International Journal of Food and Nutritional Health:Vol. 1 No. 1, pp: 66 – 87 (2026)
DOI: 10.4197/Fnj.1-1.5

From risk to enjoyable, safe swallowing: Current studies on the development of aerated food, liquid, and semi-gel structures for dysphagia management

Woroud A. Alsanei [1]*

[1] Department of Food and Nutrition, Faculty of Human Sciences and Design, King Abdulaziz University, Jeddah, Saudi Arabia; walsanei@kau.edu.sa
* Correspondence: walsanei@kau.edu.sa

Abstract: Dysphagia significantly affects quality of life, increasing risks of malnutrition, dehydration, aspiration pneumonia and long-term healthcare challenges. Traditional dietary interventions often modify food, liquid textures, but adherence can decline due to visually unappealing and unappetizing of dysphagia-friendly foods. Therefore, this review highlights the current trend of aerated (foamed, air bubbly) structures in food, liquid and semi-gel products designed for individuals with dysphagia to modified texture, sensory and swallowing experiences. This review summaries the incorporating air bubbles softening food texture, reducing choking hazards, and improving safety while consuming meals for dysphagic people. Additionally, air bubbles contribute to an improved sensory experience by enhancing mouthfeel, facilitating flavor release, achieving taste balance, and ensuring safety while also promoting healthier eating habits and overall well-being for individuals with dysphagia. Innovations in aerated structures play a crucial role in enhancing nutrition, improving palatability, and stimulating appetite. The implementation of such structures in products designed for individuals with dysphagia, requires collaboration among food scientists, nutrition experts, speech-language pathologists, and culinary specialists. However, there is a critical need for comprehensive clinical trials on aerated structures to understand their impact on swallowing dynamics and health outcomes, and to improve their development for enhancing safety, nutrition, and quality of life in affected populations.

Keywords: Aerated food structures; Air bubbles; Foam; Food textures modification; Dysphagia; Swallowing difficulty

1. Introduction

1.1 Swallowing mechanics and impairment

Swallowing is a highly coordinated and integrated process that occurs in distinct sequence of stages between the oral, pharynx, larynx, and esophagus. Swallowing process initiates during the oral phase where food is chewed and mixed with saliva. Once a well-formed bolus consistency is attained, bolus is directed towards the posterior region of the oral cavity by the tongue pressure and strength.[1-3] Subsequently, bolus is triggered the pharyngeal phase, where the soft palate and larynx close off the nasal passage and airway, respectively. Later, bolus is propelled into the esophagus, where peristaltic movements transport the bolus to the stomach.[4] In contrast, dysphagia, a prevalent medical condition characterized by difficulty swallowing, can arise from disruptions in any phase of the swallowing process and significantly affect an individual's quality of life and nutritional status (Figure 1).[5-8]

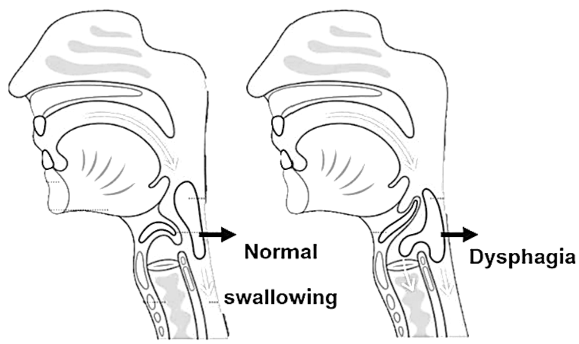

Figure 1. Schematic representation of normal swallowing and dysphagia.[9]

This review provides an overview of the mechanical and physiological challenges associated with swallowing, elaborate on dysphagia's impact on quality of life, and provide an overview of innovative dietary management techniques. By briefly examining the current trends, including texture modifications, thickening agents, food molds, and advanced food technologies such as 3D and 4D food printing. This review sought to provide valuable insights for clinicians, researchers, and culinary professionals engaged in the management of dysphagia. Furthermore, the review investigates the potential of aerated food, liquid, and semi-gel structures to enhance textures and flavors in dysphagic diets, ultimately improving the care of dysphagic patients and ensuring adequate dietary intake while minimizing the risk of malnutrition.

1.2 Dysphagia and its complications

Across literature, dysphagia can be clinically categorized into different types based on the stage of swallowing affected.[10-12] Oropharyngeal dysphagia refers to perceived or detected difficulty in the initial phase of swallowing, often linked to neurological disorders or structural issues from the oral cavity to the esophagus.[13] In contrast, esophageal dysphagia involves difficulties within the esophagus itself, which can arise from blockages, narrowing, or motility problems. Symptoms of dysphagia can include persistent coughing during or after meals, indicating possible airway entry of food or liquid, as well as choking incidents that make breathing or speaking difficult due to obstruction.[14-17] The sensation of food bolus residue (feeling stuck) in the throat or chest, accompanied by pressure or discomfort, illustrates an additional challenge faced by those with dysphagia. Other less common symptoms that may be experienced include water dribbles from the mouth and drooling, odynophagia (pain while swallowing), and regurgitation (spitting food up from the esophagus or stomach without nausea or abdominal muscles).[2,18-21] Therefore, individuals with any type of dysphagia experience various eating difficulties that can offer vital insights for diagnosing underlying issues, helping to prevent malnutrition, weight loss, dehydration, choking, and aspiration pneumonia.[22-26] These consequences elevate health concerns, require long-term care and adversely affect the overall well-being of dysphagia patients.[27] As a result, the severity of these challenges can contribute to restricted food choices, social isolation during meals, and increased anxiety surrounding swallowing, making it important to recognize these differences for proper diagnosis and effective treatment.[٣٠-٢٨]

1.3 Dysphagia and quality of life

Dysphagia can negatively affect a person's ability to consume meals safely, comfortably, and independently, impacting their social interactions and well-being. As a result, they may require assistance during mealtimes, which can diminish their sense of independence, fear of choking and self-sufficiency resulting with food rejection that leads to malnutrition.[31-33] Furthermore, the social aspect of dining can be adversely affected, as individuals with dysphagia might avoid eating in public or with others due to embarrassment. This avoidance can lead to social isolation, reducing opportunities for meaningful interactions and connections with others. Additionally, the emotional toll of dealing with dysphagia can be profound, as it may lead to feelings of frustration, anxiety, and depression, further impacting a person's overall well-being eventually.[29,33]

2. Some current challenges in dietary management for dysphagia patients

Dietary management plays a crucial role in the treatment of dysphagia but involves some complex challenges that need careful consideration (Figure 2). Ongoing challenges in dietary management for dysphagia patients highlight that insufficient dietary intake including individualized nutritional needs is a primary challenge faced by dysphagic patients.[8,22,33,34] They often exhibit varied swallowing capacities and food tolerances, requiring specialized nutritional plans to ensure adequate dietary intake while minimizing malnutritional risks.[35,36] Texture-modified diets is a cornerstone of traditional dysphagia management to accommodate swallowing difficulties which often involve the purification, thickening, or pureeing of foods to reduce the risk of aspiration.[37,38] However, adherence to these interventions often declines due to their unappealing sensory properties, such as mouthfeel, flavor release, ease to chew and swallow and overall palatability, which can potentially contribute to a decrease in appetite.[35,39-42] Additionally, these problems raise concerns regarding possible nutritional deficiencies and compliance with dietary recommendations, particularly related to nutrient bioavailability.[43,44] Certain texture alterations may prevent patients from consuming food normally and, in turn, can hinder the absorption of key nutrients and exacerbate existing deficiencies. Dietary management of dysphagia can also lead to dehydration due to thickened liquids and altered food consistencies and, therefore limiting fluid intake.[45] Additionally, the impaired swallowing capabilities of affected individuals can present as oral difficulties such as difficulty chewing, food pocketing, and delayed swallow reflex, as well as pharyngeal challenges like choking, aspiration, and the sensation of food sticking in the throat.[26,46]

Beyond these physical challenges, the impact of dysphagia's psychosocial state should not be underestimated; as it can have a substantial influence on individual's quality of life, contributing to social isolation, depression, and anxiety, which in turn can reduce appetite and food consumption.[33,39,47] Effective dietary management of dysphagia dependent on comprehensive caregiver and patient education. However, varying quality and inconsistent clinical guidelines across care settings can lead to confusing healthcare professionals and resulting in variations in patient care. Inconsistent clinical guidelines in diet formulation, with the limited adoption of the International Dysphagia Diet Standardization Initiative (IDDSI) standardized protocol which promotes customized food consistency to effectively meet individual patient needs.[48] These reasons can hinder safe swallowing practices and the effective delivery of nutrition for dysphagia patients. Moreover, technological and tool limitations in texture modification, such as the inability to precisely manage food consistency, present continuing challenges.[49] These challenges are further magnified by cost and accessibility issues, which limit the availability of specialized products and services for many patients around the world.[39,50]

As discussed above, the complexity in the dietary management of individuals with dysphagia is required a multidisciplinary collaboration for effective dysphagia management, involving dietitians, speech-language pathologists, physicians, and caregivers.[33] Such collaboration is often hindered by communication barriers and resource limitations. Cultural and personal preferences as well as food insecurity should also be considered when planning diets, as these factors influence patient compliance and satisfaction with their meals.[51-54] Lastly, it is important that monitoring and follow-up remain vital to ensure that dietary interventions are effective, however, long-term monitoring often falls short due to logistical, financial, or systemic constraints.[49,55,56] Addressing these multifaceted challenges requires a coordinated, patient-centered approach that is flexible, evidence-based, and culturally sensitive.

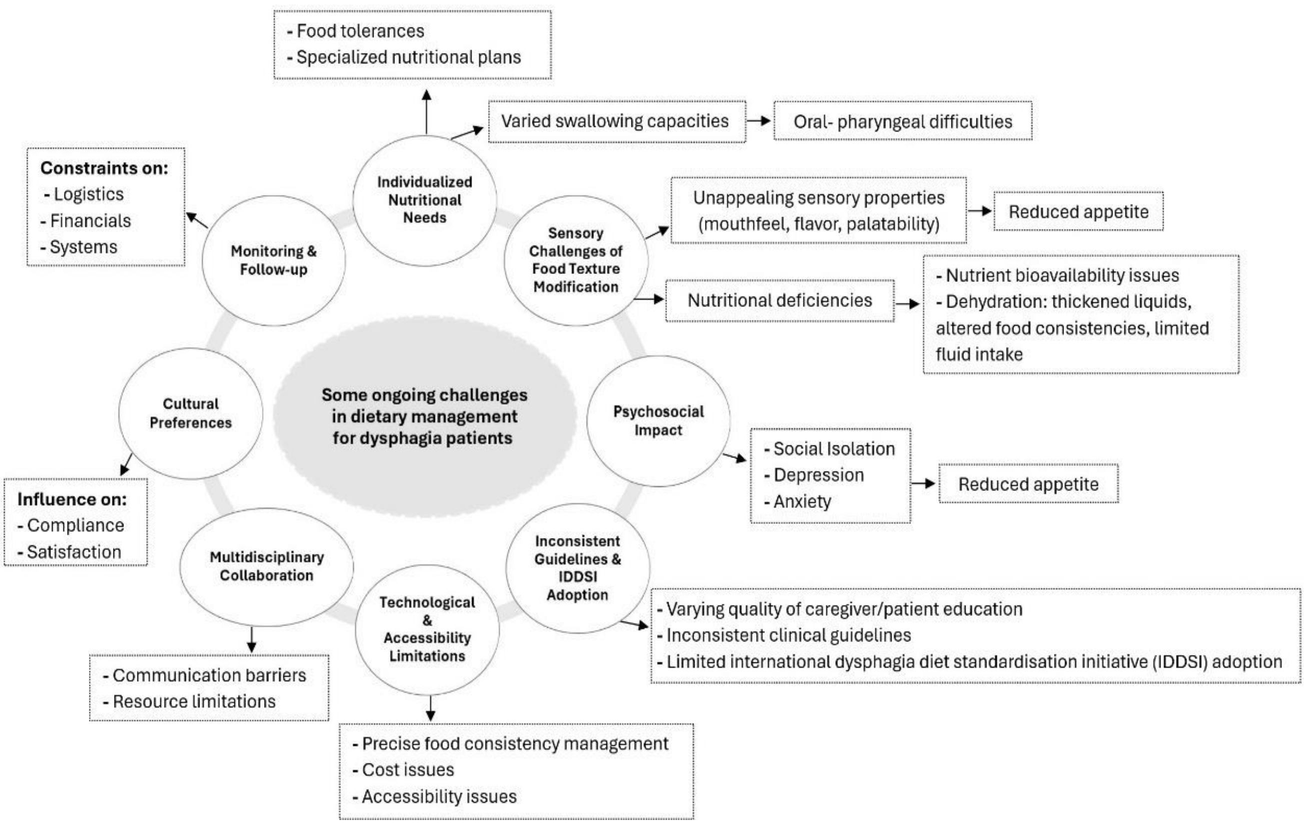

Figure 2. Diagram illustrating some continuing challenges in dietary management for dysphagia patients.[8,22,26,33-39,42-51,54-56]

3. Some current trends in dysphagia management

Current trends in dysphagia food management involve the development and application of innovative methods and technologies aimed at improving the safety, acceptability, and nutritional quality of food for patients with swallowing difficulties. There are variety of trends in the methods and techniques used, as well as industrial technologies for texture modification.

3.1 Food texture modification

Food texture modification (FTM) or texture-modified diet is a fundamental to managing dysphagia, customized to deliver suitable consistencies including puréed, minced, or soft foods to individuals with dysphagia.[57,58] These adaptations ensure safe ingestion by reducing the potential risk of choking and aspiration. These FTMs often align with the international standards such as the IDDSI framework.[59,60] Such FTMs improve safety, however, they may lack visual appeal and variety, highlighting the need for innovations that enhance palatability and nutritional value.[61]

3.2 Thickening agents

Not only foods but also liquids require modification to fulfill dysphagia patients with nutritional requirements which can be achieved using thickening agents, gelation techniques, and biopolymer integration. These methods are essential for ensuring safe consumption of food, preventing aspiration and other dysphagia-related risks by adjusting fluid viscosity, converting into gels to improve their mechanical properties and stability. Thereby enhancing cohesiveness and facilitating a more manageable and ease of swallowing process. Various biopolymer thickening agents, such as starch- or gum-based products, alginates, and pectin are used depending on the individual's needs. However, studies suggest that thickened liquids can lead to decreased compliance with hydration protocols, and that diets containing thickeners often experience an increase in viscosity over time.[62-64]

3.3 Food-shaping molds

Recent literature highlights the efficacy of food-shaping mold strategies by customized silicone molds in enhancing the palatability, safety and visual appeal of meals for dysphagic patients.[65,66] Forming foods into recognizable shapes, enhances meal acceptance and overall quality of life for dysphagic patient when integrating this strategy with standardized guidelines of texture modification such as IDDSI framework. This approach is especially beneficial in institutional settings where shaped food presentation impacts patient compliance.[65]

3.4 3D and 4D food printing technologies

Three-dimensional (3D) and four-dimensional (4D) food printing technologies offer significant transformative approaches in food design and production, particularly for addressing challenges associated with visually unappealing and unappetizing of dysphagia-friendly foods while maintaining their safety and ease of swallowing.[67] 3D printing creates customized, precise, and complex structures using layer-by-layer deposition from digital models. While 4D printing presents an extra dimension of transformation over time, emphasizing the dynamic capability of printed foods to alter their shape, texture, or properties (such as flavor and aroma release and color changes) in response to external stimuli like temperature, moisture, or pH.[68-70] Therefore, these techniques provide unique solutions to improve food variety, tailored nutritional content, presentation and potentially increasing appetite and improving the overall eating experience, especially in long-term care settings.[68] Additionally, it allows for precise control over food consistency and repeatability, aligning with individual swallowing capabilities.[50,67,71-73]

3.5 Aeration by foaming technique

Aeration by foaming is a technique utilized in the management of dysphagia-related dietary needs.[50] Nowadays, the formation of bubble-containing food structures not only introduces air into food but also appeals to consumers by enhancing visual allure of the product, offering health benefits by creating lighter alternatives in terms of textures and calories and encapsulating aroma components.[74,75] It is particularly useful in liquid foods, beverages and semi-gels in the present of different stabilizers and whipping agents, offering new options for patients with swallowing difficulties.[47,50]

4. Discussion on the development of aerated food, liquid, and semi-gel structures

4.1 Aeration concepts in food science and culinary contexts

In the context of food science, aeration is a general term for creation of air bubbles into a mixture. The mechanism behind the aeration is to enhance the texture, structure, appearance and mouthfeel of food products, which can create lightness and improve sensory attributes and also increase the volume of the mixture.[26,76] While in culinary contexts, aeration often involves whipping, whisking, beating, or stirring ingredients to create a foam or light texture.[77]

4.2 Key methods and techniques used to create air bubbles in food, liquids, and semi-gels

When incorporating air bubbles into diets, especially for dysphagia it is crucial to consider factors such as size, distribution and consistency of the bubbles, minimal mechanical resistance, uniform texture, and characteristics that ensure safe and ease swallowing. Based on relevant literature, various mechanisms governing the formation of air bubble-containing food structures have been identified in foods, liquids, and semi-gels.[67,78,79] The incorporation of air bubbles in such structures can be through different mechanisms including physical, mechanical, chemical, and biological mechanisms (Table 1). The physical mechanism refers to pre-existing air that is expanded and dispersed by pressurized systems or sudden temperature changes. Popular examples of this mechanism are ice cream mixture and air inflated chocolate during its production, carbonated beverages containing compressed carbon dioxide (CO_2) and nitrous oxide gas pressurized inside the whipped cream canister/dispenser.[80-83] The mechanical mechanism produces fine and stable air bubbles by rapid mechanical agitation when air bubbles trapping, and dispersing within networks.[84] This mechanism can be achieved by whipping, foaming, whisking, stirring, mixing, shaking, or blending which is ideal for the production of whipped cream, meringues, ice cream, milk foam, mousse desserts, and marshmallow.[85-88] Beating is a further technique of the mechanical mechanism involving vigorously agitating a mixture to create air bubbles through disrupting the structure, introducing irregular air pockets, and facilitating the effective blending of ingredients, particularly in heavier mixtures such as cake batter, beating egg whites and cream cheese frosting. Chemical mechanism creates air bubbles by chemical reactions or chemical leavening by using baking powder or soda in cakes or muffins and fizzy drink tablets. In contrast, the biological mechanism depends on gas-producing organisms by metabolic activities in sourdough bread (yeast fermentation), Sobia (fermented bread, barley or oat drink) and cheese-like fermented Sufu gel.[72,79,84,89]

Table 1. Various mechanisms for incorporating/generating air bubbles into food, liquid and semi-gel structures.[67,72,78-80,83-85,88,89]

Mechanism	Explanation	Methods/ techniques	Example of aerated structure		
			Food	**Liquid**	**Semi-gel**
Physical mechanism	Pre-existing air expanded and dispersed by pressure or temperature changes.	Pressurized systems or sudden pressure changes	Ice cream Air inflated chocolate	Carbonated beverages	Whipped cream canister/ dispenser

Mechanical mechanism	The fine and stable air bubbles generated, trapped and disperse within networks through mechanical quick agitation.	Whipping, foaming, whisking, stirring, mixing, shaking, or blending	Whipped cream Meringues Ice cream	Milk foam	Mousse desserts Marshmallow
	The process of vigorously agitating a mixture used to create air bubbles through disrupting the structure, introducing irregular air pockets and facilitating the effective blending of ingredients, particularly in heavier mixtures.	Beating	Cake batter	Egg whites	Cream cheese frosting
Chemical mechanism	Air bubbles generated by chemical reactions or chemical decomposition.	Chemical reaction (chemical leavening)	Baking powder or soda in cakes or muffins	Fizzy drink tablets	Baking powder in sponge cakes
Biological mechanism	Air bubbles introduced through biological fermented process by microorganisms.	Biological metabolic activities: (fermentation or enzymatic reactions)	Sourdough bread (yeast fermentation)	Sobia (fermented bread, barley or oat drink)	Sufu (fermented soybean product derived from tofu)

4.3 Current studies on the developing aerated food, liquid and semi-gel structures for dysphagia management

The creation of air bubbles into food, liquid and semi-gel structures specifically designed for individuals with dysphagia has gained considerable attention for enhancing swallowability, nutritional intake, mealtime experiences and social participation.[46,90] The rising interest in aeration applications, such as air bubble creation and foaming, focusing on their rheological properties, sensory acceptability, and nutritional adequacy of modified dysphagia diets.[43,91] This review will explore the current food, liquid and semi-gel aerated structures that were implemented or will be recommended with some considerations for managing dysphagia, providing softer textures that require less effort to chew and swallow.

4.3.1 Aerated food structure

Aerated food structures are solid or semi-solid foods into which air has been incorporated to modify texture and density of the final products. A study conducted by Koizumi et al[78] examined the suitability of espuma, a foam-style salmon fish, in meals designed for older adults with masticatory or swallowing difficulties. Three types of whipping creams involving milk fat, vegetable fat, and soymilk cream were blended with boiled salmon to create espuma. It was found that espuma's soymilk cream demonstrated superior structural stability, with no syneresis and fine, uniform bubbles, meeting Japanese standards for dysphagia-friendly textures and showing a minimal laryngeal residue in swallowing tests, indicating safety for consumption. Additionally, espuma's vegetable fat cream considered suitable due to its low density and stability. However, espuma's milk fat cream was excluded from the study due to the foam's insufficient stability and inability to maintain its shape. The study suggested that this aerated structuring approach can be applied to enhance the eating experience for individuals with swallowing difficulties.

David-Birman et al[87] examined the potential effects of incorporating insect-derived ingredients, specifically silkworm pupae flour (SWF) in both whipped cream and ice cream on enhancing their functional and nutritional properties while reducing the use of industrial stabilizers. An analysis was conducted on whipping cream formulations (SWF concentrations of 0, 1, 4, and 7%) and ice cream formulations (SWF concentrations of 1, 2.5, 4, and 7%). It was found that the addition of SWF significantly improved foam stability in whipped cream by reducing phase separation over 15 days, attributed to increased viscosity caused by the interactions of chitin and other macromolecules. However, SWF reduced overrun by limiting air entrapment (the air amount that could be incorporated), particularly at higher concentrations. Sensory evaluation revealed that ice creams containing less than 1% SWF were well-received, maintaining desirable textural and flavor profiles, while higher concentrations (≥4%) led to increased hardness, adhesiveness, a strong aftertaste, and diminished sweetness. These findings support the use of SWF to develop aerated food structures, such as ice cream, for specialized diets for dysphagia management, offering improved nutritional value (high-quality proteins, healthy fats, various vitamins, minerals and digestible viscous dietary fiber from chitin), functional stability, and sensory acceptability while supporting sustainable food innovation.[87,92-95]

Fribus et al[72] investigated the potential use of microfoaming-assisted 3D printing to modulate the textural and structural properties of starch-based materials, aiming to create customized food textures suitable for dietary needs, particularly for populations with swallowing difficulties. The samples were prepared by comprising wheat starch and soy protein isolate (85:15 ratio) including open-cell foam structures created through different concentrations of chemical leavening agents (glucono-delta-lactone (GDL), monocalcium phosphate (MCP), and sodium acid pyrophosphate (SAPP)). This selection aimed to produce and to evaluate the texture and structure of 3D printed starch-based aerated food structures with control carbon dioxide release during printing, where MCP providing rapid release, SAPP releasing gas thermally, and GDL ensuring consistent release. The study found that MCP and SAPP systems maintained consistent 3D printing behavior, producing stable structures, while GDL systems caused printing defects due to continuous gas generation. Textural analysis revealed a significant reduction in hardness at a concentration level of 2%, ranging from 2.79-fold (SAPP) to 10.2-fold (GDL) compared to unleavened controls. The study demonstrated that chemical leavening agents significantly influenced the textural and morphological properties of starch-based 3D printed materials; therefore, it is recommended the food industry creating dysphagia-friendly products using MCP and SAPP as reliable leavening agents for 3D printing due to their stable gas release kinetics and consistent printing behavior, producing soft, stable aerated structures. While GDL can create highly porous textures, its time-dependent material instability and printing defects make it less suitable for precise and reproducible manufacturing processes.

4.3.2 Aerated liquid structure

Aerated liquid structures refer to liquids that have been infused with air or gas, creating a bubbly or foamy consistency. The formation of air bubbles modifies the liquid's viscosity and flow behavior to deliver liquid in a more easy-to-swallow form for some dysphagic patients.[50] Marchand et al[96] investigated the friction and flow dynamics of edible albumen liquid foams sheared against tongue-like surface roughness model, revealing key insights into the behavior of foams near solid surfaces. This model was used to mimic the rough surface of the human tongue by adhering glass beads onto microscope slides with an average radius of α=225µm, comparable to the size of human tongue papillae. The study identifies three distinct friction regimes which are sliding, stick-slip, and anchored regimes, based on the roughness factor. Sliding regime indicates that roughness is minimal compared to the foam structure, allowing smooth foam flow over the surface with slight resistance. Friction is minimal and mainly determined by viscous dissipation in the Plateau borders. Stick-slip regime indicates that the foam exhibits intermittent behavior at intermediate roughness levels as the Plateau borders alternate between anchoring to surface asperities and slipping past them, resulting in fluctuating stresses. This mixed behavior reflects both surface and bulk dissipation. Anchored regime indicates that when roughness exceeds the foam structure, Plateau borders anchor to the asperities. Therefore, the foam's movement to be primarily governed by internal plastic deformation, with stress dissipation mainly occurring in the bulk. These findings underscore the practical relevance of tailoring surface roughness to control foam behavior. This model allows to study roughness-induced friction in liquid foams and to design aerated food products, particularly for individuals with swallowing difficulties. Thus, the interaction between foam and tongue-like surface can influence texture perception, ensuring a more comfortable eating experience.

Lee et al[67] conducted a study investigating the food foams stabilized by hydrocolloids as a safe and effective method for hydrating dysphagic patients using 3D printing technology. Five different foam formulations were prepared with egg white-based and egg free foams, by whipping base foamed ingredients such as egg whites, Methocel F50, and Foam Magic, with the addition of xanthan gum (XG) to enhance stability and printability. The study found that XG-stabilized foams significantly improved foam stability, printability, and structural integrity, making them suitable for dysphagic diets. While eggless formulations offered a viable alternative for vegan applications. All formulations complied IDDSI standards for safe consumption. Among the tested foams, xanthan gum-based inks demonstrated superior performance in hydration retention and texture consistency, emphasizing their potential as a customizable solution for hydration delivery to dysphagic patients.

4.3.3 Aerated semi-gel structure

Aerated semi-gel structures serve as a transitional system between gel and liquid characterized by stabilized air bubbles within gel network. Such structure integrates the gel viscoelastic properties with the lightweight foaming characteristics that contribute to both the structural and textural integrity and thereby promote safe swallowing practices. Aerated hydrogel structures can be used to formulate desirable texture that is light-soft by gelation of the continuous phase in an initial liquid foam that are more manageable to swallow for individuals with dysphagia. Its mechanism includes the reduction of the gel strength by creating air bubbles in its network. In a study by Zhang et al[97], the structural properties of alkali-heat treated egg white protein (AHEWP) was aimed to develop hydrogel foams with desired texture and swallowing safety for dysphagia.

The main findings point out that AHEWP provided desirable structural properties, allowing the formation of stable hydrogel foams due to the formation of covalent bonds and the compact structure of the aggregates at alkaline pH levels comparing to untreated egg white protein (EWP). Additionally, it was confirmed that hydrogel foamed structure is enhanced for its nutritional profile by incorporating a high-quality protein source, meeting the needs of those with dysphagia.

Chen et al[79] investigated the formation mechanism of Sufu gels, a traditional fermented soybean product derived from tofu, by *Mucor racemosus* to understand the physicochemical and structural changes responsible for their unique texture. Sufu samples were prepared from tofu, inoculated with *Mucor racemosus*, and fermented for up to 96 hours, with samples collected at 0, 24, 48, 72, and 96 hours for analysis. The study identified significant improvements in water-holding capacity (up to 93.85% at 96 hours) and textural properties, including reduced hardness (4.8N and 4.99N at 72 and 96 hours, respectively), which classified the gels as aerated semi-gel structures. At 48 hours, optimal gel uniformity and smoothness were attributed to peak protease activity and a β-sheet-dominant secondary structure, while prolonged fermentation led to softer textures. The findings highlight the suitability of these aerated Sufu gels for dysphagia patients due to their soft, smooth texture and ease of swallowing, offering a potential texture-modified food option for this population.

Ng et al[36] aimed to investigate the flow properties and behavior of thickened infant formulas designed for managing dysphagia in infants aged one year or younger, particularly focusing on the effects of time and storage temperature on consistency. Ready-made formulas and powdered formulas were thickened with starch-based, and guar gum-based agents using standardized preparation methods and analyzed at three time points using the IDDSI flow test. The results emphasize the importance of personalized dysphagia management plans designed to individual infant's needs, considering formula preparation, storage conditions, and feeding timelines. However, the ready-made formulas with either thickener produced aerated semi-gel thickened formulas characterized by significant foaming, air bubbles, and increased cohesion. Such aerated properties are unsuitable for the infants relying on bottle or tube feeding, as they increase feeding difficulty, fatigue, and the risk of aspiration, highlighting the need for alternative approaches for this vulnerable population.

Each study discussed in this section of the review indicated that their findings on various aerated (foamed, bubbly) structures can be clinically applied as suggestion for dysphagia management to improve safety and quality of life and to create more palatable diet options for those with swallowing difficulties. Similar suggestion was made by Wu et al[98], emphasizing the need for further clinical research and improved assessment tools to study the functional outcomes and long-term effects to enhance care for at-risk groups. Therefore, the implementation of such structures to be more sophisticated, personalized, and enjoyable products designed for individuals with dysphagia, requires collaboration among food scientists, nutrition experts, speech-language pathologists, and culinary specialists to be clinically studied on dysphagic patients.

5. Conclusion

This review highlighted the dysphagia and its impact on quality of life, while indicating the challenges in dietary management for affected individuals. Additionally, the review discussed some current trends in dysphagia management, including food texture modification, the use of thickening agents, innovative food-shaping molds, advancements in 3D and 4D food printing technologies, as well as aeration techniques by foaming. This review summarizes a number of current studies on the development of aerated food, liquid, and semi-gel structures as promising solutions for improving nutrition and mealtime experiences for those with dysphagia. Although these studies often do not involve dysphagic patients, they only suggest the potential suitability of such structures and the impact of various factors on the perception of aerated textures with the goal of creating safer and more palatable food options for those experiencing swallowing difficulties, without incorporating fundamental clinical studies. Therefore, the implementation of aerated structures to develop more sophisticated, personalized, and enjoyable products designed for individuals with dysphagia, requires collaboration among food scientists, nutrition experts, speech-language pathologists, and culinary specialists.

Conflicts of Interest:

Author does not have any conflict of interest.

References

1. Logemann J. A. The evaluation and treatment of swallowing disorders. Current Opinion in Otolaryngology & Head and Neck Surgery. 1998;6(6):395-400.https://doi.org/http://dx.doi.org/10.1097/00020840-199812000-00008
2. Alsanei W. A., Chen J. Studies of the oral capabilities in relation to bolus manipulations and the ease of initiating bolus flow. Journal of Texture Studies. 2014;45(1):1-12.https://doi.org/https://doi.org/10.1111/jtxs.12041
3. Furia C. L. B., Carrara-de Angelis E., Martins N. M. S., Barros A. P. B., Carneiro B., Kowalski L. P. Video fluoroscopic evaluation after glossectomy. Archives of Otolaryngology–Head & Neck Surgery. 2000;126(3):378-83.https://doi.org/https://doi.org/10.1001/archotol.126.3.378
4. Lillford P. The physics of eating. Formulation Engineering of Foods. 2013:107-35.https://doi.org/https://doi.org/10.1002/9781118597651.ch6

5. Newman R., Vilardell N., Clavé P., Speyer R. Effect of bolus viscosity on the safety and efficacy of swallowing and the kinematics of the swallow response in patients with oropharyngeal dysphagia: white paper by the European Society for Swallowing Disorders (ESSD). Dysphagia. 2016;31:232-49.https://doi.org/https://doi.org/10.1007/s00455-016-9696-8

6. Swan K., Speyer R., Heijnen B. J., Wagg B., Cordier R. Living with oropharyngeal dysphagia: effects of bolus modification on health-related quality of life—a systematic review. Quality of Life Research. 2015;24:2447-56.https://doi.org/https://doi.org/10.1007/s11136-015-0990-y

7. Macqueen C. E., Taubert S., Cotter D., Stevens S., Frost G. S. Which commercial thickening agent do patients prefer? Dysphagia. 2003;18:46-52.https://doi.org/https://doi.org/10.1007/s00455-002-0084-1

8. Cichero J. Adjustment of food textural properties for elderly patients. Journal of Texture Studies. 2016;47(4):277-83.https://doi.org/https://doi.org/10.1111/jtxs.12200

9. Children's-Health. Normal swallowing and dysphagia illustration. In: Image, editor. https://wwwchildrenscom/specialties-services/conditions/pediatric-swallowing-and-feeding-disorders: Children Health; n.d.

10. Khedr E. M., Abbass M. A., Soliman R. K., Zaki A. F., Gamea A. Post-stroke dysphagia: frequency, risk factors, and topographic representation: hospital-based study. The Egyptian Journal of Neurology, Psychiatry and Neurosurgery. 2021;57:1-8.https://doi.org/https://doi.org/10.1186/s41983-021-00281-9

11. Milewska M., Grabarczyk K., Dąbrowska-Bender M., Jamróz B., Dziewulska D., Staniszewska A., et al. The prevalence and types of oral-and pharyngeal-stage dysphagia in patients with demyelinating diseases based on subjective assessment by the study subjects. Multiple sclerosis and related disorders. 2020;37:101484.https://doi.org/https://doi.org/10.1016/j.msard.2019.101484

12. Martino R., Foley N., Bhogal S., Diamant N., Speechley M., Teasell R. Dysphagia after stroke: incidence, diagnosis, and pulmonary complications. stroke. 2005;36(12):2756-63.https://doi.org/https://doi.org/10.1161/01.str.0000190056.76543.eb

13. Ribeiro M., Miquilussi P. A., Goncalves F. M., Taveira K. V. M., Stechman-Neto J., Nascimento W. V., et al. The prevalence of oropharyngeal dysphagia in adults: a systematic review and meta-analysis. Dysphagia. 2024;39(2):163-76.https://doi.org/https://doi.org/10.1007/s00455-023-10608-8

14. Wirdefeldt K., Adami H.-O., Cole P., Trichopoulos D., Mandel J. Epidemiology and etiology of Parkinson's disease: a review of the evidence. European journal of epidemiology. 2011;26:1-58.https://doi.org/https://doi.org/10.1007/s10654-011-9581-6

15. Curtis J. A., Troche M. S. Handheld cough testing: a novel tool for cough assessment and dysphagia screening. Dysphagia. 2020;35(6):993-1000.https://doi.org/https://doi.org/10.1007/s00455-020-10097-z

16. Saccomanno S., Saran S., Paskay L. C., De Luca M., Tricerri A., Orlandini S. M., et al. Risk factors and prevention of choking. European journal of translational myology. 2023;33(4).https://doi.org/https://doi.org/10.4081/ejtm.2023.11471

17. Goh K.-H., Acharyya S., Ng S. Y.-E., Boo J. P.-L., Kooi A. H.-J., Ng H.-L., et al. Risk and prognostic factors for pneumonia and choking amongst Parkinson's disease patients with dysphagia. Parkinsonism & Related Disorders. 2016;29:30-4.https://doi.org/https://doi.org/10.1016/j.parkreldis.2016.05.034

18. Walshe M., Smith M., Pennington L. Interventions for drooling in children with cerebral palsy. Cochrane Database of Systematic Reviews. 2012(2).https://doi.org/https://doi.org/10.1002/14651858.cd008624.pub3

19. Hwang E. H., Hwang C. Dysphagia and odynophagia. Primary Care for Emergency Physicians: Springer; 2024. p. 89-99.

20. John J., Blair B., Joo L., Dargan A., Chhoun C., Dasu N. S5196 A Rare Case of Dysphagia as a Herald Sign of Gastric Diffuse Large B Cell Lymphoma. Official journal of the American College of Gastroenterology| ACG. 2024;119(10S):S3252-S3

21. Lee M., Sadeghi S., Mathiasen R. A. Dysphagia and Regurgitated Mass. Clinical Gastroenterology and Hepatology. 2024.https://doi.org/https://doi.org/10.1016/j.cgh.2024.02.005

22. Quinchia L., Valencia C., Partal P., Franco J., Brito-De La Fuente E., Gallegos C. Linear and non-linear viscoelasticity of puddings for nutritional management of dysphagia. Food Hydrocolloids. 2011;25(4):586-93.https://doi.org/https://doi.org/10.1016/j.foodhyd.2010.07.006

23. Low J., Wyles C., Wilkinson T., Sainsbury R. The effect of compliance on clinical outcomes for patients with dysphagia on videofluoroscopy. Dysphagia. 2001;16:123-7.https://doi.org/https://doi.org/10.1007/s004550011002

24. Valentini L., Schindler K., Schlaffer R., Bucher H., Mouhieddine M., Steininger K., et al. The first nutritionDay in nursing homes: participation may improve malnutrition awareness. Clinical Nutrition. 2009;28(2):109-16.https://doi.org/https://doi.org/10.1016/j.clnu.2009.01.021

25. Rofes L., Arreola V., Romea M., Palomera E., Almirall J., Cabré M., et al. Pathophysiology of oropharyngeal dysphagia in the frail elderly. Neurogastroenterology & Motility. 2010;22(8):851-e230.https://doi.org/https://doi.org/10.1111/j.1365-2982.2010.01521.x

26. Hu X., Meng Z. An overview of edible foams in food and modern cuisine: Destabilization and stabilization mechanisms and applications. Comprehensive Reviews in Food Science and Food Safety. 2024;23(1):e13284.https://doi.org/https://doi.org/10.1111/1541-4337.13284

27. Baudelet M., Van den Steen L., Duprez F., De Bodt M., Deschuymer S., Goeleven A., et al. Study protocol for a randomized controlled trial: prophylactic swallowing exercises in head-and-neck cancer patients treated with (chemo) radiotherapy (PRESTO trial). Trials. 2020;21:1-10.https://doi.org/https://doi.org/10.1186/s13063-020-4171-0

28. Smith R., Bryant L., Hemsley B. Dysphagia and quality of life, participation, and inclusion experiences and outcomes for adults and children with dysphagia: a scoping review. Perspectives of the ASHA special interest groups. 2022;7(1):181-96.https://doi.org/https://doi.org/10.1044/2021_PERSP-21-00162

29. Verdonschot R. J., Baijens L. W., Serroyen J. L., Leue C., Kremer B. Symptoms of anxiety and depression assessed with the Hospital Anxiety and Depression Scale in patients with oropharyngeal dysphagia. Journal of psychosomatic research. 2013;75(5):451-5.https://doi.org/https://doi.org/10.1016/j.jpsychores.2013.08.021

30. Farri A., Accornero A., Burdese C. Social importance of dysphagia: its impact on diagnosis and therapy. ACTA otorhinolaryngologica itálica. 2007;27(2):83.https://doi.org/https://pmc.ncbi.nlm.nih.gov/articles/PMC2640007/

31. Reddacliff C., Hemsley B., Smith R., Dalton S., Jones S., Fitzpatrick A., et al. Examining the content and outcomes of training in dysphagia and mealtime management: A systematic review informing co-design of new training. American Journal of Speech-Language Pathology. 2022;31(3):1535-52.https://doi.org/https://doi.org/10.1044/2022_ajslp-21-00231

32. Cooke P. What Speech-Language Pathologists and Caregivers Can Do to Encourage the Eating Process. Perspectives on Swallowing and Swallowing Disorders (Dysphagia). 2008;17(2):67-73

33. Pizzorni N. Social and psychologic impact of dysphagia. Dysphagia: Diagnosis and Treatment2019. p. 873-86.DOI: https://doi.org/10.1007/174_2017_132.
34. Beck A. M., Kjaersgaard A., Hansen T., Poulsen I. Systematic review and evidence based recommendations on texture modified foods and thickened liquids for adults (above 17 years) with oropharyngeal dysphagia–An updated clinical guideline. Clinical Nutrition. 2018;37(6):1980-91.https://doi.org/https://doi.org/10.1016/j.clnu.2017.09.002
35. Donini L. M., Savina C., Cannella C. Eating habits and appetite control in the elderly: the anorexia of aging. International psychogeriatrics. 2003;15(1):73-87.https://doi.org/https://doi.org/10.1017/s1041610203008779
36. Ng V., Bogaardt H., Tzannes G., Collins S., Docking K. Thickened formulas used for infants with dysphagia: Influence of time and temperature. Dysphagia. 2022;37(4):923-32.https://doi.org/https://doi.org/10.1007/s00455-021-10353-w
37. Wendin K. Sensory dynamics in emulsion products differing in fat content. 2001.https://doi.org/https://www.cabidigitallibrary.org/doi/full/10.5555/20013114880
38. Pereira N. I. A., dos Santos Oliveira M., Reis B. C. C., Nascimento B. L., Carneiro C. R., Arruda T. R., et al. Unconventional sourced proteins in 3D and 4D food printing: Is it the future of food processing? Food Research International. 2024:114849.https://doi.org/https://doi.org/10.1016/j.foodres.2024.114849
39. Rothenberg E., Wendin K. Texture modification of food for elderly people. Modifying food texture: Elsevier; 2015. p. 163-85.DOI: https://doi.org/10.1016/B978-1-78242-334-8.00007-9.
40. Hall G., Wendin K. Sensory design of foods for the elderly. Annals of Nutrition and Metabolism. 2008;52(Suppl. 1):25-8.https://doi.org/https://doi.org/10.1159/000115344
41. Edfors E., Westergren A. Home‐Living Elderly People′ s Views on Food and Meals. Journal of aging research. 2012;2012(1):761291.https://doi.org/https://doi.org/10.1155/2012/761291
42. Schiffman S., Graham B. Taste and smell perception affect appetite and immunity in the elderly. European journal of clinical nutrition. 2000;54(3):S54-S63.https://doi.org/https://doi.org/10.1038/sj.ejcn.1601026
43. Cichero J. A. Thickening agents used for dysphagia management: effect on bioavailability of water, medication and feelings of satiety. Nutrition journal. 2013;12:1-8.https://doi.org/https://doi.org/10.1186/1475-2891-12-54
44. Norton V., Lignou S., Bull S. P., Gosney M. A., Methven L. Consistent effects of whey protein fortification on consumer perception and liking of solid food matrices (cakes and biscuits) regardless of age and saliva flow. Foods. 2020;9(9):1328.https://doi.org/https://doi.org/10.3390/foods9091328
45. Caez-Ramírez G., Sotelo-Díaz L. I., Torres-Ortiz K. S. Food Texture and Rheology: An Opportunity to Improve Wellness and Nutrition of Elderly Population. Health-Promoting Food Ingredients during Processing: CRC Press. p. 409-29.
46. Hepper E. C., Patterson J. M. Healthcare professionals' perceptions of stabilized edible foam with adults with severe dysphagia; an exploratory study: Use of stabilized edible foam with adults with dysphagia. International Journal of Language & Communication Disorders. 2023;58(2):226-40.https://doi.org/https://doi.org/10.1111/1460-6984.12769
47. Nishinari K., Turcanu M., Nakauma M., Fang Y. Role of fluid cohesiveness in safe swallowing. npj Science of Food. 2019;3(1):5.https://doi.org/https://doi.org/10.1038/s41538-019-0038-8
48. Steele C. M., Alsanei W. A., Ayanikalath S., Barbon C. E., Chen J., Cichero J. A., et al. The influence of food texture and liquid consistency modification on swallowing physiology and

function: a systematic review. Dysphagia. 2015;30:2-26.https://doi.org/https://doi.org/10.1007/s00455-014-9578-x

49. Asher Wolf W., Huang K. Z., Durban R., Iqbal Z. J., Robey B. S., Khalid F. J., et al. The six-food elimination diet for eosinophilic esophagitis increases grocery shopping cost and complexity. Dysphagia. 2016;31:765-70.https://doi.org/https://doi.org/10.1007/s00455-016-9739-1

50. de Villiers M., Hanson B., Moodley L., Pillay M. The impact of modification techniques on the rheological properties of dysphagia foods and liquids. Journal of texture studies. 2020;51(1):154-68.https://doi.org/https://doi.org/10.1111/jtxs.12476

51. Kenny B. Food culture, preferences and ethics in dysphagia management. Bioethics. 2015;29(9):646-52.https://doi.org/https://journals.lww.com/ajg/fulltext/2024/10001/s5196_a_rare_case_of_dysphagia_as_a_herald_sign_of.5197.aspx

52. Riquelme L. F., Pillay M. 19 Cultural Responsiveness in Dysphagia Practice. Cultural Sensitivity and Responsiveness in Neurorehabilitation: A Personalized Approach for Speech-Language Pathologists2024. p. 369.DOI: https://books.google.com/books?hl=ar&lr=&id=-Q41EQAAQBAJ&oi=fnd&pg=PA369&dq=19+Cultural+Responsiveness+in+Dysphagia+Practice&ots=GR1VloA_XK&sig=6FXOGVFxuUjGb8vbNpfMZJnSAPQ.

53. Riquelme L. F., Pillay M., Brady Wagner L. Diversity, Culture and Practice: From Society to "the Bedside". Current Otorhinolaryngology Reports. 2023;11(4):403-13.https://doi.org/https://doi.org/10.1007/s40136-023-00485-y

54. Tucher E. L., Keeney T., Cohen A. J., Thomas K. S. Conceptualizing food insecurity among older adults: development of a summary indicator in the National Health and Aging Trends Study. The Journals of Gerontology: Series B. 2021;76(10):2063-72.https://doi.org/https://doi.org/10.1093/geronb/gbaa147

55. Thiyagalingam S., Kulinski A. E., Thorsteinsdottir B., Shindelar K. L., Takahashi P. Y., editors. Dysphagia in older adults. Mayo clinic proceedings; 2021: Elsevier.

56. Jones H. N., Leiman D. A., Porter Starr K. N., North R., Pieper C. F., Robison R. D., et al. Dysphagia in older adults is associated with food insecurity and being homebound. Journal of Applied Gerontology. 2023;42(9):1993-2002.https://doi.org/https://doi.org/10.1177/07334648231177568

57. Sungsinchai S., Niamnuy C., Wattanapan P., Charoenchaitrakool M., Devahastin S. Texture modification technologies and their opportunities for the production of dysphagia foods: A review. Comprehensive Reviews in Food Science and Food Safety. 2019;18(6):1898-912.https://doi.org/https://doi.org/10.1111/1541-4337.12495

58. Raheem D., Carrascosa C., Ramos F., Saraiva A., Raposo A. Texture-modified food for dysphagic patients: A comprehensive review. International Journal of Environmental Research and Public Health. 2021;18(10):5125.https://doi.org/https://doi.org/10.3390/ijerph18105125

59. Hadde E. K., Chen J. Texture and texture assessment of thickened fluids and texture-modified food for dysphagia management. Journal of Texture Studies. 2021;52(1):4-15.https://doi.org/https://doi.org/10.1111/jtxs.12567

60. Wu X. S., Miles A., Braakhuis A. An evaluation of texture-modified diets compliant with the International Dysphagia Diet Standardization Initiative in aged-care facilities using the Consolidated Framework for Implementation Research. Dysphagia. 2022;37(5):1314-25.https://doi.org/https://doi.org/10.1007/s00455-021-10393-2

61. Smith R., Bryant L., Reddacliff C., Hemsley B. A review of the impact of food design on the mealtimes of people with swallowing disability who require texture-modified food.

International Journal of Food Design. 2022;7(1):7-28.https://doi.org/http://dx.doi.org/10.1386/ijfd_00034_1
62. Baert F., Vlaemynck G., Beeckman A. S., Van Weyenberg S., Matthys C. Dysphagia management in Parkinson's disease: Comparison of the effect of thickening agents on taste, aroma, and texture. Journal of Food Science. 2021;86(3):1039-47.https://doi.org/https://doi.org/10.1111/1750-3841.15595
63. Lee J.-H., Yook D.-H., Kim M.-H. Study on Setting the Amount of Thickening Agent in Soup and Beverages as a Guide for Modifying the Viscosity of Dysphagia Diets. Journal of the Korean Dietetic Association. 2024;30(1):11-28.https://doi.org/http://doi.org/10.14373/JKDA.2024.30.1.11
64. Li L., Zhou T.-Q., Wang Y.-Q., Zhang Q., Yan J.-N., Wang C., et al. Rheological characterization of chia seed gum as a thickening agent used for dysphagia management. International Journal of Biological Macromolecules. 2024;275:133413.https://doi.org/https://doi.org/10.1016/j.ijbiomac.2024.133413
65. Chen L., Hemsley B., Debono D. The Impact of Food-Shaping Techniques on Nutrition, Mealtime Experiences, and Quality of Life for Older Adults in Aged Care Settings: A Systematic Review. Current Nutrition Reports. 2023;12(4):744-66.https://doi.org/https://doi.org/10.1007/s13668-023-00493-w
66. Nishinari K., Zhang K., Yang N., Gao Z., Gamonpilas C., Turcanu M., et al. Rheology for Safe Swallowing 1. Nihon Reoroji Gakkaishi. 2023;51(4):219-48.https://doi.org/https://doi.org/10.1678/rheology.51.219
67. Lee A. Y., Pant A., Pojchanun K., Lee C. P., An J., Hashimoto M., et al. Three-dimensional printing of food foams stabilized by hydrocolloids for hydration in dysphagia. International Journal of Bioprinting. 2021;7(4).https://doi.org/https://doi.org/10.18063/ijb.v7i4.393
68. Lorenz T., Iskandar M. M., Baeghbali V., Ngadi M. O., Kubow S. 3D food printing applications related to dysphagia: A narrative review. Foods. 2022;11(12):1789.https://doi.org/https://doi.org/10.3390/foods11121789
69. Ghazal A. F., Zhang M., Liu Z. Spontaneous color change of 3D printed healthy food product over time after printing as a novel application for 4D food printing. Food and Bioprocess Technology. 2019;12:1627-45.https://doi.org/https://doi.org/10.1007/s11947-019-02327-6
70. Teng X., Zhang M., Mujumdar A. S. 4D printing: Recent advances and proposals in the food sector. Trends in Food Science & Technology. 2021;110:349-63.https://doi.org/https://doi.org/10.1016/j.tifs.2021.01.076
71. Kouzani A. Z., Adams S., Whyte D. J., Oliver R., Hemsley B., Palmer S., et al. 3D printing of food for people with swallowing difficulties. KnE Engineering. 2017.https://doi.org/https://doi.org/10.18502/keg.v2i2.591
72. Fribus R., Kant J., Fahmy A. R., Jekle M. Texture modulation of starch-based materials using microfoaming-assisted 3D printing. Future Foods. 2024;9:100311.https://doi.org/https://doi.org/10.1016/j.fufo.2024.100311
73. Zhu J., Yang Y., Qiao S., Dai H., Chen H., Fu Y., et al. 4D printing of betanin/gelatin/nano-chitin complexes-functionalized surimi via disulfide bonds, and its applicability in dysphagia diets. Food Hydrocolloids. 2024;152:109891.https://doi.org/https://doi.org/10.1016/j.foodhyd.2024.109891
74. Niranjan K., Silva S. Bubble-containing foods. Food Materials Science: Principles and Practice2008. p. 281-303.DOI: https://doi.org/10.1007/978-0-387-71947-4_14.
75. Alsanei W., Chen J. Food structure development for specific population groups. 2019.https://doi.org/https://doi.org/10.1039/9781788016155-00459

76. Rolls B. J., Bell E. A., Waugh B. A. Increasing the volume of a food by incorporating air affects satiety in men. The American journal of clinical nutrition. 2000;72(2):361-8.https://doi.org/https://doi.org/10.1093/ajcn/72.2.361
77. Fameau A.-L., Saint-Jalmes A. Recent advances in understanding and use of oleofoams. Frontiers in Sustainable Food Systems. 2020;4:110.https://doi.org/https://doi.org/10.3389/fsufs.2020.00110
78. Koizumi A., Koizumi A., Mineki M. Preparation and suitability of espuma fish dishes for older adults. Food Science and Technology Research. 2023;29(3):247-56.https://doi.org/http://dx.doi.org/10.3136/fstr.FSTR-D-22-00189
79. Chen Z., Chen C., Yang R., Jin H., Liu B., Wang Z., et al. The formation mechanism of sufu gels fermented by mucor racemosus during pre-fermentation. LWT. 2024:116309.https://doi.org/https://doi.org/10.1016/j.lwt.2024.116309
80. Liu X., Sala G., Scholten E. Structural and functional differences between ice crystal-dominated and fat network-dominated ice cream. Food Hydrocolloids. 2023;138:108466.https://doi.org/https://doi.org/10.1016/j.foodhyd.2023.108466
81. Deosarkar S., Khedkar C., Kalyankar S., Sarode A. Ice cream: uses and method of manufacture. 2016.https://doi.org/http://dx.doi.org/10.1016/B978-0-12-384947-2.00384-6
82. Deng B., De Ruiter J., Schroën K. Application of microfluidics in the production and analysis of food foams. Foods. 2019;8(10):476.https://doi.org/https://doi.org/10.3390/foods8100476
83. Pugh R., Hamlett C., Fairhurst D. A short overview of bubbles in foods and chocolate. Advances in Colloid and Interface Science. 2023;314:102835.https://doi.org/https://doi.org/10.1016/j.cis.2023.102835
84. Díaz-Ramírez M., Calderón-Domínguez G., García-Garibay M., Jiménez-Guzmán J., Villanueva-Carvajal A., de la Paz Salgado-Cruz M., et al. Effect of whey protein isolate addition on physical, structural and sensory properties of sponge cake. Food Hydrocolloids. 2016;61:633-9.https://doi.org/https://doi.org/10.1016/j.foodhyd.2016.06.020
85. Lim K., Barigou M. X-ray micro-computed tomography of cellular food products. Food research international. 2004;37(10):1001-12.https://doi.org/https://doi.org/10.1016/j.foodres.2004.06.010
86. Jakubczyk E., Kamińska-Dwórznicka A., Kot A. The rheological properties and texture of agar gels with canola oil—effect of mixing rate and addition of lecithin. Gels. 2022;8(11):738.https://doi.org/https://doi.org/10.3390/gels8110738
87. David-Birman T., Romano A., Aga A., Pascoviche D., Davidovich-Pinhas M., Lesmes U. Impact of silkworm pupae (Bombyx mori) powder on cream foaming, ice cream properties and palatability. Innovative Food Science & Emerging Technologies. 2022;75:102874.https://doi.org/https://doi.org/10.1016/j.ifset.2021.102874
88. Özer Ç., Ağan C. The influence of aging egg on foaming properties of different meringue types. Journal of Culinary Science & Technology. 2021;19(6):475-84.https://doi.org/https://doi.org/10.1080/15428052.2020.1790073
89. Gladys C.-C. T., Rocío M.-P. Y., Angélica S.-L. N. Quality evaluation through sensory and image analysis of sponge cake crumb with three thermal egg pre-treatments. International Journal of Gastronomy and Food Science. 2021;25:100390.https://doi.org/https://doi.org/10.1016/j.ijgfs.2021.100390
90. Regnard C., Leslie P., Crawford H., Matthews D., Gibson L. Gastrostomies in dementia: bad practice or bad evidence? : Oxford University Press; 2010. p. 282-4.DOI: https://doi.org/10.1093/ageing/afq012.

91. Żmudziński D., Ptaszek P., Kruk J., Kaczmarczyk K., Rożnowski W., Berski W., et al. The role of hydrocolloids in mechanical properties of fresh foams based on egg white proteins. Journal of Food Engineering. 2014;121:128-34.https://doi.org/https://doi.org/10.1016/j.jfoodeng.2013.08.020
92. Mitsuhashi J. The future use of insects as human food. Forest insects as food: humans bite back. 1152010. p. 122.DOI: https://www.doc-developpement-durable.org/file/sante-hygiene-medecine/Securite-et-Hygiene-Alimentaire/Nourriture-a-Base-d-Insectes/edible-forest-insects-i1380e00.pdf#page=124.
93. Battampara P., Sathish T. N., Reddy R., Guna V., Nagananda G., Reddy N., et al. Properties of chitin and chitosan extracted from silkworm pupae and egg shells. International Journal of Biological Macromolecules. 2020;161:1296-304.https://doi.org/https://doi.org/10.1016/j.ijbiomac.2020.07.161
94. Zhou J., Han D. Proximate, amino acid and mineral composition of pupae of the silkworm Antheraea pernyi in China. Journal of Food Composition and Analysis. 2006;19(8):850-3.https://doi.org/https://doi.org/10.1016/j.jfca.2006.04.008
95. Roos N. Insects and human nutrition. Edible insects in sustainable food systems. 2018:83-91.https://doi.org/https://doi.org/10.1007/978-3-319-74011-9_5
96. Marchand M., Restagno F., Rio E., Boulogne F. Roughness-induced friction on liquid foams. Physical Review Letters. 2020;124(11):118003.https://doi.org/https://doi.org/10.1103/PhysRevLett.124.118003
97. Zhang X., Wang Z., Hu G., Yang Y., Sun H., Cai Z. Hydrogel foam with designed structural properties of egg white protein through building aggregates as potential dysphagia food. Food Hydrocolloids. 2025;158:110584.https://doi.org/https://doi.org/10.1016/j.foodhyd.2024.110584
98. Wu X. S., Miles A., Braakhuis A. Malnutrition in aged care: interplay between dysphagia and diet. Current Opinion in Otolaryngology & Head and Neck Surgery. 2023;31(6):350-6.https://doi.org/https://doi.org/10.1097/moo.0000000000000911

من الخطر إلى البلع الممتع والآمن: الدراسات الحالية حول تطوير هياكل الأطعمة والسائلة وشبه الهلامية ذات الفقاعات الهوائية لإدارة عسر البلع

ورود عبدالرحمن الصنيع[١]*

[١] قسم الغذاء والتغذية، كلية علوم الإنسان والتصاميم، جامعة الملك عبدالعزيز، جدة، walsanei@kau.edu.sa

* للتواصل: د. ورود عبدالرحمن الصنيع walsanei@kau.edu.sa

الملخص:

يؤثر عسر البلع بشكل كبير على جودة الحياة، ويزيد من مخاطر سوء التغذية والجفاف والالتهاب الرئوي التنفسي وتحديات الرعاية الصحية طويلة الأمد. غالباً ما تُغير التدخلات الغذائية التقليدية قوام الطعام والسوائل، ولكن قد يتراجع الالتزام بها بسبب مظهر الأطعمة غير الجذابة وغير الشهية. لذلك، تُسلط هذه المراجعة الضوء على الهياكل المُهَوَّاة (الرغوية، الفقاعية الهوائية) الحالية في الأطعمة والسوائل ومنتجات شبه الهلام المُصممة للأفراد الذين يعانون من عسر البلع لتحسين الملمس والتجارب الحسية والبلع. تُلخص هذه المراجعة استخدام فقاعات الهواء لتليين قوام الطعام، وتقليل مخاطر الاختناق، وتحسين السلامة أثناء تناول الوجبات. بالإضافة إلى ذلك، تُساهم فقاعات الهواء في تحسين التجربة الحسية من خلال تحسين الشعور بالفم، وتسهيل إطلاق النكهة، وتحقيق توازن المذاق، وضمان السلامة، مع تعزيز عادات الأكل الصحية والرفاهية العامة للأفراد الذين يعانون من عسر البلع. تلعب الابتكارات في الهياكل المُهَوَّاة دوراً حاسماً في تحسين التغذية، وتحسين المذاق، وتحفيز الشهية. يتطلب استخدام هذه الهياكل في المنتجات المصممة للأشخاص الذين يعانون من عسر البلع تعاوناً بين علماء الأغذية، وخبراء التغذية، وأخصائيين أمراض النطق واللغة، وخبراء الطهي. ومع ذلك، هناك حاجة ماسة لإجراء تجارب سريرية شاملة على الهياكل المهواة لفهم تأثيرها على ديناميكيات البلع والنتائج الصحية، ولتحسين تطويرها لتعزيز السلامة والتغذية وجودة الحياة لدى الفئات المتضررة.

الكلمات المفتاحية:

البُنى الغذائية المهواة؛ فقاعات الهواء؛ الرغوة؛ تعديل قوام/نسيج الأغذية؛ عُسر البلع؛ صعوبة البلع