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Nutritional, functional and sensory analysis of millet porridge using maltodextrin starch for dysphagia

Ayamita Paul, Nazni P

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Abstract

The study focuses on evaluation of nutritional, viscous, osmolality and textural parameters of Barnyard Millet with addition of different concentration (0.5%,1%,1.5%, 2%,2.5%, 3%, 3.5% and 4% of total weight of ingredients) of thickeners (Potato and Rice Starch) for the condition of dysphagia considering NDD (National Dysphagia Diet) parameters. Macro-nutrients of the porridge, giving optimum nutrition for the patient, help maintain nutritional intake, and prevent malnutrition. The control sample's nutrient composition is low than the millet porridge prepared with the thickeners' different concentrations. Variation in Viscosity based on the concept of rheology or flow of porridge is seen due to variation in starch gelatinization with differences in the grit size. Thickness related attributes included perceived Viscosity, ease of manipulation, and ease of swallowing. Osmolality understands the number of particles of a porridge per kilogram of solvent (mmol/kg), helping us understand the patient's flow. Textural parameters of thickened porridge, analyzed using the Single Cycle Penetration test, were increased with increased concentration of the thickener used with one drop in the middle. Overall, 1% Starch porridge is nutritionally adequate and can be swallowed with ease for a dysphagia patient.

Key words: Dysphagia, Porridge, Millet, Barnyard, Functional Analysis, Thickened Liquid.

Introduction

Dysphagia is a swallowing disorder that provides difficulty in transmitting the bolus in the upper digestive tract.(Syahariza, Hong,2017) Dysphagia comes from a Greek word, which means difficulty swallowing. One in 17 people will develop some form of Dysphagia in their lifetime. The condition affects 40–70% of patients with stroke, 60–80% of patients with neurodegenerative diseases, up to 13% of adults aged 65 and older and > 51% of institutionalized elderly patients, as well as 60–75% of patients who undergo radiotherapy for head and neck cancer(Juan Malagelada ***et al***.,2014)(Alicia Costa ***et al.,***2019). The prevalence of OD is highest in older patients with neurological diseases and increases age and frailty. OD's prevalence among independently living older persons is 16% in the 70–79-year group and 33% in the ≥80 years group.(Rainer Wirth ***et al***.,2016). Dysphagia is a delay of a fluid or solid bolus. It moves from mouth to the stomach, choking (laryngeal penetration and aspiration may occur without concurrent choking or coughing), swallow-related coughing.(Muhammad Aslam, M.F.Vaezi,2013).

Dysphagia is not a disease but a symptom of underlying disease(Syahariza, Yong,2017), which can be managed with proper intervention. Diet modification is one way that the patient can be fed, helping maintain their nutritional intake. Diet modification can be divided into thickened liquid and texture modified food. Thickened food is believed that modified consistency food is higher than average, giving the glottis more time to close. Studies now focus on thickened fluids as it has higher Viscosity and texture modified foods which are nutritionally enriched. The liquid that travels more slowly through the oral cavity because of their higher viscosities provides the patient with additional time to prepare for pharyngeal swallow onset. According to Hanson ***et al***., food that increased in Viscosity can help individuals have more time to prepare food bolus during swallowing, resulting in safer swallowing. Miller and Watkin and Goulding, and Bakheit illustrated that a high viscosity fluid could also aggravate swallowing, possibly because it increases the force required by the tongue to move the bolus and worsen Dysphagia.(S.T. O'Keeffe, 2018, Jane Ong, 2007).

Furthermore, the patient may reject projects with too high a viscosity, resulting in dehydration and malnutrition. Hence, it proves that the Viscosity must be accurate to a certain degree.(Katleen J. R. Vallons **et al**.).

Consequently, thickened fluids and texture-modified foods is rarely a diet of choice, but a diet of necessity if an individual is to maintain their nutritional needs orally. The provision of texture-modified foods and fluids is a prescription for individuals with

Ayamita Paul
Department of Nutrition and Dietetics, Periyar University

Nazni P
Department of Nutrition and Dietetics, Periyar University.
Email: naznip@gmail.com

Dysphagia. By determining the Dysphagia cause and severity, health professionals can evaluate the food texture and fluid thickness safest for an individual to swallow. It is commonly done by the addition of thickeners to achieve the desired texture for people with Dysphagia, which aids in reducing the risk of aspiration.(Michael Groher, 2015) Texture modification of foods and thickening of fluid forms a routine part of the assessment and treatment of swallowing difficulties (Dysphagia). Dysphagia adds to reduced dietary intake and potentially malnutrition, aspiration, and asphyxiation. Regular fluids require excellent muscle control and accurate timing between the swallowing system and the breathing system.(Cichero et al.,2007) Dysphagia and low nutritional status have been estimated to impact over 16% to 60% of stroke survivors or neurogenerative patients, leading to increased morbidity and poor long-term functional outcomes. (Michael A. Crary 2016).

Commercial thickener helps to thicken the liquid diet, which modifies the texture and is useful for dysphagic patients. These commercial thickeners are very expensive and only available in pharmaceutical shops. (Syahariza, Hong,2017)Native maltodextrin starches such as rice or potato are mixed to improve starch properties without any chemical modification. Barnyard millet (***Echinochloa crusgalli*** (L.) P. Beauvois) is a multi-purpose crop cultivated for food and fodder. It is a good protein source digestible. It is also most effective in reducing blood glucose and lipid levels. (B. Dayakar Rao ***et al.,***2018)(Veena B, 2005). Whey protein concentrates contain a low level of fat and cholesterol, but it has elevated levels of bioactive compounds, and carbohydrates in lactose. 70–80% of the protein content is more present. Whey has the ability to increased endogenous GSH production. GSH is the body's most potent naturally occurring antioxidant and plays a role in immune system support.(Gangurde ***et al.***,2011)Starch is the crucial ingredient in providing the desirable viscous characteristics of food products and is ideal as a thickening agent. Starch granules are semicrystalline particles composed of a mixture of two polysaccharides, amylose, and amylopectin.(Sylvia Carolina et al**.,** 2015).

This study evaluates characteristics of commonly used thickeners, maltodextrin Starch (Rice and Potato) for millet porridge model where a different level of starch is added using textural, osmolality, dense, and nutritional properties. This texture modified food has been analyzed in several ways to provide an objective measurement for the dietary management for dysphagia patients. This research's objective was to characterize the sensory properties of liquids thickened with potato and rice starch.

Materials and Method

Different ingredients for the development of porridge-like Barnyard, Starch, and Whey concentrate were procured from the local departmental store. After purchasing, the millet grains were given to a milling company to turn them into a fine powder. Then the powder was carried into an air-tied container. Then the millet powder was sieved through a copper sieve (500 microns). First, the millet powder was mixed with vegetable powder, whey powder, oil, and salt. Then water was added to the mixture of powder. The liquid is then transferred into a container and placed in the streamer for 30 minutes. The porridge was prepared in an electric steamer. Two starch powders were added in different liquid mixtures and continuously stirred to prevent lump formation in the porridge for making variations. Then the porridge was cooled down to the temperature of 25-30 degrees Celsius. The control sample without any addition of starch powders was prepared for comparison.

Table 1: Material used in making Millet Porridge

Materials	**Amounts**
Barnyard Millet	100g
Salt	3g
Potato Starch	*
Rich Starch	*
3 Red Vegetable Powder (Tomato/Beetroot/Carrot)	4g
Sunflower Oil	2
Water	475m^3
Whey Protein Powder	5g

Table 2: All Varieties of Millet porridge with different % of Starches

Variation	Ingredients							
	BM (g)	VP (g)	WC (g)	Salt (g)	SO (ml)	Water (m^3)	PS (g)	RS (g)
CBOF	100	4	5	3	2	400		
BOF1	97.5	4	5	3	2	400	1.25	1.25
BOF2	95	4	5	3	2	400	2.5	2.5
BOF3	92.5	4	5	3	2	400	3.75	3.75
BOF4	90	4	5	3	2	400	5	5
BOF5	87.5	4	5	3	2	400	6.25	6.25
BOF6	85	4	5	3	2	400	7.5	7.5
BOF7	82.5	4	5	3	2	400	8.75	8.75
BOF8	80	4	5	3	2	400	10	10

BM: Barnyard Millet; VP: Vegetable Powder; WC: Whey Concentrate; SO: Sunflower Oil; PS: Potato Starch; RS: Potato Starch

Nutrient Analysis

Determination of carbohydrate

The total carbohydrate content was persistent according to the method Dubois ***et al.,***1956; AOAC, 2006. 1.0 m^3 of the sample was mixed with 1.0 m^3 phenol solution and added 5.0 m^3 of 96% sulphuric acid to each tube and shake well. Then this was incubated in the boiling water bath for 20 minutes. After that, the absorbency was read at 490 nm against a reagent blank. Triplicates values were taken, and the results were expressed as mg/g sample.

Determination of Proteins

Protein content was determined according to the method of (Lowry ***et al.,1957;*** AOAC, 2006).1.0 ml of sample was mixed with 0.5 ml of 0.1 N NaOH and 5 ml of alkaline copper reagent. Then the mixture was incubated at room temperature for 30 minutes. After that, 0.5 ml of Folin- Ciocalteau reagent was added to it, and the mixture was incubated again at room temperature for 10 minutes. Absorbency was read at 660 nm against a reagent blank. Triplicates values were taken, and the results were expressed g/100g sample.

Determination of crude fat

Crude fat was determined by the ether extract method using the Soxhlet apparatus where powdered sample (1g) was wrapped in filter paper, placed in a fat-free thimble, and then added to the extraction tube.(Arlington, AOAC, 2006) The weight, cleaned, and dried receiving beaker was filled with petroleum ether and fitted into the apparatus, and then water and heater were turned

on to start the extraction. After six rounds of siphoning, ether was allowed to evaporate, and the beaker was disconnected before the last siphoning. The extract was then transferred into a clean glass dish, where the ether was washed and evaporated on the water bath. The plate was then placed in an oven at 105 degrees Celsius for 2 hours and cooled. Then the sample was allowed to cool in a desiccator and weight (W1). The sample crucibles were ashed in a muffle furnace at 550 degrees Celsius for 4 hours. The analysis was performed in triplicates, and the results were expressed g/100g sample.

Viscosity Analysis

The Viscosity of each of the porridge preparations, thinned, as described, was measured by Fungilab viscometer (Barcelona) based on Weissenberg effect using disc spindle L2 at the temperature of 25-30 degrees Celsius. The porridge was poured in 500 m^3 Conical Flask and then measured. These are the Shear rate (with coaxial spindles) (s-1) and Shear Stress (with coaxial spindles) (N/m2). All measurements were carried out immediately after cooling down the porridge samples using different RPM. Triplicate values were taken for different r.p.m. Readings were taken in Centipoise (cP) and converted to milli Pascal-seconds(mPa-s)(1 **cP** = 10^{-3} **Pa·s** = 1 mPa·**s).** Values were taken at 2 minutes' intervals.

The following equations and mathematical descriptions were undertaken for obtaining shear rate and shear stress values to identify the flow behavior of juice, squash, and gelling strength of jam viscosity:

Shear rate :- $Y = \frac{2w\ Rc^2\ Rb^2}{X^2\ (Rc^2 - Rb^2)}$ **(1)**

Shear stress :- $r = \frac{M}{2\pi\ (Rb^2 - Rb^{2L})}$ **(2)**

Viscosity :- $\eta = \frac{r}{\gamma}$ **(3)**

Rc =radius container (cm)
Rb = radius of spindle (cm)
X = radius at which shear rate is being calculated (Rc-Rb)
M =torque input by instrument (final load)
L = effective length of spindle **(**Bourne,2002**)**

Osmolality Analysis

Osmolality is a measure of the number of particles of a substance per kilogram of solvent (mmol/kg). In contrast, the osmolarity is the measure of the number of particles of a substance per liter of solution.(Schafer L,2009)From each variation, few drops of the sample were taken, and osmolality was measured by Osmometer 3250. Triplet value was taken for each sample. Repeatability is a measure of a method's ability to obtain the same result time after time on the same sample. Most ionic solutes do not completely dissociate. Osmolality is a unit of concentration that takes into account the dissociative effect. Osmolality is usually expressed in mmol/kg H2O. One milliosmol (mmol) is 10-3 osmols.

Osmolality is defined as: where:
Osmolality= øNC= osmol/kg H2O

ø = osmotic coefficient, which accounts for the degree of mol-molecular dissociation.
N = number of particles into which a molecule can dissociate.
C = molal concentration of the solution.(Advanced Instrument Inc, 2003)

Texture Analysis

Textural properties of thickened millet porridge were evaluated by a texture profile analysis (TPA) with a TVT 6700 Texture analyzer (Perten Instruments, Sweden) through Single Cycle Penetration. 671545 Cone probe 45* stainless steel was used to perform the test. Each sample was taken with a 20 mm height. The tests were carried out at the following settings: test speed: 2.0 mm/s, initial speed: 1.00 mm/s, post-test speed: 10 mm/s,retract speed= 10.0 mm/s compression: 15 mm, and starting distance from the sample: 5 mm. Trigger force= 50 mN,data rate= 200 PPS, distance above trigger= 0.0 mm, diameter= 0.0 mm.The puncture test was performed with the conical probe. The test is characterized by penetrating the probe into the food, causing irreversible crushing or flowing of the food. Puncture testing instruments are all maximum-force instruments. They may be classed into single-probe instruments, such as the Magness–Taylor, EFFI-GI, Chatillon, and the Bloom Gelometer. Peak force obtained as a result of compression), consistency (positive area of the obtained graph), cohesiveness (maximum negative force), and viscosity index (negative area of the curve). All of the measurements were carried out at 25 °C and were replicated three times for each sample.(Bourne,2002).

Sensory Evaluation

Students in the age group of 20-30 years were taken as the population for sensory analysis. The samples of different varieties were presented in small steel bowls at 25-degree temperature. Ten students were given the cooked porridge to judge the color, taste, aroma, mouth-feel, and consistency of the different varieties of the porridge on a 5 point Hedonic scale (Extremely Dislike 2-Dislike 3- Neither Like nor dislike 4- Like 5- Extremely Like)

Statistical Analysis

Statistical analysis for textural measurement was conducted using SPSS Statistics Desktop 22.0 (IBM Corporation, US). The results obtained were represented as the mean values of three individual replicates ± standard deviation (SD). Comparison of mean was performed by one-way ANOVA using Tukey's test at 5% probability level.

Result and Discussion:

This texture modified porridge is giving optimum nutrition for the patient to maintain nutritional intake. The control sample's nutrient composition is lower than the millet porridge prepared with a different thickener concentration.

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The control sample is the lowest in carbohydrate and protein content, and it is the highest in fat content among all other variations. Other varieties with rice and potato starch concentrated were having more nutritional importance than the control sample. The chart shows that the bars for carbohydrate and protein content in the control one are the lowest among all other variations, and the bar for fat content is the highest.

The European Society of Parenteral and Enteral Nutrition and American Society for Parenteral and Enteral Nutrition also recommended that ambulant and bedridden patients with oral cancer should have daily energy intakes of 30 to 35 and 20 to 25 kcal/kg body weight, respectively; minimum daily protein need of 1 g/kg body weight and target need of 1.2 to 2 g/kg body weight should be observed (Arends ***et al.***, 2006; Giles, Kubrak, Baracos, Olson, & Mazurak, 2016). Costa, Carrion, Puig-Pey, Juarez, and Clave (2019) suggested the energy requirements of 25 kcal/kg/day for the elderly with Dysphagia but otherwise having

normal nutritional status early risk of malnutrition and 35 kcal/kg/day for malnourished elderly with Dysphagia.

Two macronutrients, carbohydrate and protein content, are increasing with increasing starch content. There is rising starch content in the barnyard millet porridge, which leads to an ascending increase in the number of macro-nutrients; carbohydrate and protein. Barnyard millet porridge with 4% Starch contains the highest amount of carbohydrate and protein content present and lowest in fat content among all other variations. They were showing an ascending order in carbohydrate and protein content. Fat content in different porridges was arranged in descending order.

Table 3: Three significant nutrients (carbohydrate, protein, fat) value of Barnyard millet porridge prepared by using rice and potato starch at different concentrations

Sample	Carbohydrate (g/100ml)	Protein (g/100ml)	Fat (g/100ml)
CBOF	63.23 ± 0.04^{a}	5.25 ± 0.02^{a}	4.23 ± 0.04^{i}
BOF1	64.17 ± 0.03^{b}	8.15 ± 0.02^{b}	3.87 ± 0.02^{h}
BOF2	64.55 ± 0.03^{c}	8.74 ± 0.03^{c}	3.72 ± 0.02^{g}
BOF3	64.95 ± 0.04^{d}	9.23 ± 0.05^{d}	3.44 ± 0.02^{f}
BOF4	65.16 ± 0.03^{e}	9.53 ± 0.01^{e}	3.38 ± 0.02^{e}
BOF5	65.34 ± 0.03^{f}	10.16 ± 0.02^{f}	3.14 ± 0.02^{d}
BOF6	65.75 ± 0.02^{g}	10.26 ± 0.03^{g}	2.95 ± 0.04^{c}
BOF7	66.25 ± 0.04^{h}	11.37 ± 0.03^{h}	2.83 ± 0.02^{b}
BOF8	66.52 ± 0.03^{i}	12.75 ± 0.03^{i}	2.73 ± 0.01^{a}

*values followed by the same letter within a column are not significantly different. ($P<0.0$)

Viscosity Measurement

Viscosity is a property of liquids that is closely related to the resistant flow. Instrumental viscosity measurements of the thickened liquid samples are a mixture of millet, vegetable powder, and whey concentrate powder by torque measurement. The resultant starch solution's Viscosity is dependent on the amylose to amylopectin ratio of the starch, and most starches contain approximately 25% amylose and 75% amylopectin (Utrilla-Coello et al. 2014; Eliasson 2017). After swelling, the starch granules expand to between 14.9 and 33.3 µm, and the swelling occurs in all directions (Eliasson 2017).

Unsurprisingly, the results show a marked influence of the porridge dry matter content: the apparent viscosity values increased rapidly with the dry matter content. The patients affected with Dysphagia are suggested to drink liquids thickened to honey-like consistency and have a significant viscosity of 1300±100 m.Pa. s at a shear rate of 50 per second at 20 degrees Celsius. (National Dysphagia Diet)

T**able 6** shows all the viscosity measurement values which were collected in 18 different rpm. In the controlled Sample, Rpm 100,60,50,30,20,12,10 shows shallow viscosity values in the range of 10-30mPa-s, leading to aspiration, choking.

The control one, which is made with the ingredients mentioned above without only starch powders, shows a relatively low amount of Viscosity, which is not suggested for dysphagia patients as a too high liquid flow can cause aspiration choke in these type of patients.

Hence they are not suggested except 1% starch concentrated porridge. Rpm 0.3 is apt with the standard given by NDD (National Dysphagia Diet). BOF1 (0.5% Starch Millet Porridge)-1424mPa-s, BOF2 (1% Starch Millet Porridge)-1181mPa-s BOF3 (1.5% Starch Millet Porridge) - 1252mPa-s in 0.3 rpm are the ones that comes near to the standard. With increasing starch, there is an increase in Viscosity, so the value is in ascending order. The Barnyard millet porridge with 1% Starch in 0.3 rpm has the Honey-like thick fluids characteristic (351–1750 mPa-s) according to the National Dysphagia Diet (USA fluid viscosity scale).

Table 4: Viscosity boundaries defined for Dysphagia by the National Dysphagia Diet (Richard J. Dewar *et al.*)

Consistency term	**Subcategory**	**Viscosity (cP)**
Thick	High Low	1750+ 351+
Medium	High Low	350+ 51+
Thin	High Low	50+ 1+

Table 5: Comparison between the Australian fluid texture modification scale, the National Dysphagia Diet (US) and the UK (adult) texture classification systems for individuals with Dysphagia (Julie A.Y. Cichero *et al*.,2007)

Australian fluid viscosity scale	**USA fluid viscosity scale**	**UK fluid viscosity scale**
Regular	Thin 1–50 mPa-s	Thin Fluid
Level 150—Mildly thick	Nectar-like thick fluids 51–350 mPa-s	Naturally Thick Fluid Thickened fluid-Stage 1
Level 400—Moderately thick	Honey-like thick fluids 351–1750 mPa-s	Thickened fluid-Stage 2
Level 900—Extremely thick	Spoon-thick fluids >1750 mPa-s	Thickened fluid-Stage 3

Osmolality

The freezing point in the osmometer measures the Osmolality of the Barnyard millet porridge. The normal osmolality of plasma is approximately 280–303 milli-osmoles per kilogram and is affected by water content changes. The osmolality standard for Dysphagia is 270-300 mmol/kg. The salt solution's Viscosity–concentration behavior and sucrose solutions are interlinked at constant temperatures, which affects the flow behavior.[Bourne,2002]The American Academy of Pediatrics (AAP) Committee on Nutrition cautioned against infant feeds over 400 mmol/m^3 [450 mmol/kg] without a warning statement on the label until more evidence was obtained to hyperosmolality and safety reasons. As shown in table 7, the control sample shows the lowest osmolality, which is not suitable for suggesting those patients with Dysphagia. Osmolality increases in the last variation gradually with the increasing starch powder content.

Table 7: Osmolality Values of Different Samples of Barnyard Millet Porridge

Samples	Osmolality
CBOF	307 ± 2.00^{b}
BOF1	315 ± 1.52^{c}
BOF2	212 ± 1.73^{a}
BOF3	367 ± 1.52^{d}
BOF4	374 ± 2.00^{e}
BOF5	316 ± 5.29^{c}
BOF6	410 ± 2.00^{f}
BOF7	477 ± 1.73^{h}
BOF8	419 ± 1.00^{g}

*values followed by the same letter within a column are not significantly different. ($P<0.05$)

Table 6: Viscosity values for two different rpm of Barnyard millet porridge prepared by using rice and potato starch at different concentration

Sample	Viscosity (mPa-s) 100 rpm	Viscosity (mPa-s) 60 rpm	Viscosity (mPa-s) 50 rpm	Viscosity (mPa-s) 30 rpm	Viscosity (mPa-s) 20 rpm	Viscosity (mPa-s) 12 rpm	Viscosity (mPa-s) 10 rpm	Viscosity (mPa-s) 6 rpm	Viscosity (mPa-s) 5 rpm
CBOF	25.90± 0.79^{b}	21.60± 0.10^{b}	18.10± 0.30^{b}	15.76± 0.51^{a}	20.26± 1.72^{a}	20.40± 4.15^{a}	17.06± 0.94^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}
BOF1	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	643.77± 557.64^{c}	714.63± 6 18.95^{c}	884.63± 766.14^{cd}	1319± 51.38^{f}	1487± 38.12^{e}	1497± 97.92^{e}
BOF2	0.00± 0.00^{a}	378.97± 3.15^{f}	398.40± 2.62^{f}	463.27± 6.63^{bc}	507.83± 8.90^{bc}	569.90± 10.06^{bc}	549± 15.62^{d}	565.13± 4.9^{c}	507.93± 7.11^{c}
BOF3	223.00± 7.00^{e}	236.33± 1.12^{e}	242.13± 1.45^{e}	276.57± 2.53^{ab}	309.87± 1.25^{a}	358.87± 5.99^{ab}	373± 6.13^{c}	457.07± 24.11^{c}	448.83± 18.36^{c}
BOF4	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	139.32± 32.71^{d}	200.27± 401.65^{e}	2550± 84.3^{h}	3194± 168.06^{f}	3082± 55.44^{f}
BOF5	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	218.48± 42.23^{e}	2367± 28.56^{g}	3165± 96.31^{f}	3213± 36.29^{g}
BOF6	72.76± 0.56^{c}	84.53± 0.41^{c}	89.63± 0.75^{c}	99.03± 1.52^{a}	110.17± 1.25^{a}	113.67± 1.92^{ab}	122± 3.49^{b}	1389± 4.3^{b}	149.7± 16.93^{b}
BOF7	84.90± 0.43^{d}	96.90± 2.13^{d}	94.60± 0.60^{d}	99.56± 0.85^{a}	109.07± 0.90^{a}	104.97± 2.55^{ab}	115± 4.01^{b}	118.9± 1.96^{ab}	115.73± 4.14^{b}
BOF8	295.80± 1.75^{f}	486.53± 5.28^{g}	158.93± 201.68^{g}	1375.00± 24.40^{d}	853.03± 17.98^{c}	117.57± 48.30^{d}	1125± 33.01^{e}	1295± 91.87^{d}	1202± 53.44^{d}

Sample	Viscosity (mPa-s) 4 rpm	Viscosity (mPa-s) 3 rpm	Viscosity (mPa-s) 2.5 rpm	Viscosity (mPa-s) 2 rpm	Viscosity (mPa-s) 1.5 rpm	Viscosity (mPa-s) 1 rpm	Viscosity (mPa-s) 0.6 rpm	Viscosity (mPa-s) 0.5 rpm	Viscosity (mPa-s) 0.3 rpm
CBOF	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}	0.00± 0.00^{a}
BOF1	1424± 36.51^{e}	1414± 8.76^{ab}	1453± 38.9^{f}	1433± 49.69^{e}	1408± 26.03^{c}	1455± 190.7d	1051± 39.83^{b}	968± 135.62^{ab}	1424± 36.51^{a}
BOF2	522± 50.75^{c}	585.4± 68.96^{ab}	767± 88.02^{d}	839.93± 110.41^{cd}	989.77± 89.24^{b}	1051± 103.1^{b}	1059± 46.75^{b}	1148± 78.16^{b}	1181± 134.43^{a}
BOF3	460± 33.05^{c}	1912± 2441.09^{b}	568.47± 96.28^{c}	100.67± 10.96^{c}	796.33± 93.2^{b}	853.9± 108.6^{b}	1064± 133.98^{b}	1216± 97.60^{b}	1252± 137.99^{a}
BOF4	3815± 110.67^{g}	3939± 160.54^{c}	3754± 102.3^{g}	3895± 279.17^{f}	4027± 583.65^{d}	4335± 257.43e	4422± 402.66^{e}	4884± 150.96^{d}	4995± 165.98^{b}
BOF5	3521± 70.92^{f}	3829± 101.05^{c}	3966± 81.81^{h}	4514± 143.15^{g}	4729± 168.87^{e}	5005± 159.95^{f}	5186± 474.41^{f}	5373± 423.37^{d}	5892± 271.78^{b}
BOF6	163.77± 9.67^{b}	197.03± 22.28^{a}	257.9± 36.33^{b}	346.2± 65.55^{b}	590.4± 160.04^{b}	1367± 264.85^{cd}	3125± 560.08^{d}	5339± 1539.51^{d}	12726± 3508.12^{c}
BOF7	145.9± 10.94^{b}	154.97± 7.61^{a}	244.23± 48.67^{b}	353.97± 44.46^{b}	776.53± 210.38^{b}	1623± 228.8^{d}	2250± 341.07^{c}	4381± 958.20^{d}	10618± 2746.08^{c}
BOF8	1184± 79.95^{d}	1274± 103.34^{ab}	1121± 37.07^{e}	983.7± 141.39^{d}	964.27± 28.38^{b}	1118± 42.53^{bc}	2320± 320.9^{c}	2995± 203.96^{c}	5884± 308.85^{b}

*values followed by the same letter within a column are not significantly different. (P<0.05)

Textural Measurement

Textural properties of millet porridge prepared by different thickener were presented in Table 9. Generally, textural parameters (Stickiness, Resilience, Adhesiveness, and Stringiness) values increased with thickener at various concentrations compared to the control sample, which disrupts the porridge flow.

Food texture recommends for dysphagia diets should be soft, moist, elastic, smooth, and easy to swallow (Tokifuji et al., 2013; Yoshioka et al., 2016). Sticky and adhesive textures and thin liquids should be avoided since these textures can cause food residue to accumulate in the oropharynx and may lead to aspiration after swallowing (Park, Kim, Lee, & Park, 2017).

Stringiness is the quality of being made of strings or resembling strings. Another meaning of stringiness is a fiber-like texture, which can be similar to a wire structure.1%(BOF2) Starch added porridge shows a stringiness of 0.83, which provides elasticity; therefore, more comfortable to swallow. The high Stringiness value of millet porridge with 4%(BOF8) potato and rice starch further affirm that this sample requires more force to initiate the food pipe flow. Resilience means a substance or a particle's ability to return to its usual shape after being bent, stretched, or pressed. 4%(BOF8) Starch added millet porridge has the highest resilience, and the lowest is seen in 0.5%(BOF1) and 1%(BOF2) Starch added millet porridge.

Stickiness is the adhesion property, which describes the strength of those attractions between two particles present in the porridge. The one %starch added porridge(BOF2)is on the lower side with a value of 3.33, ideal for dysphagia patients. Adhesion is the tendency of dissimilar particles or surfaces to cling to one another. Cohesion refers to the movement of similar or identical particles/ surfaces to stick to one another. Millet porridge containing 1% starch, has 0 adhesion, which is needed for the condition.

Table 8: Comparison between Australia clinical food texture scale, National Dysphagia Diet (US) and the UK food texture classification systems for individuals with Dysphagia [Julie A.Y. Cichero *et al*.,2007]

Australian food texture scale	USA food texture scale	USA food texture scale
Regular	Regular	Normal
Texture A—Soft (1.5 cm)	Dysphagia Advanced (‘bite-sized’), 2.5 cm	Texture E (1.5cm)
Texture B—Minced and Moist (0.5 cm)	Dysphagia Mechanically altered (0.6 cm)	Texture D
Texture C—Smooth Pureed	Dysphagia Puree	Texture C
		Texture B
		Texture A

Table 9: Textural properties (Peak force A, Height, Weight, Stickiness, Adhesiveness, Stringiness, Resilience) of Barnyard millet porridge prepared using rice starch and potato starch different concentrations.

Sample	Peak Force A	Sticki-ness	Resilie-nce	Adhesive-ness	String-iness
CBOF	1618± 407.68^{a}	-4.33 ±1.52^{abc}	0.10± 0.00^{a}	0.26± 0.30^{a}	0.45±0.66^{a}
BOF1	1797± 302.56^{a}	-5.00 ±2.64^{abc}	0.10± 0.00 ^{a}	0.96± 1.50^{a}	0.24±0.29^{a}
BOF2	2133± 346.68^{a}	-3.33 ±0.57^{bc}	0.10± 0.00^{a}	0.00± 0.00 ^{a}	0.83±0.10^{a}
BOF3	2361± 252.91^{a}	-4.00 ±2.64^{abc}	0.16± 0.11^{a}	0.36± 0.55^{a}	0.14±0.17^{a}
BOF4	1924± 762.94^{a}	-6.00 ±0.00^{ab}	0.33± 0.40^{a}	10.70± 7.46^{b}	4.85±2.86^{b}
BOF5	2003± 209.38^{a}	-2.33 ±0.57^{c}	0.36± 0.25^{a}	0.10± 0.00^{a}	0.08±0.10^{a}
BOF6	2001± 95.42^{a}	-2.66 ±1.52^{c}	0.23± 0.23^{a}	0.10± 0.00^{a}	0.16±0.15^{a}
BOF7	2052± 156.80^{a}	-3.33 ±1.52^{bc}	0.43± 0.20^{a}	0.13± 0.05^{a}	0.10±0.05^{a}
BOF8	1972± 513.63^{a}	-6.66 ±1.52^{a}	0.53± 0.40^{a}	8.46± 11.46^{ab}	4.21±3.69^{b}

*values followed by the same letter within a column are not significantly different. (P<0.05)

Sensory Evaluation

All subjects' responses were recorded as a numerical value. Thickness was increased with the increasing starch content of the porridge. The aroma of beetroot was coming in it, and the taste of three red vegetables like beetroot, tomato, and carrot was there. The color of porridges was intact with increasing starch content, but all the varieties were not well accepted. The sensory attitude was acceptable in terms of color, aroma, but taste, mouth-feel depended on the sample and person taste choice. Sensory attributes included aroma, taste, mouthful, colour, and consistency in the samples depending on the medium being thickened. These attributes, such as taste, mouthful, and texture, decreased in intensity with an increasing thickness. According to the National Dysphagia Diet Taskforce guidelines, current work on the sensory properties of thickened liquids has focused on Maltodextrin starches forming thickened liquids. Thus far, researchers have reported that starch powder thickeners impart a starchy flavor and a grainy texture (Lotong et al., 2003; Matta et al., 2006).

Table 10 shows that the control sample was liked in every category, and among the starch porridges, the 0.5% starch had the highest overall acceptability. Considering all measurements such as Viscosity, osmolality, and texture, 1% Starch porridge is suitable for swallowing and average taste.

The same explanation is described in figure 2 the colour and aroma of all the variation of starch added millet porridge is perfect. The control was very well accepted in terms of all sensory attributes. Students accepted the thick porridge with 3%, 3.5%, and 4% starch more than the porridges with lesser starch content in terms of taste.

Conclusion

Dysphagia refers to a patient's perception of difficulty in the passage of a swallowed bolus from the mouth to the stomach. Diet modification is one way that the patient can be fed, helping maintain their nutritional intake. Barnyard millet varieties were found nutritionally superior compared to finger millet varieties as it contains phytochemicals, such as phenolic acids, flavonoids, and tannins. Thickened fluids slow the act of swallowing and, by doing so, enhance safe swallowing. However, exclusive oral consumption can lead to adequate hydration and nutrition if they accept the food. Studies now focus on thickened fluids as it has higher Viscosity and texture modified foods which are nutritionally enriched. Therefore, this work examines two native starch-based thickeners' suitability at room temperature (25 to 30-degree Celsius). Different types of thickener and its concentration affects the different properties of millet porridge. This study shows with the addition of whey concentrate and starts, the porridge is nutritionally dense. It can avoid malnutrition in

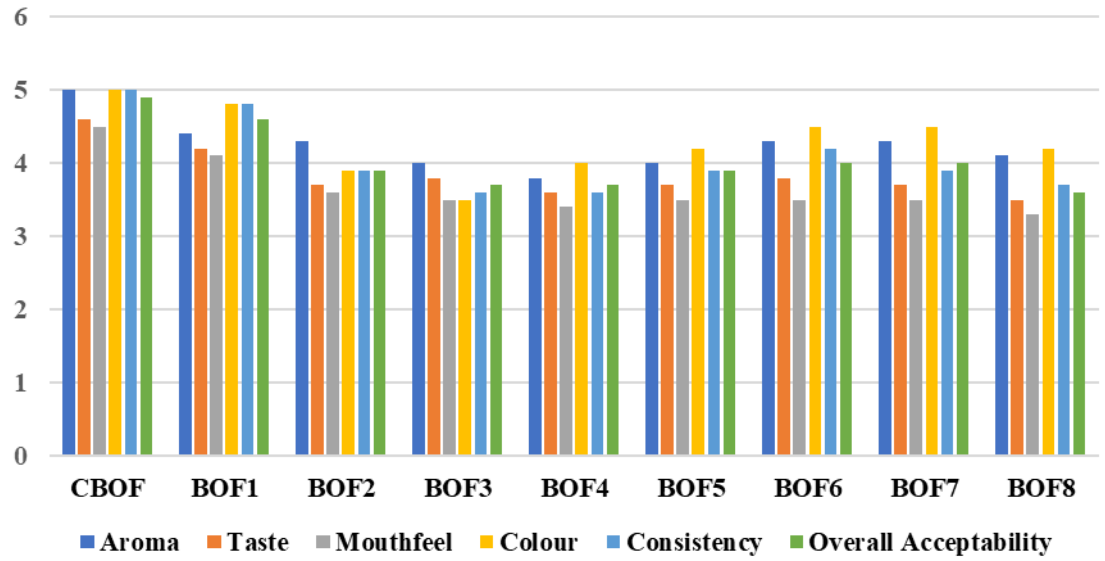

Figure 2: Mean organoleptic scores of developed Barnyard Millet Thickened Porridge

dysphagia patients as they are more prone to malnutrition. After analyzing Viscosity, osmolality, texture, and sensory, it is clear that 1% of starch with thickness-related attributes included adhesiveness and ease of manipulation, leading to ease of swallowing. The standard Viscosity is 1300±100mPas, and the osmolality standard for Dysphagia is 270-300mmol/kg. 1% starch attains the average values recommended by the National Dysphagia Diet. 1% starch added millet porridge gives the proper texture for ease of swallowing. 1% Starch porridge is suitable for swallowing and has an average taste. All the macronutrient present is highest in 4% starch porridge as it contains the highest content of starch. According to the measurement of Viscosity and osmolality, we came to see that the 4% starch porridge would be challenging to swallow. Hence, 1% Starch porridge is nutritionally adequate and can be consumed with ease for a dysphagia patient. The National Dysphagia Diet has fixed some standards, such as the range of Viscosity and osmolality, to be maintained for the betterment of swallowing by the patient. 1% starch added porridge falls under the spectrum compared to the control sample or the other higher percentage of starches added to the porridge.1% Starch content in the porridge makes it thick but not too thick, resulting in dehydration. This project aims to create a porridge with osmolality and Viscosity (according to the National Dysphagia Diet) and nutritionally apt for the patient to avoid conditions such as malnutrition, aspiration, and asphyxiation. It is nutritionally adequate and helps in swallowing for a dysphagia patient.

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