest procedures.

These factors can change the polysaccharide composition, molecular weight, hydration behaviour, and rheological performance of a solution, causing variations in viscosity, gel strength and water-holding capacity. As a result, materials prepared from different batches of the same plant source can have variable functional properties.

Hence, it is important to develop standardized cultivation, extraction and quality-control procedures that allow for reproducible performance and industrial production [22].

7.2 Standardization of Extraction and Processing

The composition and functionality of hydrocolloids are affected by extraction methods. For instance, extraction temperature, pH, solvent ratio (which may affect molecular weight and yield), extraction time (which can influence yield and molecular properties), drying technique (affecting conductivity and charge stability) and purification method (impact on rheological behavior) are parameters that may considerably affect the obtained results.

Currently, there is considerable heterogeneity between published extraction protocols making direct comparison of studies challenging. Subsequent studies should develop standardised extraction protocols that balance functional performance and cost-effectiveness for large scale food manufacturing.

7.3 Limited Clinical Evidence

While extensive research has been conducted to characterize the physicochemical and rheological properties of natural hydrocolloids, their efficacy in dysphagic patients is comparatively underexplored.
Most published investigations continue to be confined to lab-scale or formulation work. Currently, the evidence available for swallowing biomechanics, aspiration prevention, nutritional outcomes, long-term safety, and patient acceptance continues to be inadequate.
Close systematic randomized clinical trials with the incorporation of instrumental swallowing evaluations, standardized rheological metrics, and patient-reported outcomes are vital to imprint strong evidence for its clinical utility.

7.4 Sensory Acceptance and Consumer Compliance

Sensory quality is a major determinant of long-term adherence to texture-modified diets. Patients may reject products that are excessively viscous, have an undesirable mouthfeel, or poor appearance and altered flavor leading to decreased food intake contributing to impaired nutritional status.
Multiple naturally derived hydrocolloids facilitate moisture retention and texture, but fulfilling sensory performance requires precise functionality and concentration considerations. In the future, product development for functional food products should combine texture with sensory evaluation and rheological optimization to deliver foods which are both clinically beneficial and consumer acceptable.

7.5 Regulatory and Industrial Considerations

Manufacturers now need to prove product safety, microbiological stability, quality consistency and compliance with national and international food regulations before hydrocolloids of natural origin can become a common part of clinical nutrition.
Reliable availability of the raw materials, inexpensive processing technologies with established quality-control procedures are also necessary for industrial implementation. Collaboration amongst researchers, food manufacturers, regulatory bodies and the healthcare community will be fundamental to expedite commercialization.

7.6 Emerging Technologies and Future Research

In recent years, advances in food engineering opened doors for tailoring texture-modified foods. Novel approaches including three-dimensional food printing, artificial intelligence (AI) assisted formulation development, digital rheological modelling and precision nutrition could change the way we manage dysphagia.
Future research should prioritize:

- Standardisation of extraction and characterisation methods for natural hydrocolloids
- Exploration of synergetic combinations of hydrocolloids to improve rheological behavior and sensory properties.
- Clinical trials on swallowing safety, nutritional outcomes, and acceptance of patients.
- Personalised texture-modified foods for specific swallowing abilities
- Sontag, M., & Hillebrecht (2021). 3D food printing and artificial intelligence-informed design of next-generation dysphagia foods.
- Alignment of rheological testing with IDDSI framework to enhance comparability between studies.

These research priorities will facilitate the translation of laboratory findings into practical clinical applications and support the development of safer, more nutritious and more palatable texture-modified foods.

7.7 Overall Perspective

Natural hydrocolloids presents a key opportunity for progression of dysphagia nutrition beyond conventional thickening approaches. Their proximate ability to offer desirable rheological functionality, nutritional functionality, sustainability along with clean-label can deliver food science and clinical nutrition solutions that are in line with every emerging trends.
While the remaining challenges are significant, it is likely that interdisciplinary engagement among food scientists, clinicians, nutritionists, engineers and speech-language pathologists will facilitate timely progress in designing evidence based hydrocolloid formulations that improve dysphagia management by augmenting swallowing safety, nutritional status or quality of life for dysphagic individuals.

8. Conclusion

Recently, many natural hydrocolloids have been developed as multifunction ingredients including texture-modified foods and thickened liquids for dysphagia management. Thus, they are employed as potential alternative to traditional commercial thickening agents due to their ability to change viscosity, increase bolus cohesiveness and water retention and evidence of favorable shear-thinning performance. Unlike many synthetic or semi-synthetic starch-based thickening agents, various plant-derived hydrocolloids can also act as a source of dietary fiber and phytonutrients which could positively affect the nutritional quality of dysphagia diets while providing optimal swallowing properties. The current evidence related to seven most prevalent natural hydrocolloids such as okra mucilage, konjac glucomannan, chia seed mucilage, basil seed gum and flaxseed mucilage, psyllium husk and aloe vera gel was critically evaluated in this review. Each type of hydrocolloid contained unique physicochemical properties, yet overall each tended to improve the rheological behaviour of texture-modified foods through hydration, viscosity increase, gel formation, moisture retention and bolus stability. The results indicated that konjac glucomannan had the strongest thickening properties, while psyllium husk showed a high water-binding capacity among these materials. Notably, chia and flaxseed mucilages presented enriching nutritional benefits via their abundant dietary fiber and omega-3 fatty acid contents, while okra mucilage and basil seed gum provided promising clean-label alternatives with excellent rheological functionality. Even using aloe vera gel alone, whose thickening efficiency is relatively low, in incorporation with a variety of multifunctional hydrocolloids can promote their hydration degree and sensory quality. The evidence reviewed also demonstrates the complexity of dysphagia management and that viscosity is not solely predictive of success. Key rheological properties including shear-thinning behavior, yield stress, bolus cohesiveness, and oral processing stability act additively to affect swallowing safety and should be incorporated into the formulation of texture-modified foods. This combination of rheological parameters with validated food texture classification approaches (e.g., the International Dysphagia Diet Standardisation Initiative [IDDSI] framework) enables the development of clinically meaningful acceptability-friendly products.

However, this has poorly predicted completion of key challenges despite promising laboratory data. The high variability in plant materials, absence of validated extraction procedures, few clinical studies performed on these natural hydrocolloids and the lack of evidence regarding their effect on long-term patient outcomes results in challenges in being able to implement them widely into practice. Additionally, sensory acceptability, manufacturing reproducibility, compliance with regulatory guidelines and mass-market commercialization remain to be seen for the inclusion of these materials into everyday health care environments. Studies introduced herein call for multidisciplinary approaches incorporating food scientists and clinicians, nutritionists, speech-language pathologists, and biomedical engineers within better-defined guidelines. The evidence of clinical application of natural hydrocolloids needs improvement with standardized extraction procedures, advanced rheological characterization, randomized clinical trials and instrumental swallowing assessment. Moreover, novel technologies have created promising options to construct texture-modified foods appropriate for particular swallowing capabilities and nutritional needs like three-dimensional food printing, artificial intelligence-assisted formulation of the food, and personalized nutrition.

Hydrocolloids of natural origin provide a novel, science-based and clinically-oriented approach to enhance the quality of texture-modified foods for patients with dysphagia. The multifunctional properties of these ingredients allow for opportunities to improve swallowing safety, nutritional value, sensory quality and product sustainability simultaneously. While additional clinical evidence will be needed, advances in food science, rheology and clinical nutrition are likely to continue to hasten the translation of these natural ingredients into evidence based dysphagia management. In conclusion, the addition of natural hydrocolloids into texture-modified food systems may enhance safety during swallowing along with nutritional status and quality of life among dysphagia individuals.

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