Effects of High Protein and Low Carbohydrate Smoothie Formulas on Swallowing Capacity in Older Adults: A Cross-Over Study

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Abstract

Background

Dysphagia is a common problem in older adults that can lead to nutritional deficiencies. Nutrition support is an alternative nutritional therapy, specifically manufactured for the older individuals at risk of dysphagia. This study aimed to develop four high protein (23-34% energy ratio) and low carbohydrate (25-38% energy ratio) smoothie formulas (white sesame (WS) vs. white sesame and low carbohydrate (WSLC) vs. black sesame and low carbohydrate (BSLC) vs. chicken shitake (CS); 1 kcal/ml) for the older people with dysphagia and to assess their effect on swallowing capacity compared to completed commercial formula (Ensure®).

Methods

A double-blind, randomized, placebo-controlled cross-over study involved 63 participants aged 65 years or over. Subjects were divided into asymptomatic (n=32, aged 72.9 ± 5.66 year) or symptomatic swallowing difficulty (n=31, aged 75.0 ± 6.48 year) groups based on swallowing screening questionnaires. Swallowing capacity was assessed using Fiberoptic Endoscopic Evaluation of Swallowing (FEES), performed by experienced healthcare professionals, for three drinks (WS, CS vs. Ensure®) in a blinded random sequence.

Results

Spare retention of a food bolus in each formula had been identified in the asymptomatic (47-66%) and symptomatic (59-71%) groups. WS had fewer premature spills than Ensure® in the symptomatic group, but not in the asymptomatic group (5±0.03 vs. 4.7±0.12, $p < 0.05$), while CS had fewer premature spills than Ensure®.

Conclusions

This result suggests that consumption of smoothie drinks, particularly WS (51-350 centipoise), may help reduce the risk and severity of food aspiration in the older people at risk compared to commercial formula (1-50 centipoise). These smoothies may be the alternative completed formulas without additional thickeners for the management and supplementation in older people with dysphagia.

Trial registration: Clinical Trial ID: NCT04901182, https://clinicaltrials.gov/ct2/show/NCT04901182 (25/05/2021)

Introduction

The global population is aging, with 771 million people aged 65 years or over in 2022, primarily in developing countries [1]. In 2022, 18.9% of Thais were older individuals, and this is projected to increase to 31.4% by 2042 [2]. Dysphagia, a syndrome characterized by difficulty in swallowing, affects at least

one-third of older adults diagnosed with neurodegenerative diseases or non-communicable diseases such as stroke, oral cancer, and nerve disorders [3–5]. Most seniors with dysphagia eventually experience multiple health issues, leading to a progressive impairment of various organ functions. Muscle mass tends to decline, associated with reductions in strength and musculoskeletal function and synchronization [6, 7]. Untreated dysphagia can result in reduced food intake, suffocation, aspiration, malnutrition, and pneumonia [8–10]. Large studies in nursing homes [11] and in a hospital [12] have concluded that individuals with dysphagia face a higher risk of choking, food aspiration, and increased mortality [13]. Managing dysphagia involves addressing underlying causes, utilizing behavioral treatments [14], making environmental modifications [15], practicing swallowing exercises [16], employing compensatory management, and implementing diet modifications [17].

Among Thai individuals aged 60 years or over, malnutrition prevalence ranges from 6–10% based on 71 studies [18]. Chaleekrua *et al*. reported that the prevalence of swallowing problems among healthy Thai community-dwelling older people was 11% [19]. However, official statistics and systematic records on malnutrition in older Thais with swallowing difficulties are lacking. Nutritional support is an alternative strategy to treat malnutrition in older individuals with swallowing disorders [17, 20]. With aging, factors such as tooth loss, impairment of taste sensation, and changes in masticatory muscle strength and integrity become crucial considerations when choosing a nutrition supplement [21, 22]. Modifications in the amount, frequency, and rate of intake, along with texture modification following the International Dysphagia Diet Standardisation Initiative (IDDSI) have proven useful as fundamental compensatory interventions in reducing dysphagia and its complications [23–25]. Regardless of the underlying medical conditions, nutrition supports provide protein, fat, energy, and essential micronutrients. These products can be administed orally without contraindications or enterally through a feeding tube [26, 27]. This underscores the notion that good nutrition in an older age with dysphagic risks is linked to healthy aging. Undernourished patients face an increased risk of infections, falls, pressure injuries, and mortality [28]. Maintaining an adequate diet is crucial to meet the needs of older people with comorbidities [29].

IDDSI has classified a terminology to describe diets based on food texture (regular, easy to chew, soft & bite-sized, minced & moist, pureed and liquidized) and the thicknesses of drinks (extremely thick, moderately thick, mildly thick, slightly thick and thin), while pureed food is the equivalent to extremely thick drinks at the IDDSI level 4 [24]. Modifying diets or supplements may alter taste, appearance, and texture, affecting decreased palatability and tolerability. Attempts to enhance acceptability may reduce essential macronutrients like protein and fat, potentially leading to decreased adherence and protein-energy malnutrition [4].

In Thailand, there is limited choices of commercial diets for dysphagia patients. Many of these are nutritionally inadequate, often consisting of high carbohydrate choices like congee or soft-boiled rice. The prescription of medical nutrition supplements is relatively low in Thailand due to limitations in public and private insurance reimbursement. Patients with illnesses may have reduced appetites and are often restricted to consuming therapeutic diets for extended periods, putting some patients at risk of inadequate nutritional intake [28]. Studies have found that patients on modified diets consume fewer

calories, fluids, and protein compared to those on a regular hospital diet, primarily due to the challenges of consuming less palatable and energy-dense foods [25, 30]. Pureed foods and moderately thick liquids are helpful in preventing food and fluids from entering the lungs compared to other textures [31, 32]. However, each patient's ability to tolerate the oral intake of dysphagia diets requires individual evaluation.

The objective of this study was to develop and conduct sensory tests on four high-protein texture-modified formulas primarily composed of locally available natural Asian ingredients and herbs. These formulas were designed to align with IDDSI level 4, denoting a textural profile similar to pureed and equivalent to extremely thick liquids or smoothies. We also compared the effect on swallowing capacity of older people at risk of dysphagia when consuming these formulas versus consuming a well-known commercial conventional formula (Ensure®), using fiberoptic endoscopic evaluation of swallowing (FEES).

Methods

Modified nutrition-dense smoothie diets

The four developed formulas comprised white sesame soy milk smoothie (WS), white sesame soy milk smoothie (low carbohydrate, WSLC), black sesame soy milk smoothie (low carbohydrate, BSLC), and chicken shitake smoothie (CS) (Supplementary Appendix S1). The composition of energy, carbohydrate, protein, fat, and micronutrients was determined by the Asia Medical and Agricultural Laboratory and Research Center, Bangkok, Thailand, according to the AOAC standard protocol [33]. The four smoothies developed for use in this study provide a normocaloric (1.0-1.1 kcal/ml), hypoglycedic (25-38%), hyperproteic (24-28%) nutritional composition (Table 1). Ensure®, a completed commercial formula (Abbott Nutrition, USA) served as a control. Ensure® was prepared from vanilla powdered formula with a standard 1 kcal/ml recipe according to the manufacturer's instructions, contained 54% carbohydrate, 15% protein, and 29% fat. Detailed physical properties of the smoothies, including color, pH, and viscosity, can be found in Table 2. The viscosity of the modified nutrition dense smoothie diets varied greatly. WS (194 centipoise; cP), WSLC (155 cP), BSLC (214 cP), and CS (81 cP) met the IDDSI criteria for extremely thick drinks or pureed foods. All four nutrition-dense smoothie diets have a nectar-like texture (51-350 cP). Ensure® (6 cP) is classified as a thin liquid (1-50 cP) [34]. All smoothies were prepared in one batch to maintain homogeneity. The 5-ml of each smoothie and Ensure® were prepared in a tasting cup and blind labeled with random three-digit codes.

Table 1 Composition of nutritionally dense smoothies and completed commercial formula per 100 g

Nutrient compositions	WS[a]	WSLC[a]	BSLC[a]	CS[a]	Ensure® (control)[b]
Energy (kcal)	105	103	106	107	100
Carbohydrate (g, %)	10.1, 38	7.1, 28	6.8, 25	9.6, 36	13.4, 54
Protein (g, %)	6.3, 24	7.3, 28	6.6, 25	7.4, 28	3.7, 15
Fat (g, %)	4.3, 37	5.1, 44	5.9, 50	4.3, 36	3.3, 29
Saturated fat (g)	1.9	2.1	2.1	2.6	0.3
Cholesterol (mg)	5.7	15.9	17.3	18.5	N/A
Dietary fiber (g)	0.6	0.5	1.5	0.8	1
Sugar (g)	4.3	3.2	4.8	2	N/A
Sodium (mg)	53	64	46.9	143	83.7
Calcium (mg)	24	25	64.2	41.9	104.7
Iron (mg)	0.8	0.8	1.1	0.9	0.6

Abbreviations: BSLC, black sesame soy milk smoothie (low carbohydrate); CS, chicken shitake smoothie; g, gram; kcal, kilocalorie; mg, milligram; N/A, not available; WS, white sesame soy milk smoothie; WSLC, white sesame soy milk smoothie (low carbohydrate).

[a]Analysis from Asia Medical and Agricultural Laboratory and Research Center Co., Ltd.

[b]Data from Abbott Nutrition (prepared from Ensure® powder 23.3 g in water 84.8 g).

Table 2 Physical properties of test diets

Test diets	Color[a]			pH[b]	Viscosity (Centipoise)[c]
	L*	a*	b*		
WS	64.58 ± 0.07	6.88 ± 0.10	26.78 ± 0.27	6.04 ± 0.01	193.99 ± 17.59
WSLC	66.44 ± 0.41	6.93 ± 0.02	26.93 ± 0.21	6.17 ± 0.00	154.82 ± 9.73
BSLC	56.82 ± 0.40	3.02 ± 0.02	15.29 ± 0.14	6.04 ± 0.01	214.47 ± 29.18
CS	58.73 ± 0.18	6.23 ± 0.09	25.07 ± 0.16	6.11 ± 0.02	80.85 ± 0.07
Ensure® (control)	80.89 ± 0.05	0.28 ± 0.01	15.54 ± 0.01	5.97 ± 0.00	6.20 ± 0.10

Abbreviations: BSLC, black sesame soy milk smoothie (low carbohydrate); CS, chicken shitake smoothie; WS, white sesame soy milk smoothie; WSLC, white sesame soy milk smoothie (low carbohydrate).

[a]The color values were measured using color measurement spectrophotometer (Model Color Quest XE, Hunter lab, USA) in CIE-color system (L*, a*, b*). The color parameters: L* represents lightness from black to white (0 to 100); a* represents redness from green (-) to red (+); and b* represents yellowness from blue (-) to yellow (+).

[b]The acidic/basic values were measured using pH meter (Model SevenCompact, Mettler-Toledo, Switzerland).

[c]The viscosity values were measured using Coaxial spindle CCT-40, Rheometer (Model RST-CC Touch™, Brookfield Engineering Laboratories, Inc, USA).

Study participants

Adults aged 65 years or over were recruited through social media advertisements and posters at Siriraj Hospital, Mahidol University, Bangkok, Thailand. Inclusion criteria required the ability to understand in the Thai language and to follow healthcare professionals' instructions during a swallowing test. Participants with severe dysphagia, a history of tube feeding, or facial bone or skull surgery were excluded. Individuals in palliative care, bedridden, or unable to provide informed consent were also excluded. Sample size calculation was performed using G*Power software version 3.1, Germany. Relying on literature effect size of 0.77 in swallowing study in older subjects [35], 31 patients per group were required to achieve 80% power at 5% level of significance. Participants were separated into two groups by using screening questionnaires to ask whether they are aware of any past or current swallowing difficulties (Supplementary Appendix S2). Participants without a history of swallowing difficulties, coughing, or choking when eating or drinking were assigned to an asymptomatic swallowing difficulty (ASD) group.

Participants with symptomatic swallowing difficulties or with a history mentioned above in the ASD group were assigned to a symptomatic swallowing difficulty group (SSD). Informed consent was obtained, and the study was approved by the Siriraj Institutional Review Board (COA no. Si 010/2018). The study was conducted as a randomized controlled double-blind trial, with random three-digit codes used for blind labeling diets and the diets being provided to participants by research staffs. This was done to ensure that participants and healthcare professionals remained unaware of the specific formulas provided.

Sensory evaluation

Sensory assessments were conducted using a 9-point hedonic scale to determine the acceptability of the four formulas compared to Ensure® (Figure S1, Supplementary Appendix S3). Sensory attributes evaluated included characteristic, color, smell, taste, viscosity, homogeneity, swallowing, and overall satisfaction [36]. Sensory evaluations were performed consecutively with 5-minute intervals and were followed by face-to-face interviews with research staff. Participants were provided with water to clean their mouths between samples, and the order of formula presentation was randomized for each participant.

Swallowing test

Swallowing capacity, reflecting the ability of the person to swallow specific quantities of foods or drinks in a given time, was assessed using FEES performed by two well-trained experienced healthcare professionals [37]. During FEES, a flexible laryngoscope with a 4.0 mm diameter distal chip was passed transnasally, with the use of topical anesthetics (3% ephedrine and 4% lidocaine) [38] when the participants sat upright. The tip of the endoscope was placed within the oropharynx beneath the soft palate to visualize the pharynx and larynx before and after all liquid swallows. Two of the developed smoothies, WS (194 cP) and CS (81 cP), were selected for the swallowing test, assuming the viscosity of WS represented that of WSLC and BSLC to reduce burden time of swallowing test in participants. Participants received three trials of 5-ml food boluses (WS, CS, and Ensure®) in a randomized sequence via a spoon by research staff, with instructions to swallow once on cue (Figure S1). The endoscope was then placed above the vocal cords to visualize gross aspiration into the trachea. After each trial, participants were allowed to drink 30 ml of green-dyed water to minimize food residue. The examination was halted if aspirated liquid was detected in any trial. A healthcare professional assessed the severity of swallowing disorders, and enteral complications (nausea, vomiting, abdominal distension, and gastric residue) and adverse events were recorded to evaluate the safety of the trials. Food residue was evaluated based on FEES findings, considering the presence or absence of post-swallow residue [39]. If residue was present, then additional scores were weighed toward three anatomical regions: premature spillage when the bolus leaks or falls into the hypopharynx before swallowing, retention of the bolus and/or secretion, and entrance of the bolus into the larynx or trachea. The healthcare professional rated the food residue as a percent of the space filled by assigning 5 scores based on the perception of the amount of residue compared to the total amount of bolus swallowed (Supplementary Appendix S4) [40].

Statistical analysis

Statistical analyses were performed using STATA version 15.0 (Stata Corporation, College Station, TX, U.S.). Median ratings of taste and appearance for the test diets (WS, WSLC, BSLC, CS and Ensure®) were compared using nonparametric Kruskal-Wallis analysis by ranks. When significant differences were observed ($p \leq 0.05$), Mann–Whitney U tests were performed on different combinations of the five test diets to determine the individual differences between them, and the *p*-values were adjusted for multiple comparisons using Bonferroni adjustment. Severity scores of swallowing disorders were compared using One-way ANOVA and the Scheffe's test.

Results

Baseline characteristics

The characteristics of the participants are presented in Table 3. The initial segment of the study involved a sensory test with 65 participants, with a mean age of 75.0 ± 6.48 years and 54% females. The primary underlying diseases among participants were hypertension, dyslipidemia, and diabetes mellitus. The swallowing screening identified solid foods, dry foods, and viscous foods as the top three types of foods causing difficulty for participants. The participants reported the top three symptoms of swallowing disorders as stuck food in the throat, choking on food, and repeated swallowing. Two participants participated solely in the sensory test due to personal reasons and did not attend the swallowing test. Of the 63 participants in the swallowing test, 32 were classified in the ASD group, and 31 in the SSD group based on their swallowing disorder histories. The ASD group included two individuals with previous strokes, while the SSD group comprised two participants with neurological histories and eight with head and neck cancer.

Table 3 Baseline characteristics of participants who participated in the sensory and swallowing test

Demographic data	Sensory test (N = 65)	Swallowing test (N = 63)	
		ASD (n = 32)	SSD (n = 31)
Age (years), Mean (SD)	75.0 ± 6.48	72.9 ± 5.66	75.0 ± 6.48
Female, n (%)	35 (53.8)	22 (68.8)	11 (35.5)
Underlying diseases, n (%)[a]			
Hypertension	33 (56.9)	13 (46.4)	19 (65.5)
Dyslipidemia	33 (56.9)	17 (60.7)	16 (55.2)
Diabetes Mellitus	15 (25.9)	11 (39.3)	4 (13.8)
Cancer	8 (13.8)	0 (0.0)	8 (27.6)
Stroke	4 (6.9)	2 (7.1)	2 (6.9)
Gastritis	1 (1.7)	0 (0.0)	1 (3.4)
Others	28 (48.3)	10 (35.7)	17 (58.6)
None	7 (10.8)	4 (12.5)	2 (6.5)
Swallowing screening, n (%)			
Types of foods, which patients were able to eat[b]			
Clear liquid foods	60 (92.3)	32 (100.0)	26 (83.9)
Full-liquid foods	61 (93.8)	32 (100.0)	27 (87.1)
Soft foods	59 (90.8)	32 (100.0)	25 (80.6)
Semi-solid foods	60 (92.3)	32 (100.0)	26 (83.9)
Viscous foods	58 (89.2)	32 (100.0)	24 (77.4)
Solid foods	57 (87.7)	32 (100.0)	23 (74.2)
Dry foods	58 (89.2)	32 (100.0)	24 (77.4)
History of swallowing disorders, yes (> 1 time/week)[c]	31 (47.7)	0 (0.0)	31 (100.0)
Food stuck in throat	23 (74.2)	0 (0.0)	23 (74.2)
Choking on food	15 (48.4)	0 (0.0)	15 (48.4)
Painful swallowing	3 (9.7)	0 (0.0)	3 (9.7)
Throat irritation	7 (22.6)	0 (0.0)	7 (22.6)

Demographic data	Sensory test (N = 65)	Swallowing test (N = 63)	
		ASD (n = 32)	SSD (n = 31)
Nasal regurgitation	2 (6.5)	0 (0.0)	2 (6.5)
Repeated swallowing	13 (41.9)	0 (0.0)	13 (41.9)
Not able to eat dry foods or liquid foods	7 (22.6)	0 (0.0)	7 (22.6)

Note: Continuous variables are presented as mean. Categorical variables are presented as count (percentage of participants in each group).

Abbreviations: ASD, asymptomatic swallowing difficulty; SD, standard deviation; SSD, symptomatic swallowing difficulty.

[a] participant may have more than one underlying disease.

[b] participants were able to eat more than one kind of food.

[c] participants may have more than one swallowing disorder condition.

Sensory acceptability

Sensory evaluation of key properties of test diets using a 9-point hedonic scale indicated that the sensory rating of test diets ranged from neutral to 'like very much' (Figure 1, Table S1). Participants rated Ensure® significantly higher in characteristic, color, smell, taste, swallowing, and overall satisfaction compared to modified nutritionally dense smoothie diets. Except for viscosity and homogeneity, ratings were closer between WS, CS, and Ensure®. Color preference leaned toward WS and WSLC over BSLC and CS. The median smell rating score in WS and CS was higher after taste. Participants moderately favored the viscosity of WS, CS, and Ensure® both before and after testing. In terms of taste, the participants moderately liked Ensure® and WS. Participants moderately liked the homogeneity and swallowing of WS, CS, and Ensure®. Overall satisfaction tended to increase after tasting across all formulations.

Swallowing disorders detected by FEES

A healthcare professional assessed four swallowing abnormalities using FEES (Table S2). Most participants in the ASD group experienced bolus retention when swallowed WS (66%) and Ensure® (59%). In the SSD group, most participants found bolus retention when swallowing all formulas, especially Ensure® (71%). Laryngeal penetration was a symptom found when participants in the SSD group swallowed all formulas. The proportion of participants in each severity level of swallowing disorders detected by FEES is shown in Table S3. Sixteen percent and 23% of the ASD and SSD groups, respectively, had mild to marked premature spillage when they swallowed Ensure®. Over half of the ASD

group (53%) and 42% of the SSD group did not retain or secrete material when swallowing CS. Almost 10% of the SSD group had materials leakage into the larynx above the trachea when swallowed Ensure®. Notably, no significant associations were found between severity levels and specific dietary formulations. When comparing between the formulas (Figure 2), it was found that the FEES scores of the ASD group were not significantly different in all the formulas. On the other hand, the premature spillage of material score of the SSD group showed a significant difference ($p < 0.05$) between WS and Ensure®.

Pre-examination awareness of dysphagia

After enrollment, participants were asked the routine screening question, 'Do you have a swallowing problem?' Notably, 50% (32/63 participants) of the participants were classified in the ASD group when reporting no history of swallowing difficulties, coughing, or choking when eating or drinking. However, upon FEES assessment, 37% (12/32 participants) of the ASD group exhibited symptoms of the disorder (FEES score < 15) across all diet formulas. Most of the symptoms found in this group were bolus retention of mild severity. In contrast, 23% (7/31 participants) of the SSD group, reporting a history of swallowing disorders, did not exhibit symptoms (FEES score = 15) across all diet formulas when detected by FEES.

Discussion

Modified nutrition dense smoothie diets were formulated as ready-to-eat meal supplement derived from natural ingredients, containing essential nutrients tailored for the older individuals with a particular focus on their higher protein content (6.3-7.4 g/100 g diet) compared to Ensure® (3.7 g/100 g diet). Older individuals necessitate higher dietary protein intake, up to 1.2 g/kg body weight/day, to counteract sarcopenia and maintain musculoskeletal health [41]. Unfortunately, meeting these protein requirements poses challenges for many older adults, often attributed to factors such as tooth loss, which can impede the eating process. Therefore, a nutrition dense diet supplement with texture modification has the potential to enhance overall food intake. This study evaluated these modified nutrition-dense smoothie diets and Ensure® using 65 older adults attending a swallowing clinic at the Siriraj hospital. Solid foods, dry foods, and viscous foods were identified as the top three categories causing difficulty for participants. The predominant symptoms of swallowing disorders reported were food getting stuck in the throat, choking on food, and repeated swallowing-early indicators of swallowing disorders in the older persons due to physiologic changes. Additionally, other signs of dysphagia include coughing, nasal passage of food or liquid, and chewing difficulties. An epidemiological study demonstrated variable dysphagia prevalence in the older population across different medical conditions, ranging from 50-80% in nursing home residents with Alzheimer's or Parkinson's disease to 30-40% in the community [15, 17, 42]. Sensory factors, particularly food temperature, influenced participants' preferences. Jelly-like foods were the most favored, followed by warm and cold liquids, room-temperature liquids, and mousse-like foods. This could be due to the nature of the jelly food that makes it feel like dessert. In addition, the delicious taste emerged as a pivotal factor influencing individual food preferences more than other sensory

aspects [43]. In this study, participants assessed various sensory attributes, revealing that that Ensure® received the highest scores, likely owing to its familiarity. However, the modified nutrition-dense smoothie diets were well-accepted by the older individuals, with the median scores ranging from neutral to 'like very much' on the 9-point hedonic scale.

For the swallowing test, a healthcare professional assessed participant for four symptoms. Among the 32 participants in the ASD group, most experienced symptoms of bolus retention across all three test diets, with mild retention especially notable when swallowing WS and Ensure®. Although the incidence of mild bolus retention in the SSD group did not differ significantly from the control group, it was more prevalent when Ensure® was swallowed. Two important insights can be derived from this information. Firstly, approximately 60% of normal older individuals experienced early-stage swallowing problems that were not yet causing noticeable issues. These may be indicative of presbyphagia, associated with anatomical and functional changes in swallowing physiology during aging in healthy older adults, often undiagnosed as dysphagia [44]. Older individuals with presbyphagia are at a higher risk of developing more severe dysphagia in the future, and silent aspiration may occur if they are unaware of the existence of dysphagia. The FEES exam, a gold standard method for evaluating the early stage of swallowing disorders, prompted healthcare professionals to advise older individuals with presbyphagia to perform tongue-strengthening exercises and select appropriate food textures to enhance their swallowing. Secondly, sticky foods tend to be problematic and increase the risk of choking and residue. The tongue, which gradually weakens with aging, playing a critical role in pushing food boluses downward toward the pharynx during the swallowing process. The maximum tongue strength, which diminishes with aging, affects the food in the vallecula after swallowing. However, the incidence of mild to marked retention of bolus when swallowed Ensure® (71%) was higher than when swallowed WS (61%) and CS (55%). This implies that WS (194 cP) and CS (81 cP) did not have concerns about their adhesiveness, reducing the risk of residue, despite having higher viscosity than Ensure® (6 cP).

The severity of swallowing disorders detected by FEES evaluation was categorized into three symptoms. The first symptom was premature spillage of material, assessing food spillage before swallowing. This occurs during feeding and before the pharyngeal swallow condition, rendering an individual unable to prevent liquid food from flowing down the throat. The ASD group demonstrated proficiency in preventing premature spillage, while the SSD group exhibited a significant difference ($p < 0.05$) between swallowing WS and Ensure®. In the SSD group, premature spillage of material occurred more frequently when swallowing Ensure®. The risk of food aspiration may increase due to the premature spilling of food into the oropharynx and its subsequent entry into the unprotected laryngeal opening before the pharyngeal phase of swallowing is triggered [45]. This can lead to serious health issues such as pneumonia. Aging-related decreases in sensory-motor physiology, including reduced tongue strength and neurological function, may limit the ability of older individuals to hold food boluses before swallowing, particularly with low-viscosity liquid foods. Modified nutrition-dense smoothie diets, with high viscosity classified as nectar-like texture (51-350 cP) according to the National Dysphagia Diet (NDD) [34] and extremely thick drinks or pureed foods according to IDDSI [24]. This special property of smoothies was matched with the

ability to hold food boluses in older individuals. Low-viscosity liquids like Ensure® require thickening agents to enhance safety for individuals with dysphagia [46]. The second and third symptoms were retention/pooling of material and/or secretion, and the passage of food through the larynx or trachea. No significant differences were observed in the latter two symptoms between the formula diets in both the ASD and SSD groups. The highest severity was found when Ensure® was swallowed in both the ASD and SSD groups. Giving the similar viscosity levels of modified nutrition-dense smoothie diets, even though WSLC and BSLC were not tested for swallowing. It could be inferred that both formulas were safe for individuals with swallowing disorders and tended to reduce the chance of food flowing down the throat before swallowing. The study has limitations, including the absence of long-term data and reliance on swallowing screening questionnaires for group classification. However, it underscores the importance of recognizing and addressing presbyphagia in older adults. Further research is warranted to establish the long-term benefits of modified nutrition-dense smoothie diets in improving the nutrition status of older individuals with dysphagia.

Conclusion

Modified nutrition-dense smoothie diets were well-accepted by the older individuals and demonstrated improved flow characteristics before swallowing compared to less viscous foods like the comparator formula. These diets hold the potential to enhance swallowing safety without necessitating for additional thickeners.

Abbreviations

ASD: Asymptomatic swallowing difficulty; BSLC: Black sesame soy milk smoothie (low carbohydrate); cP: centipoise; CS: Chicken shitake smoothie; FEES: Fiberoptic Endoscopic Evaluation of Swallowing; IDDSI: International Dysphagia Diet Standardisation Initiative; NDD: National Dysphagia Diet; SSD: Symptomatic swallowing difficulty; WS: White sesame soy milk smoothie; WSLC: White sesame soy milk smoothie (low carbohydrate)

Declarations

Acknowledgements

Not applicable.

Authors' contributions

KM conceptualized the research design and obtained project funding. PS produced the sample of modified nutritionally dense smoothie diets for use in this study. SO, PK, and PT were responsible for FEES. PM, BP, TW, SS, SP, and SO were responsible for data collection. PM, AS, and KM analyzed the data. PM and KM produced the first draft of the manuscript, and were major contributors in writing the manuscript. All authors read and approved the final manuscript.

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Data availability

The data used in the study is not publicly available, but the data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The protocol was approved by the Siriraj Institutional Review Board, Human Research Protection Unit, Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand (IRB COA No. Si 010/2018). All participants signed an informed consent form.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. United Nations, Department of Economic Social Affairs, Population Division. World population prospects 2022: United Nations; 2022.
2. Department of Older Persons. Situation of the Thai older persons 2022. In. Bangkok: Foundation of Thai Gerontology Research and Development Institute, Institute for Population and Social Research, Mahidol University; 2023: 1-128.
3. Wattanapan P, Kovindha A, Permsiripanich W, Manimmanakorn N, Kuptniratsaikul V. Swallowing problem in patients with stroke: multi-center study in Thailand. J Med Assoc Thai. 2016;99(suppl. 7):S76-S80.
4. Thiyagalingam S, Kulinski AE, Thorsteinsdottir B, Shindelar KL, Takahashi PY. Dysphagia in older adults. Mayo Clin Proc. 2021;96(2):488-97.
5. Cho SY, Choung RS, Saito YA, Schleck CD, Zinsmeister AR, Locke GR, 3rd, Talley NJ. Prevalence and risk factors for dysphagia: a USA community study. Neurogastroenterol Motil. 2015;27(2):212-9.
6. Trombetti A, Reid KF, Hars M, Herrmann FR, Pasha E, Phillips EM, Fielding RA. Age-associated declines in muscle mass, strength, power, and physical performance: impact on fear of falling and quality of life. Osteoporos Int. 2016;27(2):463-71.

7. Wilkinson DJ, Piasecki M, Atherton PJ. The age-related loss of skeletal muscle mass and function: Measurement and physiology of muscle fibre atrophy and muscle fibre loss in humans. Ageing Res Rev. 2018;47:123-32.
8. Kurosu A, Osman F, Daggett S, Peña-Chávez R, Thompson A, Myers SM, VanKampen P, Koenig SS, Ciucci M, Mahoney J *et al*. Factors associated with self-reported dysphagia in older adults receiving meal support. J Nutr Health Aging. 2021;25(10):1145-53.
9. Ney DM, Weiss JM, Kind AJH, Robbins J. Senescent swallowing: impact, strategies, and interventions. Nutr Clin Pract. 2009;24(3):395-413.
10. Tagliaferri S, Lauretani F, Pelà G, Meschi T, Maggio M. The risk of dysphagia is associated with malnutrition and poor functional outcomes in a large population of outpatient older individuals. Clin Nutr. 2018;38(6):2684-9.
11. Wirth R, Pourhassan M, Streicher M, Hiesmayr M, Schindler K, Sieber CC, Volkert D. The impact of dysphagia on mortality of nursing home residents: results from the nutrition day project. J Am Med Dir Assoc. 2018;19(9):775-8.
12. Patel DA, Krishnaswami S, Steger E, Conover E, Vaezi MF, Ciucci MR, Francis DO. Economic and survival burden of dysphagia among inpatients in the United States. Dis Esophagus. 2018;31(1):1-7.
13. Pedersen A, Wilson J, McColl E, Carding P, Patterson J. Swallowing outcome measures in head and neck cancer–How do they compare? Oral Oncol. 2016;52:104-8.
14. Speyer R. Behavioral treatment of oropharyngeal dysphagia. In: Dysphagia: Diagnosis and Treatment. Edited by Ekberg O. Cham: Springer International Publishing; 2019: 669-86.
15. Barczi SR, Sullivan PA, Robbins JA. How should dysphagia care of older adults differ? Establishing optimal practice patterns. Semin Speech Lang. 2000;21(04):0347-64.
16. Kulbersh BD, Rosenthal EL, McGrew BM, Duncan RD, McColloch NL, Carroll WR, Magnuson JS. Pretreatment, preoperative swallowing exercises may improve dysphagia quality of life. Laryngoscope. 2006;116(6):883-6.
17. Sura L, Madhavan A, Carnaby G, Crary MA. Dysphagia in the elderly: management and nutritional considerations. Clin Interv Aging. 2012;7:287-98.
18. Chuansangeam M, Wuthikraikun C, Supapueng O, Muangpaisan W. Prevalence and risk for malnutrition in older Thai people: a systematic review and meta-analysis. Asia Pac J Clin Nutr. 2022;31(1):128-41.
19. Chaleekrua S, Janpol K, Wattanapan P. Swallowing problems among community-dwelling elderly in northeastern Thailand. J Prim Care Community Health. 2021;12:1-5.
20. de Sire A, Ferrillo M, Lippi L, Agostini F, de Sire R, Ferrara PE, Raguso G, Riso S, Roccuzzo A, Ronconi G *et al*. Sarcopenic dysphagia, malnutrition, and oral frailty in elderly: a comprehensive review. Nutrients. 2022;14(5):982.
21. Cichero JAY. Evaluating chewing function: expanding the dysphagia field using food oral processing and the IDDSI framework. J Texture Stud. 2020;51(1):56-66.

22. Matsuo K, Fujishima I. Textural changes by mastication and proper food texture for patients with oropharyngeal dysphagia. Nutrients. 2020;12(6):1613.
23. Christmas C, Rogus-Pulia N. Swallowing disorders in the older population. J Am Geriatr Soc. 2019;67(12):2643-9.
24. IDDSI framework and detailed level definitions. https://iddsi.org/IDDSI/media/images/Complete_IDDSI_Framework_Final_31July2019.pdf. Accessed 1 December 2023.
25. Wright L, Cotter D, Hickson M, Frost G. Comparison of energy and protein intakes of older people consuming a texture modified diet with a normal hospital diet. J Hum Nutr Diet. 2005;18(3):213-9.
26. Ojo O. The use of oral nutritional supplements in the acute care setting. Br J Nurs. 2016;25(12):664-6.
27. Ojo O, Brooke J. The use of enteral nutrition in the management of stroke. Nutrients. 2016;8(12):827.
28. Rattray M, Desbrow B, Roberts S. Comparing nutritional requirements, provision and intakes among patients prescribed therapeutic diets in hospital: an observational study. Nutrition. 2017;39-40:50-6.
29. Villar Taibo R, Martinez Olmos MA, Bellido Guerrero D, Vidal Casariego A, Peino Garcia R, Martis Sueiro A, Camarero Gonzalez E, Rios Barreiro V, Cao Sanchez P, Duran Martinez R *et al*. Epidemiology of home enteral nutrition: an approximation to reality. Nutr Hosp. 2018;35(3):511-8.
30. Finestone HM, Foley NC, Woodbury MG, Greene-Finestone L. Quantifying fluid intake in dysphagic stroke patients: a preliminary comparison of oral and nonoral strategies. Archives of physical medicine and rehabilitation. 2001;82(12):1744-6.
31. Complete IDDSI Framework detailed definitions. https://iddsi.org/Documents/IDDSIFramework-CompleteFramework.pdf. Accessed 1 December 2023.
32. Logemann JA, Gensler G, Robbins J, Lindblad AS, Brandt D, Hind JA, Kosek S, Dikeman K, Kazandjian M, Gramigna GD *et al*. A randomized study of three interventions for aspiration of thin liquids in patients with dementia or parkinson's disease. Journal of speech, language, and hearing research : JSLHR. 2008;51(1):173-83.
33. Association of Official Analytical Chemistry (AOAC). Official methods of analysis of AOAC international, 19th edn. Gaith-ersburg: AOAC International; 2012.
34. National Dysphagia Diet Task Force, American Dietetic Association. National dysphagia diet: standardization for optimal care: American Dietetic Association; 2002.
35. Cock C, Besanko LK, Burgstad CM, Thompson A, Kritas S, Heddle R, Fraser RJ, Omari TI. Age-related impairment of esophagogastric junction relaxation and bolus flow time. World J Gastroenterol. 2017;23(15):2785-94.
36. Peryam DR, Pilgrim FJ. Hedonic scale method of measuring food preferences. Food Technol. 1957;11:9-14.
37. Susan E. Langmore. Endoscopic evaluation of oral and pharyngeal phases of swallowing. GI Motility online. 2006.

38. O'Dea MB, Langmore SE, Krisciunas GP, Walsh M, Zanchetti LL, Scheel R, McNally E, Kaneoka AS, Guarino AJ, Butler SG. Effect of lidocaine on swallowing during FEES in patients with dysphagia. Ann Otol Rhinol. 2015;124(7):537-44.
39. Langmore SE, Schatz K, Olson N. Endoscopic and videofluoroscopic evaluations of swallowing and aspiration. Ann Otol Rhinol Laryngol. 1991;100(8):678-81.
40. Rommel N, Borgers C, Van Beckevoort D, Goeleven A, Dejaeger E, Omari TI. Bolus residue scale: an easy-to-use and reliable videofluoroscopic analysis tool to score bolus residue in patients with dysphagia. Int J Otolaryngol. 2015;2015:780197.
41. Putra C, Konow N, Gage M, York CG, Mangano KM. Protein source and muscle health in older adults: a literature review. Nutrients. 2021;13(3).
42. Rofes L, Arreola V, Almirall J, Cabré M, Campins L, García-Peris P, Speyer R, Clavé P. Diagnosis and management of oropharyngeal dysphagia and its nutritional and respiratory complications in the elderly. Gastroenterol Res Pract. 2011;2011.
43. Wakui N, Ashizawa Y, Ikarashi N, Machida Y. Evaluation of enteral nutrient flavor and rating due to differences in form. J Food Nutr Disord. 2017;06.
44. Cavallero S, Dominguez LJ, Vernuccio L, Barbagallo M. Presbyphagia and dysphagia in old age. Geriatric Care. 2020;6(3).
45. Massey BT, Shaker R. Oral, pharyngeal and upper esophageal sphincter motility disorders. GI Motility online. 2006.
46. Cichero JA. Thickening agents used for dysphagia management: effect on bioavailability of water, medication and feelings of satiety. Nutr J. 2013;12:54.

Figures

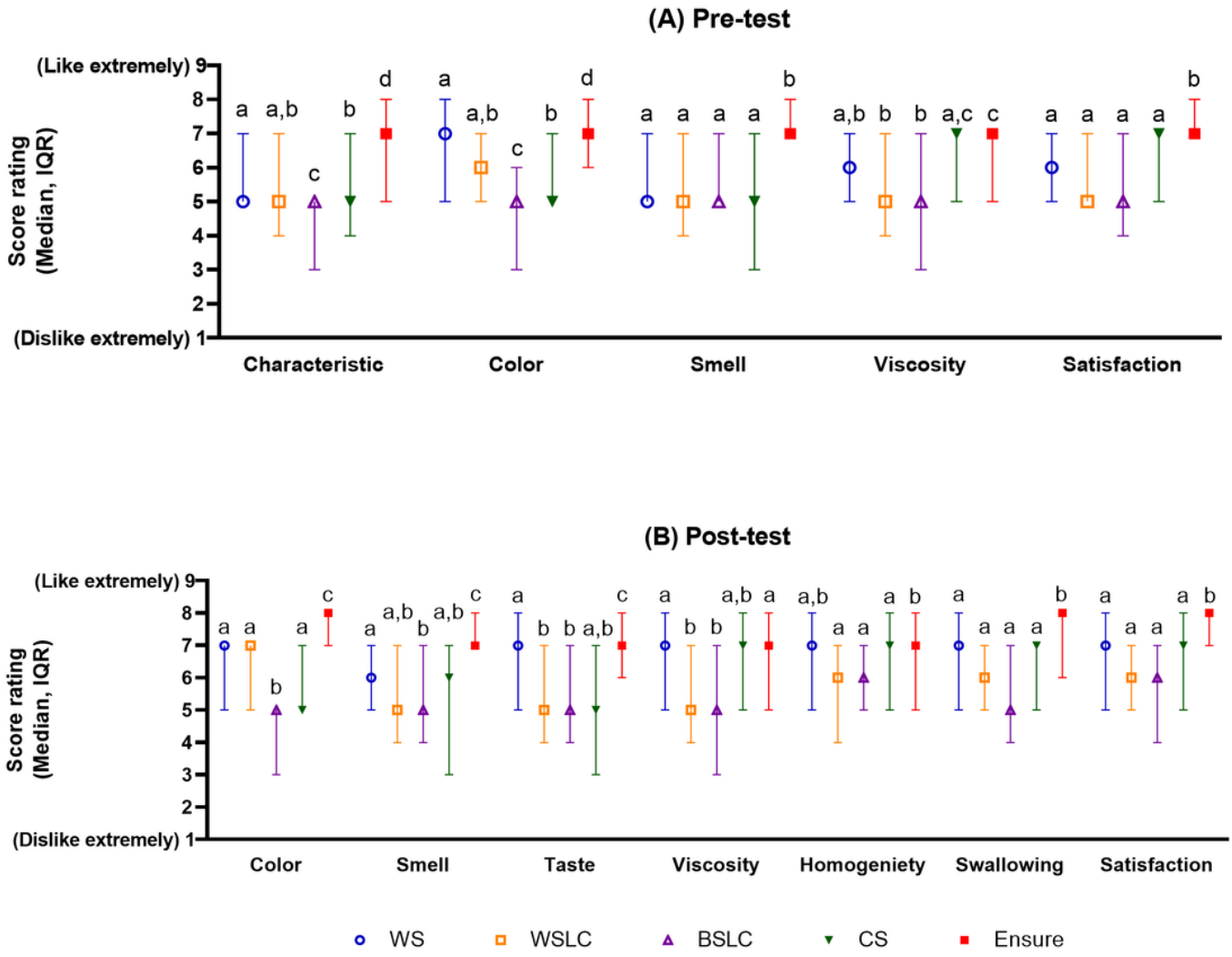

Figure 1

Participants evaluation of key properties of test diets on a 9-point hedonic scale. Panel (A) Pre-test: participants evaluation before tasting, Panel (B) Pre-test: participants evaluation after tasting. *Significant difference between test diets using the nonparametric Kruskal-Wallis method ($p < 0.05$). Different superscript letters (a,b,c,d) indicate significant differences between test diets using Mann-Whitney comparisons (Bonferroni adjusted) ($p < 0.05$). Abbreviations: BSLC, black sesame soy milk smoothie (low carbohydrate); CS, chicken shitake smoothie; IQR, Interquartile range; WS, white sesame soy milk smoothie; WSLC, white sesame soy milk smoothie (low carbohydrate).

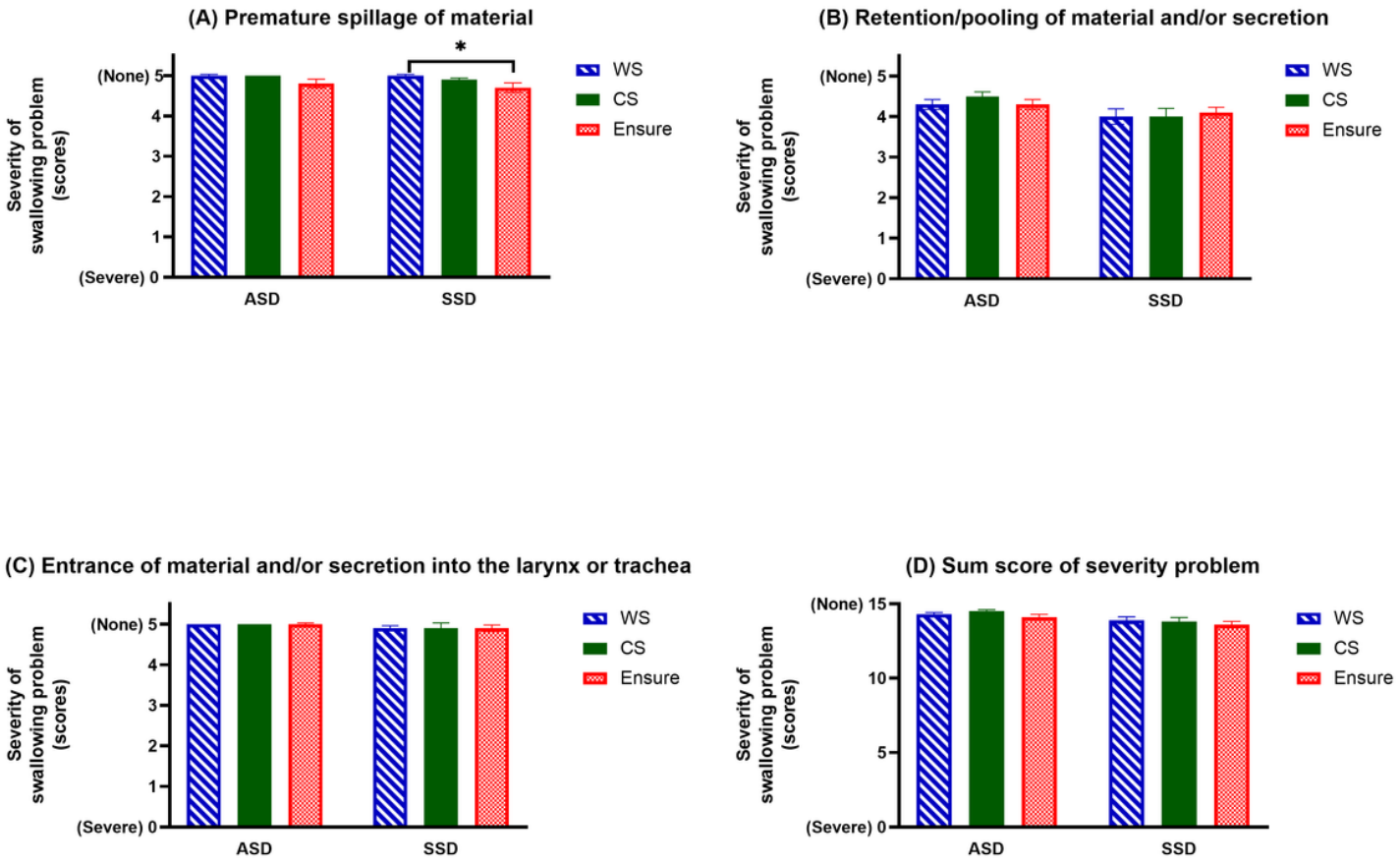

Figure 2

Severity of swallowing disorders in test diets detected by FEES evaluation. Panel (A) premature spillage when the bolus leaks or falls into the hypopharynx before swallowing, Panel (B) retention of the bolus and/or secretion, Panel (C) entrance of the bolus into the larynx or trachea, Panel (D) Sum score of severity problem. *Significant difference between test diets using Analysis of Variance (ANOVA) and Scheffe's test ($p < 0.05$). Higher scores mean less severe swallowing disorders. Abbreviations: ASD, asymptomatic swallowing difficulty; BSLC, black sesame soy milk smoothie (low carbohydrate); CS, chicken shitake smoothie; SSD, symptomatic swallowing difficulty; WS, white sesame soy milk smoothie; WSLC, white sesame soy milk smoothie (low carbohydrate).

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