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Pureed banana inflorescences and their potential uses in dysphagia diets

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ABSTRACT

This study aimed to develop new vegetable purees derived from banana inflorescences as well as recipes suitable for individuals suffering from dysphagia. The effects of hydrocolloids (modified tapioca starch; MTS, gum acacia; GA, xanthan gum; XG, carboxymethyl cellulose; CMC, and gelatin; GEL) on the quality of purees were investigated. Banana inflorescences turned out to be a good choice for the preparation of purees that complied with "Level 4 Pureed Food for Adults" as examined by the International Dysphagia Diet Standardization Initiative (IDDSI) methods. The addition of XG and CMC to the purees improved their qualities. However, the effects of hydrocolloids depended on the types and concentrations used. Some hydrocolloids, such as GA and GEL, have been discovered to be unsuitable. The kale leaf, pumpkin, and Riceberry-flavored soups, made from banana inflorescence purees as a main ingredient, were successfully prepared. All recipes adhered to the IDDSI guidelines for "Level 3 Liquidized Food for Adults". The finding in this study could promote the use of banana inflorescence as a potential ingredient for purees suitable to be used as dysphagia diets.

Contribution/Originality: This study first demonstrates the formulation of banana inflorescences as pureed diets and then as recipes suitable for dysphagic people while maintaining the appetizing properties.

1. INTRODUCTION

The fact that banana is widely cultivated and consumed has made it the most important fruit globally (Ramírez-Bolaños, Pérez-Jiménez, Díaz, & Robaina, 2021). However, owing to the way bananas are harvested, a large amount of waste, representing 80% of the total biomass, is generated in the plantations (Padam, Tin, Chye, & Abdullah, 2014) resulting in both elevated carbon footprint and soil toxicity (Adsal, Üctug, & Arikan, 2020) as well as a problem of food safety arising from food waste management (Campos, Gómez-García, Vilas-Boas, Madureira, & Pintado, 2020). Recently, there has been a renewed interest in banana residues mostly due to a variety of bioactive compounds present in them (Lau et al., 2020; Ramírez-Bolaños et al., 2021).

Banana inflorescence is an edible byproduct of banana cultivation. Asians commonly use the whitish inner part (stalk) of the banana inflorescence and the flowers below the bracts as food ingredients (Panyayong & Srikaeo, 2022; Wickramarachchi & Ranamukhaarachchi, 2005).

Banana inflorescences have been reported to have numerous health benefits because they contain an abundance of high-quality proteins, functional phytochemicals, minerals, dietary fibers, and vitamins (Bhaskar, Salimath, &

Nandini, 2011; Lau et al., 2020; Ramírez-Bolaños et al., 2021; Thaweesang, 2019). Additionally, the ratio of essential to non-essential amino acids in banana inflorescences is 0.54, which surpasses the recommendation of the World Health Organization (WHO) (Ramu et al., 2017a).

Banana inflorescences have a wide range of bioactive components with great potential. They have shown anti-inflammatory, antioxidant, anti-cholesterolemic, and anti-hyperglycemic activities owing to the bioactive compounds present in them (China et al., 2011; Liyanage et al., 2016; Ramu et al., 2017b; Sandjo et al., 2019). Sterols, polyphenols, and triterpenes are the major groups of secondary metabolites found in banana inflorescences (Lau et al., 2020).

The nutrients that abound in banana inflorescence make it suitable for use in formulating diets for individuals with special dietary needs. At present, population ageing is one of the most important demographic trends globally. Nonetheless, a rise in life expectancy has increased the prevalence of chronic diseases and multimorbidity that are related to old age (Agarwal, Marshall, Miller, & Isenring, 2016). Dysphagia, which is difficulty in swallowing food and liquid, is one such chronic condition that is common among the elderly (Cichero, 2016). There is a need to subject diets for dysphagic patients to textural modifications to make them soft and safe to swallow (Syahariza, Nuraihan, Norziah, & Fazilah, 2016). In a variety of foods, hydrocolloids and certain proteins can be used as thickeners, binders, gelling agents, coatings, pH adjusters, emulsion stabilizers, suspensions dispersions and foams, and also to enhance heat resistance and salt tolerance (Pematilleke, Kaur, Rai, Adhikari, & Torley, 2021; Siriwongwilaichat & Kongpanichtrakul, 2021). Nonetheless, the majority of these texture-modified foods and thickened liquids lack sensory and nutritional qualities (Keller, Chambers, Niezgoda, & Duizer, 2012). Banana inflorescence has a meat-like appearance, flavor, and texture; all these attributes make it suitable for use as a plant-based ingredient in the production of different meat substitutes (Keerthana, Rawson, Vidhyalakshmi, & Jagan Mohan, 2022). It could be used as a nutritive ingredient in the preparation of diets for the elderly and/or people who suffer from dysphagia. As dysphagia is the primary indication for recommending texture-modified diets to individuals, the textures of the diets can range from pureed to soft (Wright, Cotter, Hickson, & Frost, 2005).

Pureed diets are often used as initial dysphagia diets for patients who present with moderate to severe dysphagia because, if the dysphagic patients are able to fulfill their nutritional requirements by eating pureed diets, they can avoid enteral feeding that requires the use of a percutaneous endoscopic gastrostomy tube (Sakamoto et al., 2016). Although pureed meals are very effective for managing dysphagia, people who are forced to consume them regularly may lose interest. A new pureed vegetable developed from banana inflorescences expands the options for pureed diets. Not only can the pureed vegetables be consumed directly, but also they can be incorporated into a recipe to make food a more effective vehicle for the delivery of nutrients while preserving the proper texture and mouthfeel (Spence, Navarra, & Youssef, 2019). Given the importance of banana inflorescence as a promising new vegetable ingredient, this study first demonstrates the formulation of banana inflorescence as pureed diets and then as recipes suitable for dysphagic people while maintaining the appetizing properties.

2. MATERIALS AND METHODS

2.1. Ingredients and Hydrocolloids

The researchers obtained the fresh ingredients required for the preparation of the puree samples from the local markets in Uttaradit Province (Thailand). The ingredients were stored in a refrigerator at 4°C until they were used. The hydrocolloids or thickeners used in this study included gum acacia (GA), modified tapioca starch (MTS), xanthan gum (XG), gelatin (GEL), and carboxymethyl cellulose (CMC). All hydrocolloids are food grade and are obtained from Krungthepchemi Co., Ltd. (Thailand).

2.2. Preparation of Pureed Banana Inflorescences

Pureed banana inflorescences were prepared using a wide range of thickeners as mentioned above. These thickeners have the potential to improve textural quality and were commonly used in formulating pureed vegetables (Ilhamto, Keller, & Duizer, 2014). The researchers used a vacuum high-speed blender (Philips Model HR3752/00) to prepare all pureed food products. The control formulation for pureed banana inflorescence consisted of 200 g boiled inner part of banana inflorescence, 100 g chicken stock, 5 g boiled chicken breast, 5 g grated ginger, 5 g coriander root, 2 g salt, 2 g ground pepper, and 2 g garlic powder. This recipe produced 321 g of pureed banana inflorescence. To study the various thickeners, the amount of boiled banana inflorescence in the control recipe was substituted with the thickeners at 3, 6, and 9 g. Five thickeners were used as mentioned above. Hence, a total of 16 puree samples including the control were investigated in this study. They were labeled as control, MTS-3, MTS-6, MTS-9, GA-3, GA-6, GA-9, XG-3, XG-6, XG-9, CMC-3, CMC-6, CMC-9, GEL-3, GEL-6 and GEL-9, respectively.

2.3. Determination of Pureed Banana Inflorescence Qualities

The qualities of freshly prepared purees from banana inflorescences were determined by subjecting them to textural evaluation using both the international standard method (qualitative) and instrumental (quantitative) techniques.

2.3.1. The IDDSI Testing Methods

To ensure that the purees are suitable for people suffering from dysphagia, this study follows the framework of the International Dysphagia Diet Standardization Initiative (IDDSI Framework) (IDDSI, 2019a).

The researchers tested pureed banana inflorescences using the IDDSI Testing Methods (IDDSI, 2019b). In this study, "Level 4 Pureed Food for Adults" is required for pureed foods which only require the tongue to be able to move forward and back to bring the food to the back of the mouth for swallowing.

The soup recipes made from pureed banana inflorescences were tested for "Level 3 Liquidized Food for Adults". This demonstrated the use of the puree for creating a variety of recipes with different textures.

2.3.2. Instrumental Texture Analysis

The texture of pureed banana inflorescences was also evaluated instrumentally using a texture analyzer (Model TA-XT plus, Stable Micro Systems, UK) with supporting Exponent software. The back-extrusion procedure, which is in line with the method described by Makroo, Prabhakar, Rastogi, and Srivastava (2019) with some modifications, was used. This test relied on the displacement of material through an annular gap between the probe and the container. As the probe moves downward, the material is forced upward through the annular gap, while as the probe moves upward, the material flows back into the cell through the annular gap. At a predetermined position, the force is measured during the downward and upward cycles. The container supplied with the equipment was filled with the sample up to 75% of the height. When a surface trigger of 5 g was attained (the point at which the probe's bottom surface is in full contact with the product), the disc proceeded to penetrate to a depth of 25 mm with a test speed of 2 mm/s and then returned to the original position. The force vs distance plot generated was used to obtain the texture parameters including firmness (the peak or maximum force), consistency (the area of the curve up to the peak), cohesiveness (the maximum negative force during the return of the probe) and work of cohesion (the area of the negative region of the curve) (Alkarkhi, Bin Ramli, Yong, & Easa, 2011).

2.4. Recipes from Pureed Banana Inflorescences

Pureed banana inflorescences may be used to create various recipes. In this study, various soups from banana inflorescence purees were prepared using the puree (XG-3) as the base ingredient. The soups included kale leaf, pumpkin, and Riceberry flavored soups. The standard recipe consisted of 95 g of banana inflorescence puree (XG-3), 100 g of chicken stock, and 20 g of flavored ingredients (kale leaf powder, pumpkin powder, or Riceberry flour). All the ingredients were thoroughly combined, poured into a stainless-steel pot, and then heated for 20 minutes on an electric hot plate until boiling. The soups were allowed to cool to room temperature before they were tested.

2.5. Sensory Evaluation

Six key sensory attributes were evaluated by 30 selected consumers: appearance, color, odor, taste, texture, and overall liking. Samples were evaluated for consumer preference using a 5-point hedonic scale for the liking of the soups on each sensory attribute (1 = dislike very much, 2 = dislike slightly, 3 = neither like nor dislike, 4 = like slightly, 5 = like very much). In the consumer test, the room was air-conditioned to maintain a temperature of 25°C. The soup samples were freshly prepared in the morning of the day and then kept at the same room temperature. All samples were presented in random order at the same time. The sensory evaluation protocol has been approved by Pibulsongkram Rajabhat University Ethics Committee.

2.6. Statistical Analysis

The experiments were run in at least duplicates and the mean values with standard deviations were reported. SPSS software version 22 was used for One-way Analysis of Variance (ANOVA) and Duncan's multiple range post-hoc test to identify the significant difference at a 95% confidence level (α=0.05).

3. RESULTS AND DISCUSSION

3.1. Pureed Banana Inflorescence Qualities

The IDDSI test results for all pureed banana inflorescence samples, 16 samples including the control (without any thickener), are shown in Table 1. The researchers did not forget the fact that "Level 4 Pureed Food for Adults" is required for purees intentionally made as dysphagic diets and that they must pass both the IDDSI fork drip and spoon tilt tests. The samples of the purees that pass both tests are shown in Figure 1.

Table 1. IDDSI fork drip and spoon tilt tests of pureed banana inflorescence.

Samples	IDDSI test results	
	Fork drip	Spoon tilt
Control	Passed	Passed
MTS-3	Passed	Passed
MTS-6	Passed	Passed
MTS-9	Passed	Passed
GA-3	Passed	Passed
GA-6	Passed	Passed
GA-9	Passed	Passed
XG-3	Passed	Passed
XG-6	Passed	Passed
XG-9	Passed	Passed
CMC-3	Passed	Passed
CMC-6	Passed	Passed
CMC-9	Failed	Passed
GEL-3	Failed	Passed
GEL-6	Failed	Failed
GEL-9	Failed	Failed

Note: MTS = Modified tapioca starch, GA = Gum acacia, XG = Xanthan gum, CMC = Carboxymethyl cellulose, GEL = Gelatin; 3, 6, and 9 indicate the amount (g) substituted in the formulations.


Figure 1. The example of purees that pass the IDDSI fork drip test (Left) and the IDDSI spoon tilt test (Right).

Pureed foods must not be too sticky to avoid them sticking to the cheeks, teeth, roof of the mouth, or throat. The IDDSI fork drip test and the IDDSI spoon tilt test were carried out on all puree samples. For the IDDSI fork drip test, puree must sit in a mound or pile above the fork; liquid does not dollop or drip continuously through the fork prongs. For the IDDSI spoon tilt test, puree holds its shape on the spoon and falls off fairly easily if the spoon is tilted or lightly flicked. The purees have to pass both tests (IDDSI, 2019b).

Table 1 clearly shows that banana inflorescences could be effectively used to make purees. The control sample passed the fork drip and spoon tilt tests, exhibiting similar results as most samples that had hydrocolloids added to them. The rich protein and fiber contents in the banana inflorescences could contribute to these distinctive properties.

Fiber extracted from banana inflorescence bracts was found to contain high cellulose and lignin contents of 56.48% and 28.44% respectively, and low wax content of 1.05% (Amutha, Sudha, & Saravanan, 2022). Ethanolic extractions of banana inflorescence powder have revealed that it contains crude fiber (15.41%), cellulose (19%), hemicellulose (21%), and lignin (17%) (Pongsuwan et al., 2022). This study assumed that rich fiber and protein polymers in banana inflorescences act as natural components that prolong the stability of the pureed banana inflorescences. Dietary fiber-rich banana inflorescences exhibited higher water-holding capacity than that of cellulose, wheat bran, corn, potato peel fiber, citrus fruits, grapes, and consequently prevented syneresis and improved the viscosity and texture of foods (Begum & Deka, 2019). Some plant fibers are able to form complexes with proteins, typically through electrostatic interactions when the two molecules have opposite charges. Intriguing functional properties of the complexes include decreased aggregation and precipitation of proteins, enhanced thermal stability, and modification of the viscosity of mixed systems (Chevalier, Rioux, Angers, & Turgeon, 2019).

Hydrocolloids are also widely used in pureed foods; however, little is known about their effects on the textural changes of such foods (Ilhamto et al., 2014). Comparing the hydrocolloids used in this study, there are differences in the behaviors of selected hydrocolloids in pureed banana inflorescences under small and large deformations. The effects of hydrocolloids on the properties of the purees depended on the types and concentrations of the hydrocolloids used. When matched for the IDDSI fork drip and spoon tilt tests, XG at all concentrations produced the best result. Therefore, XG-3 is chosen as the base ingredient for the preparation of the recommended recipes. Notably, GEL altered the texture of freshly prepared banana inflorescence puree, making it unsuitable for dysphagia diets.

The behaviors of hydrocolloids, when added to pureed foods, can also be examined using the instrumental techniques. A typical textural graph as evaluated by the back extrusion method using the texture analyzer is shown in Figure 2. In addition, the numerical textural properties of pureed banana inflorescences are shown in Table 2.

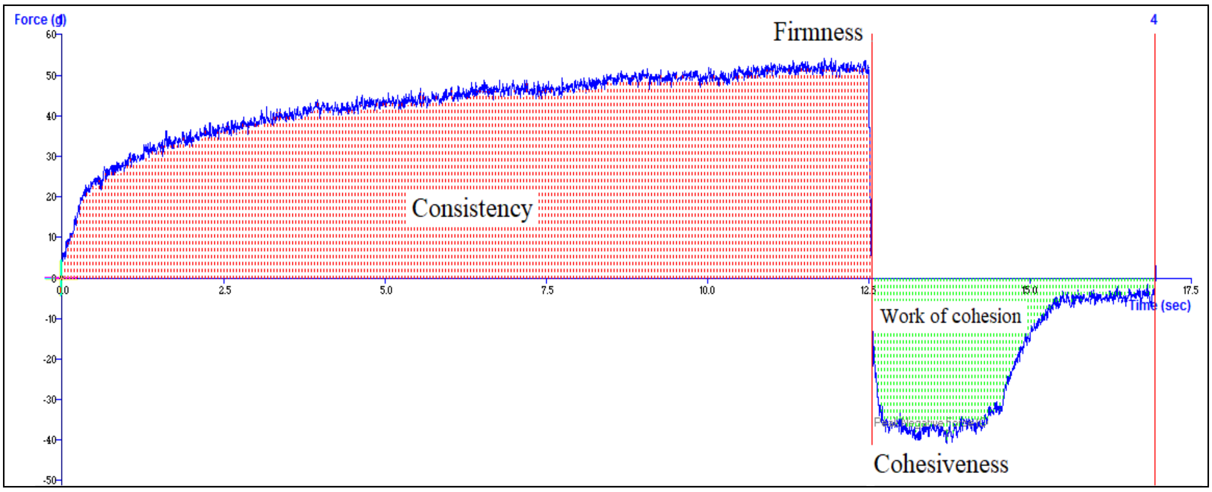


Figure 2. A typical graph produced from back extrusion tests of the purees.

Table 2. Instrumental texture results of the pureed banana inflorescences.

Samples	Firmness	Cohesiveness	Consistency	Work of cohesion
Control	136.65±3.65^{hi}	143.11±3.54^{ij}	1,513.80±55.93^{hij}	252.60±14.71^{i}
MTS-3	206.43±5.29^{h}	223.84±9.79^{ghi}	2,210.27±55.19^{gi}	343.58±13.38^{hi}
MTS-6	290.87±23.28^{h}	328.33±26.56^{fg}	2,914.26±13.16^{fg}	472.32±6.01^{fgh}
MTS-9	418.37±43.70^{e}	496.93±61.42^{cd}	4,204.13±718.44^{cde}	671.14±114.18^{de}
GA-3	58.67±4.92^{ij}	50.68±7.51^{jk}	522.69±43.32^{j}	87.81±2.94^{jk}
GA-6	39.20±5.03^{j}	28.89±7.09^{jk}	412.16±58.40^{j}	61.79±13.22^{ke}
GA-9	55.23±0.11^{j}	46.24±1.48^{j}	597.58±9.04^{j}	106.29±2.83^{j}
XG-3	198.87±7.57^{h}	322.19±9.73^{fh}	2,244.77±107.18^{gh}	541.12±9.88^{eg}
XG-6	510.90±16.66^{cd}	821.45±89.88^{b}	5,457.63±32.90^{b}	1,079.37±25.64^{b}
XG-9	591.47±0.53^{c}	1,115.63±21.18^{a}	4,465.70±1105.64^{bd}	1,454.13±187.00^{a}
CMC-3	315.68±9.15^{fg}	340.97±1.75^{ef}	3,256.15±20.63^{efg}	496.40±5.82^{eh}
CMC-6	569.41±13.28^{fg}	580.79±2.54^{c}	5,282.53±103.11^{bc}	800.47±71.26^{cd}
CMC-9	797.59±11.96^{b}	781.61±7.51^{b}	6,974.76±225.89^{a}	1,135.54±18.49^{b}
GEL-3	45.55±10.53^{j}	41.58±15.66^{j}	418.47±108.71^{j}	85.06±28.65^{jl}
GEL-6	349.54±59.83^{ef}	445.56±84.75^{de}	3,648.17±698.10^{df}	615.87±90.79^{def}
GEL-9	895.88±65.39^{a}	1,147.71±47.61^{a}	8,112.03±95.31^{a}	1,505.46±13.19^{a}

Note: Values are mean±standard deviation (n=10).
The means that do not share a letter are significantly different ($p<0.05$).

Although the rheological and mechanical behaviors of hydrocolloid gels have been studied from a "safe-swallow" perspective for dysphagia, the impact of hydrocolloid addition on pureed food matrices is still in the conceptual stage despite the importance of product development within the healthcare industry (Ishihara, Nakauma, Funami, Odake, & Nishinari, 2011). This study demonstrated the use of different hydrocolloids in the matrix of banana inflorescence puree. Among all hydrocolloids used in this study, GA provided the lowest textural values. Increasing the concentration of GEL from 3 g to 6-9 g dramatically increased the textural values. Notably, hydrocolloid-added samples exhibited a greater degree of variation than the control sample (refer to Table 2). High variability in rheological and sensory properties has also been reported in carrot purees with added hydrocolloids (Sharma, Kristo, Corredig, & Duizer, 2017). Hydrocolloids were found to enhance product consistency and cohesiveness and reduce the syneresis of the product. The deterioration of the puree's texture during storage could be reduced by adding small amounts of hydrocolloids (Funami, 2016).

People suffering from dysphagia use hydrocolloids extensively to modify their diets (Wiriyawattana & Tunnarut, 2022). It is crucial to choose appropriate hydrocolloids or thickeners as puree texture modifiers. Starch-based thickeners are the most common hydrocolloids used in the commercial production of dysphagia foods and in the preparation of in-house pureed foods in long-term care homes, while xanthan is the most studied hydrocolloid in dysphagia diets next to starch (Cichero, 2013). However, starch thickeners have been shown to increase post-deglutition residue (which increases the risk of post-swallowing aspiration in dysphagic patients) and, in general, are not well accepted by patients (Rofes, Arreola, Mukherjee, Swanson, & Clavé, 2014).

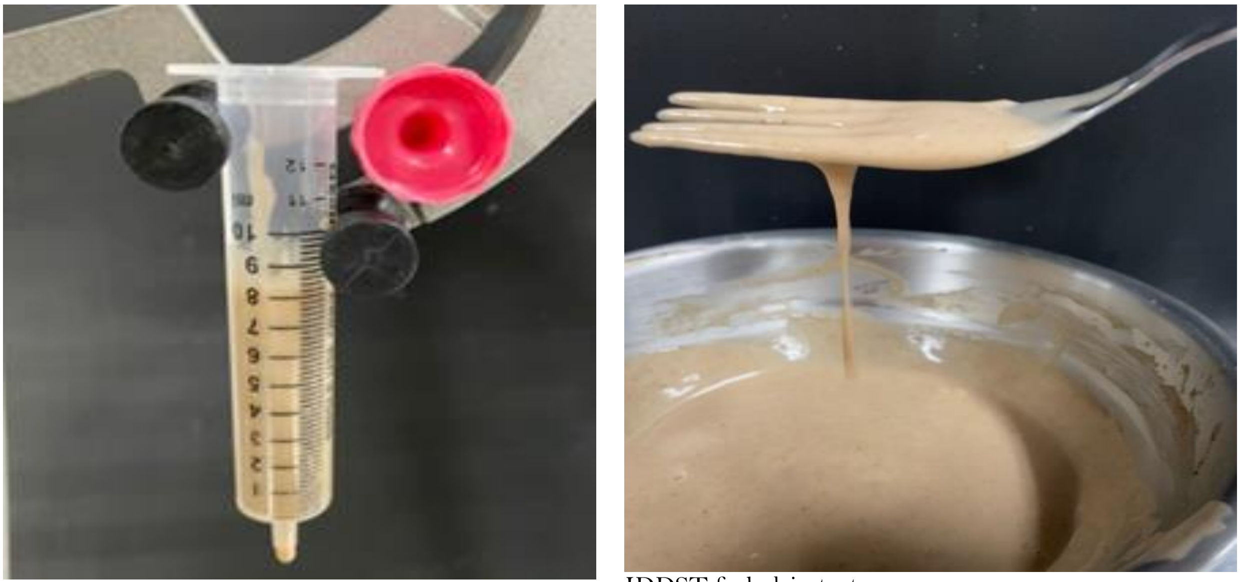
Matching both quantitative and qualitative IDDSI fork drip and spoon tilt tests (Table 1-2), XG and CMC at the lowest concentration used in this study (3 g) produced the best result. XG was found to give high viscosity at low shear rates (also high yield stress) and low viscosity, while CMC provided clear and odorless solutions of high viscosity (Sharma et al., 2017). In this study, the use of MTS produced results similar to those of the control sample. GEL should not be used in banana inflorescence purees because it modifies the textures of pureed banana inflorescence to the extent that the puree becomes unsuitable for dysphagia diets.

3.2. Recommended Recipes from Pureed Banana Inflorescences

Pureeing food is an effective way of creating diets suitable for people suffering from dysphagia; however, those who are forced to consume purees regularly may lose interest. The development of flavorful and appealing pureed meals is recommended (Hotaling, 1992). This study developed three ready-to-eat soups from pureed banana inflorescences, namely kale leaf-flavored, pumpkin-flavored, and Riceberry-flavored soups. The XG-3 puree was used as the base ingredient. While the purees themselves conformed to the "Level 4 Pureed Food for Adults", for the soup recipes, "Level 3 Liquidized Food for Adults" was aimed. This demonstrated that purees are suitable for creating a wide range of recipes. The appearances and the IDDSI tests of the soups are shown in Figure 3. All the recipes passed both the IDDSI flow test and the IDDSI fork drip test for "Level 3 Liquidized Food for Adults" as shown in Figure 4. These tests are used to determine how thick a liquid is by observing how fast it flows through a 10 mL syringe in 10 seconds and how quickly it flows through the prongs of a dinner fork. For this level, there should be no less than 8 mL remaining in the syringe after 10 seconds of flow. Using the IDDSI Fork Test the liquid drips slowly in dollops through the prongs of a fork.

Kale Pumpkin Riceberry

Figure 3. Appearances of the soups.



IDDSI flow test

IDDST fork drip test

Figure 4. Example of the soups being tested using the IDDSI flow test and the IDDSI fork drip test for "Level 3 Liquidized Food for Adults".

IDDSI Level 3 soups may be used for individuals who have difficulty moving their tongues. It can be eaten with a spoon or drunk from a cup but cannot be eaten with a fork because it drips through the fork prongs. It also has a smooth texture with no 'bits' (lumps, fibers, husk, bits of shell or skin, particles of gristle or bone). The thicker consistency gives more time for the tongue to "hold and move" the liquidized food (IDDSI, 2019a).

3.3. Sensory Properties

The sensory scores for all three flavored soups prepared from banana inflorescence purees are presented in Figure 5. In general, the panelists gave mean scores of more than four for all the selected sensory attributes and in all samples. The mean scores for color were slightly lower than those of the other attributes. Comparing among samples, the soups with pumpkin had higher scores in all sensory attributes than those of the other flavored soups. Riceberry and kale-flavored soups produced similar sensory results.

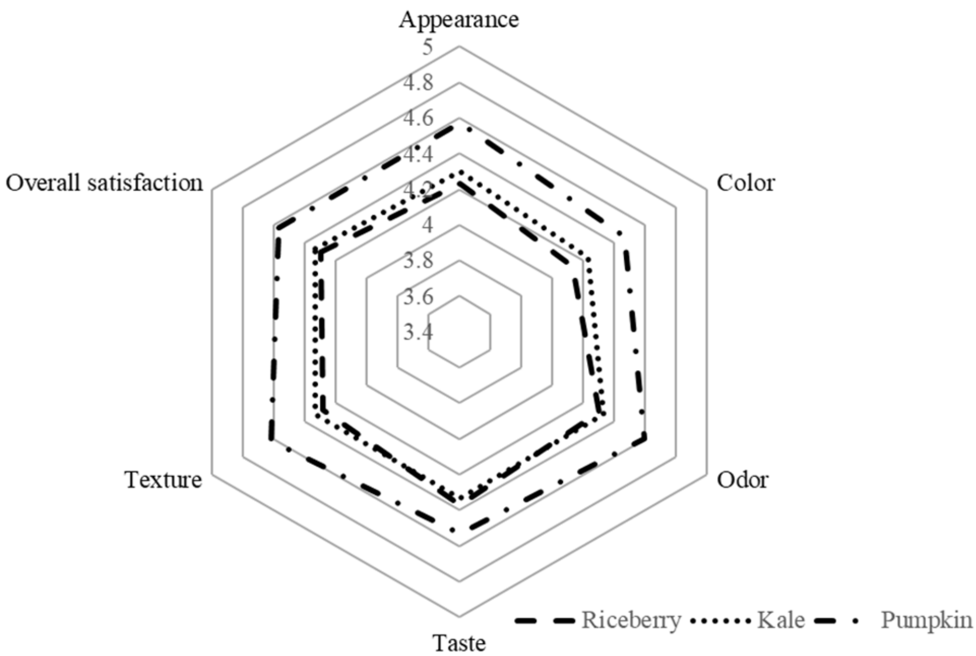


Figure 5. Radar chart representing mean scores, 5-point hedonic scale, of the sensory evaluation for the soups (Kale, Pumpkin, and Riceberry flavored soups).

Banana inflorescence has been shown as an excellent ingredient for Thai foods as well as for other cuisines (Panyayong & Srikaeo, 2022). Kale leaf, pumpkin, and Riceberry-flavored soups made from banana inflorescence purees added more nutritional benefits to the existing nutritious banana inflorescence purees. Colored vegetables and rice (Riceberry) possess beneficial health effects because they are rich in phytochemicals such as flavonoids, betalains, and carotenoids and have high antioxidant capacity (Leardkamolkarn et al., 2011; Sharma, Katoch, Kumar, & Chatterjee, 2021).

The inability of older adults or dysphagic patients to accept the appearance, texture, and flavor of pureed foods makes their consumption very difficult. There is a need to develop palatable, nutrient-dense pureed foods while keeping portion sizes reasonable (Ilhamto et al., 2014). Creating recipes from pureed banana inflorescences with flavoring from colored vegetables or cereals could help overcome those challenges. There is a need to find a balance between safety and enjoyment. Pureed foods must be appetizing and safe to prevent individuals from avoiding food out of fear of choking while obtaining a nutritionally adequate diet (Ettinger, Keller, & Duizer, 2014). Greater emphasis has been placed on textural and nutritional properties; more emphasis is needed on attributes that lead to liking, and future research can guide food manufacturers.

4. CONCLUSION

The development of a new pureed vegetable from banana inflorescence expands the options for pureed diets suitable for individuals suffering from dysphagia. Pureed vegetables cannot only be consumed directly but also they can be incorporated into a recipe to make a food more effective in delivering nutrients while maintaining the proper texture and mouthfeel. Functional components, such as dietary fiber in banana inflorescences, could enhance the qualities of the purees. Additionally, hydrocolloids could also be used to modify the texture and preserve the qualities of the purees. This research demonstrated the use of banana inflorescence puree in the preparation of some flavored soups. These recipes may be helpful in terms of appetizing while meeting the safety requirements for dysphagia diets.

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