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RHEOLOGICAL STUDIES OF TEXTURE-MODIFIED CHICKEN RENDANG WI TAPIOCA AND SAGO STARCHES AS FOOD THICKENER FOR PATIENTS WI DYSPHAGIA

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ABSTRACT

Dysphagia refers to the term of having difficulty in swallowing or moving foods and liquids from the mouth to the stomach, which will lead to dehydration and malnutrition. Texture modified food is one of common method used in dysphagia management, by altering the rate of food travelling down the pharynx. In this study, texture modified chicken rendang was developed to comply Texture C (fine puree with lump free) as outline by Australian dysphagia standard. Rendang, one of popular traditional dish in Malaysia was selected; aim to introduce high protein diet in patient with dysphagia problem. Texture modification was carried out by adding commercial thickener, and later was compared to formulation with addition of tapioca and sago starch as the thickener. Effect of using different types of food thickener, together with different level of starch addition and serving temperature on the rheological properties of developed food were investigated. Results showed that all thickened samples demonstrated a shear thinning effect throughout the temperature studied, contributed by starch integrity loss due to heating. Both storage modulus (G') and loss modulus (G") values of samples containing starch decreases as temperature increases, indicating a weak gel like properties associated with each sample. The addition of 5% of starch was found to be optimal for the sample to remain stable even at 85°C. Tapioca starch could potentially use as cheaper thickener alternative due to its stable structure upon oscillation frequency and temperature increment during rheological analysis, when to compared to sago starch. Introduction of chicken rendang puree, thickened with starch potentially help to provide safer food for patients with dysphagia.

Keywords: Rheological study, Texture modified food, Chicken *rendang*, Tapioca and sago starch, Dysphagia.

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Contribution/ Originality

This study contributes in the existing literature of texture modified food for patients with dysphagia. This study investigates the possibility of using tapioca and sago starch as the source of food thickener, to replace the use of commercial thickener, which normally marketed at a higher price.

1. INTRODUCTION

Dysphagia is the medical term for difficulty or inability to swallow liquid food or medication; it occurs during oropharyngeal or the oesophageal phase of swallowing (Berber and Joshi, 2010). Dysphagia is associated with advancing age; however, it can occur at any time during the lifespan as it may results from one of several pathologies such as neuromuscular disorders, brain injury, or stroke (Cichero, 2006). Texture modification of foods and thickening of fluid are the most common practice use in the assessment and treatment of dysphagia. Texture-modified food is defined as food altered in its texture, whether in the degree of hardness, adhesion, cohesion,

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consistency, crunchiness, chewiness or gumminess, particle size, or rate at which the food breaks down in the mouth. Meanwhile, thickening of fluid is normally carried out by addition of food thickeners; either starch-based or gum-based types. Thickened food products can alter the rate of food travelling down the pharynx (Zargaraan *et al.*, 2013).

Rheological analysis of foods plays a vital role in the management of patients with dysphagia as the swallowing ability among these patients is vastly different (Cichero *et al.*, 2000). Rheology is defined as the study of deformation and flow of matter, which is greatly relevant as all food is subjected to large deformations in the mouth before swallowing, as well as during processing. During swallowing, the food bolus is subjected to variable shear rates, and the maximum shear rate depends on the viscosity of the bolus (Nicosia, 2007). Therefore, rheological characterization of food is utmost important in developing special food for patients with dysphagia, allowing an easy masticated food and safe swallowing process.

People with dysphagia are often malnourished. The inadequate balance of calories and protein may results in weight loss and even lead to death if left untreated (Evans, 2005). Pureed food is the most easily tolerated by individuals with dysphagia (Aviv *et al.*, 2000). Providing a meat based pureed food to patients with dysphagia can certainly help to fulfil their daily protein requirement. Most of dysphagia food product consists of thickening agent. In puree food, thickeners act by binding the liquid to create a more cohesive product (Richman *et al.*, 1994).

In the present work, the stability of chicken *rendang* puree incorporated with different types of starch as thickener will be evaluated based on rheological studies. The suitability of using tapioca and sago starch to replace commercial thickener will be assessed. Tapioca and sago are the two major native starches in Malaysia.

2. MATERIALS AND METHODS

2.1. Preparation of Chicken Rendang Puree

Chicken rendang was prepared by following a traditional recipe for rendang making. All materials were purchased from the local markets in Penang. The chicken breast meat (100g) was ground until fine using a bowl cutter mixer R5 (Robot Coupe, France). All other ingredients were added based on weight of chicken breast meat. The chicken *rendang* was allowed to cool for 30 minutes before being processed into puree form by using food processor (Model MK-5087M, Panasonic, Osaka). Commercial thickener (modified corn starch, Thixer), tapioca and sago was later added with concentrations of 5, 6 and 7%. These samples were then stored in -20°C freezer until further analysis.

3. RHEOLOGICAL MEASUREMENTS

3.1. Oscillatory Analysis

A controlled stress rheometer (AR 1000, TA Instruments, New Castle, DE) equipped Peltier temperature control system and 20mm parallel plate attachment was used in the experiment. The sample temperature was ramped between 28°C and 85°C with an increment of 10°C. The exposed sample perimeter was covered with silicone oil to minimize evaporation at higher temperature. Dynamic oscillatory tests were carried out at a frequency sweep from 0.1 to 10 Hz. The oscillation stress was selected based on linear part of the viscoelastic range. Data was taken at temperature 28°C, 55°C and 85°C, to represents room temperature, serving temperature and heating temperature respectively. All rheological measurements were carried in duplicate. Storage modulus (G') and loss modulus (G") were obtained from the software (Rheology Advantage, TA version 2.3).

4. RESULTS AND DISCUSSION

4.1. Effects of Temperature

The effects of different temperature on the dynamic shear modulus of chicken *rendang* puree with and without thickener are presented in Figure 1(a)-(j). The curves of storage modulus (G') and loss modulus (G") were plotted as a function of frequency. Storage modulus was seen higher than loss modulus values over the entire frequency range which indicates a weak gel like properties associated with each sample. Similar behavior was observed for baby food product (Ahmed and Ramaswamy, 2007). The larger value of storage modulus is an indication of strong particle-particle interactions and/or the network type structure in a stabilized form (Carreau *et al.*, 2002).

Figure 1(a) illustrates changes in storage and loss modulus of chicken *rendang* puree without the addition of starch (control) as a function of angular frequency and temperature.

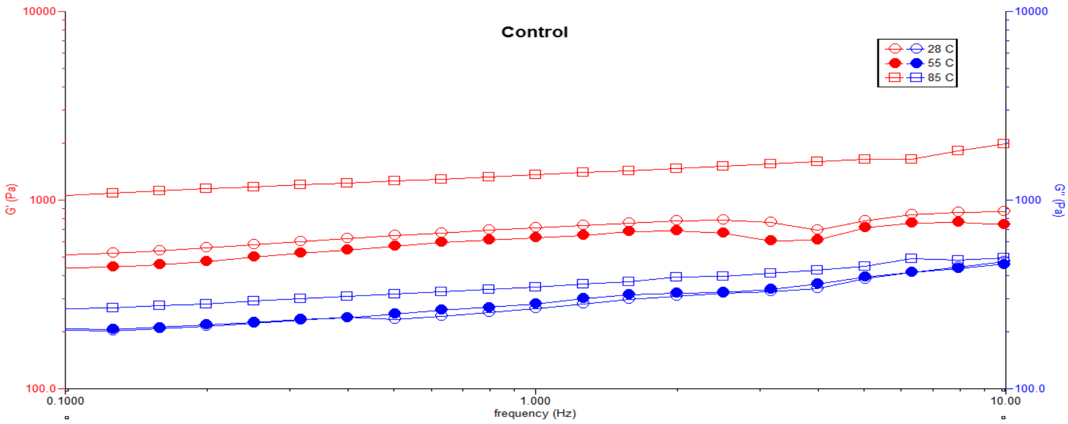

Figure-1. (a): Effect of temperature on dynamic rheology of chicken *rendang* puree without addition of starch as thickener (control)

Meanwhile, Figure 1(b)-(j) represents samples with the addition of modified corn starch (MC), sago (SX) and tapioca (TX) at 5%, 6% and 7%. The G' and G" values were presented in Table 1.

Table-1. Effect of thickeners and concentration of thickeners on dynamic rheological

Thickener	Conc. (%)	Temp. (˚C)	G’			G”		
			A (Pa.s⁻¹)	b(-)	R^2	A (Pa.s⁻¹)	b(-)	R^2
Control (without thickener added)		28	554.63	0.116	0.962	201.37	0.179	0.958
		55	476.43	0.126	0.949	208.93	0.175	0.981
		85	1104.08	0.119	0.976	272.9	0.141	0.988
Sago	5	28	933.25	0.112	0.997	325.84	0.171	0.995
		55	699.84	0.116	0.975	273.53	0.149	0.994
		85	665.27	0.12	0.929	225.42	0.139	0.97
	6	28	1216.19	0.14	0.997	420.73	0.151	0.994
		55	799.83	0.15	0.988	253.51	0.14	0.968
		85	853.1	0.098	0.969	218.27	0.121	0.945
	7	28	809.1	0.091	0.968	238.78	0.179	0.99
		55	663.74	0.09	0.893	184.5	0.123	0.88
		85	682.3	0.033	0.432	141.91	0.117	0.831
Tapioca	5	28	659.17	0.1	0.946	206.54	0.181	0.983
		55	601.17	0.123	0.938	190.11	0.16	0.966
		85	717.79	0.104	0.914	223.87	0.105	0.881
	6	28	3243.4	0.067	0.996	468.81	0.131	0.97
		55	1009.25	0.092	0.93	205.12	0.145	0.95
		85	672.98	0.096	0.974	175.79	0.157	0.974

	7	28	690.24	0.145	0.924	190.99	0.177	0.971
		55	478.63	0.139	0.841	166.72	0.104	0.874
		85	425.6	0.144	0.788	145.21	0.121	0.916
Modified cornstarch	5	28	1140.25	0.13	0.995	316.23	0.165	0.982
		55	779.83	0.117	0.983	193.64	0.168	0.975
		85	843.33	0.079	0.929	173.78	0.145	0.976
	6	28	4017.91	0.122	0.972	1629.3	0.137	0.952
		55	2312.06	0.115	0.987	933.25	0.14	0.984
		85	1786.49	0.092	0.991	736.21	0.113	0.98
	7	28	729.46	0.091	0.941	189.23	0.188	0.983
		55	578.1	0.13	0.864	161.06	0.157	0.923
		85	822.24	0.055	0.82	164.44	0.13	0.953

From the data, sample that contained thickener showed a higher G' values than the control sample. It proves that presence of thickener plays an important role in enhancing the structure of the products. For control sample, G' and G" were seen decreasing with an increase in temperature from 28°C to 55°C while an increase were noticed at 85°C which shows a shear thickening effect. The change and increase in G'-ω and G"-ω curves indicates the possibility of protein denaturation initiation. There were 3 predominant proteins that have been recognized generally; sarcoplasmic, myofibrillar and stromal proteins which the denaturation is in the range of 63 - 83°C (Ahmed and Ramaswamy, 2007). Protein denature is normally associated with conformational changes of protein on heating (Tornberg, 2005).

Some starch-thickened samples (SX 6% and 7%, TX 5%, MC 5% and 7%) also exhibited similar trend as the control sample. However, some samples; SX 5%, TX 6% and 7%, MC 6% showed a continuous decreasing value of G'. These could be due to shear thinning effect of starch gel. The decrease of G' indicates that the gel structure is starting to destroy, caused by the melting of the crystals present in the gel which deforms and loosen the structure,

thus reducing the elasticity (Eliasson, 1986). This observation is consistent with a study carried out by other researcher, which indicate that the swollen starch particles changes the rigidity of starch to became rheologically shear thinning (Carreau *et al.*, 2002). The inconsistent G' trends among thickened samples might be contributed by the inhomogeneous nature of the samples. Higher value of G' is desirable since starch-thickened food will react with salivary enzyme (amylase) during chewing process, causing the product to become less viscous (Wendin *et al.*, 2010). All 6% concentration showed highest G' value than other concentrations (5 and 7%), with MC being the highest, followed by TX and SX. It is known that modified starch possess a greater stability towards shearing than native starch does. In terms of stability upon heating, TX with 5% addition remains stable with temperature increment. For both SX and MC at 5% starch, the temperature only affects the stability moderately. Meanwhile, MC at 7% also exhibits greater structure stability compared to SX at 7%. The optimal concentration of starch added can be estimated based on A value (Table 1). Larger A value indicates strong particle- particle interactions and/ or the stabilized form of network structure (Carreau *et al.*, 2002). Based on Table 1, 6% starch addition was selected based on the highest A value obtained.

4.2. Effect of Different Starches

A comparison was made between control and those with added thickeners (SX, TX and MC). The G' and G" exhibited higher value in all SX, TX and MC compared to control sample, indicating that the thickeners addition enhanced the gel structure (Zhang and Barbut, 2005). This finding is supported by results of Genccelep et al. (2015) which concluded that thickeners contributed to the viscoelastic properties of meat emulsions. Carballo et al. (1996)

reported that modified corn starch affected the microstructure of meat emulsions and favored the formation of more compact and stronger heat-induced protein network.

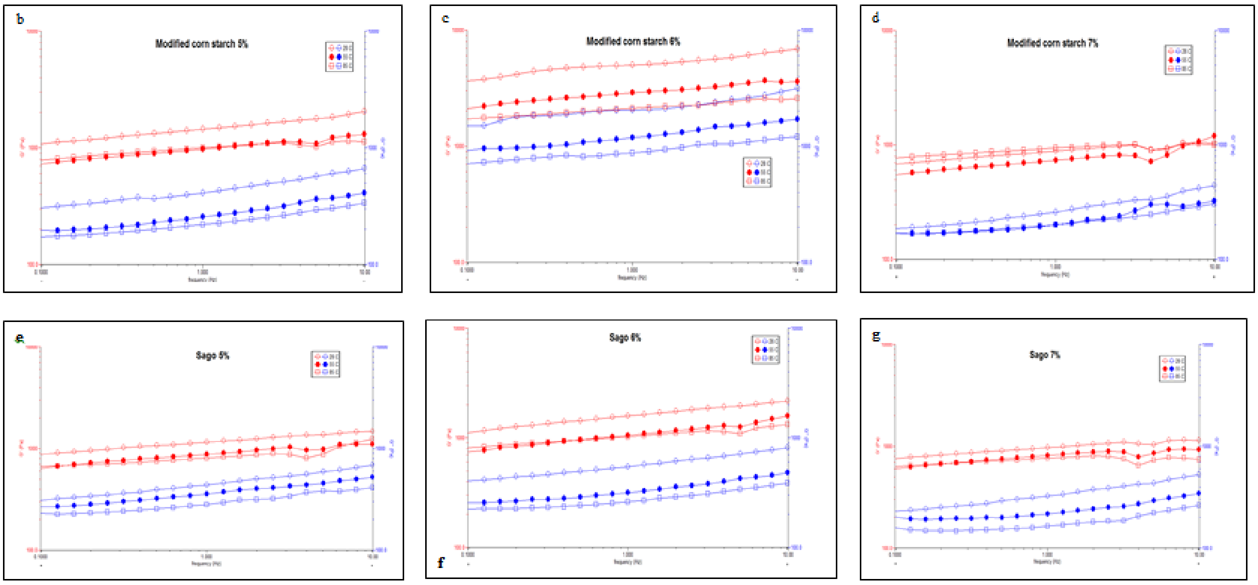

Figure-1. (b)–(g). Effect of temperature on dynamic rheology of chicken rendang puree with addition of starch as thickener

Furthermore, it was observed that TX has the closest G' values to MC (commercial thickener), indicating TX has higher elasticity and more extensible. It is known that G' measures how much energy stored in the sample and how much energy is recovered from it for every cycle of sinusoidal shear deformation, indicates whether the sample has a solid or elastic characteristics (Karim *et al.*, 2000). Gel strength (represents as G') is inversely proportional to the amylose content and its molecular mass (Ellis and Ring, 1985).

This statement has been seconded by Ahmad and Williams (1998) which showed that G' value would decrease with the increasing molecular mass of the amylose. It is known that the amylose content of TX is lower than the SX (Wattanachant *et al.*, 2002) hence this proves why TX sample provided higher G' values at 6% concentration than SX sample at the same starch concentration.

4.3. Mathematical Modelling

In order to determine storage and loss modulus in terms of frequency dependence, dynamic frequency sweep test were conducted. The modulus value was modeled by power-type equation as follows:

G' or $G'' = A(\omega)^b$

where ω is the frequency and A and b are constants (Steffe, 1996).

The regression coefficients (R^2) were calculated and presented in Table 1. Both storage and loss modulus values were found to be adequately fitted (R^2>0.90) throughout temperature range of 28 - 85˚C. For all samples, the A values for storage modulus were observed to be higher than the A values for the loss modulus. This indicate that all samples exhibited a solid like characteristic within the given temperature range. For the slopes of the corresponding b values, samples with thickener have a wider range than the control sample [0.119 (G') and 0.141 – 0.179 (G'')], as compared to SX, TX and MC [0.033 to 0.150 (G') and 0.104 - 0.188 (G'')]. Similar results were observed based on each thickeners composition, and different types of starch. The A values from storage modulus were seen higher than the loss modulus indicating a solid like characteristics. The R^2>0.90 shows that most of storage and loss modulus fitted adequately except 7% composition at 55°C and 85°C. This dynamic rheological parameters used in this study tend to be very useful in describing the viscoelastic properties of the products. It could serves as an indication of protein denaturation as well as shear thinning or shear thickening effect of the chicken rendang puree.

5. CONCLUSION

Storage modulus (G') and loss modulus (G") values of starch-thickened samples decreases as temperature increases, as lose its integrity upon heating, which lead to shear thinning. Results showed that storage modulus were seen higher than loss modulus values over the entire frequency range which indicates a weak gel like properties associated with each sample. Control sample (chicken *rendang* without any starch addition) exhibit shear thinning effect at temperature above 55°C, while all thickened samples demonstrated a shear thinning effect throughout the temperature studied. The optimum starch concentration for all thickened samples was found around 5%, in which it remained stable even at 85°C. Addition of commercial thickener was found to exhibit the most stable structure, followed by tapioca and sago starch, upon oscillation frequency and temperature increment during rheological analysis. In conclusion, it was shown that tapioca starch could potentially use as cheaper thickener alternative in preparing chicken *rendang* puree. Development of this product would add to more choices of texture modified food, which is safe for patients with dysphagia consumption.

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Competing Interests: The authors declare that they have no conflict of interests.

Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

REFERENCES

Ahmad, F.B. and P.A. Williams, 1998. Rheological properties of sago starch. Journal of Agricultural and Food Chemistry, 46(10): 4060 4065.

Ahmed, J. and H.S. Ramaswamy, 2007. Dynamic rheology and thermal transitions in meat-based strained baby foods. Journal of Food Engineering, 78(4): 1274-1284.

Aviv, J.E., M. Parides, J. Fellowes and L.G. Close, 2000. Endoscopic evaluation of swallowing as an alternative to 24-hour ph monitoring for diagnosis of extraesophageal reflux. Annals of Otology, Rhinology and Laryngology, 184(10): 25 -27.

Berber, O. and J.R. Joshi, 2010. Dysphagia. British Journal of Hospital Medicine, 71(4): 61- 63.

Carballo, J., P. Fernandez, G. Barreto, M.T. Solas and F.J. Colmenero, 1996. Morphology and texture of bologna sausage as related to content of fat, starch and egg white. Journal of Food Science, 61(3): 652- 655.

Carreau, P.J., F. Cotton, G.P. Citerne and M. Moan, 2002. Rheological properties of concentrated suspensions: Application to foodstuffs. In J. Welti-Chanes, G.V. Barbosa-Canovas andJ.M.Aguilera (Eds.), Engineering and food for the 21st century. FL, USA: CRC- Press. pp: 327 - 346.

Cichero, J.A.Y., 2006. Chapter 9: Conditions commonly associated with Dysphagia. In Dysphagia: Foundation, theory and practice, Edited by Julie, J.A.Y. and Murdoch, B.E. England: John Wiley & Sons, Ltd. pp: 237-298.

Cichero, J.A.Y., O. Jackson, P.J. Halley and B.E. Murdoch, 2000. Which one of these is not like the others. An inter-hospital study of the viscosity of thickened fluids. Journal of Speech, Language, and Hearing Research, 43(2): 537–547.

Eliasson, A.C., 1986. Viscoelastic behaviour during the gelatinization of starch i. Comparison of wheat, maize, potato and waxy-barley starches. Journal of Texture Studies, 17(3): 253–265.

Ellis, H.S. and S.G. Ring, 1985. A study of some factors influencing amylose gelation. Carbohydrate Polymer, 5(3): 201- 213.

Evans, C., 2005. Malnutrition in the elderly: A multifactorial failure to thrive. Permanente Journal, 9(3): 38 - 41.

Genccelep, H., S.F. Turker, M. Anil, B. Agar and S. Turhan, 2015. The effect of starch modification and concentration on steady state and dynamic rheology of meat emulsions. Food Hydrocolloids, 48: 135-148.

Karim, A.A., M.H. Norziah and C.C. Seow, 2000. Methods for the study of starch retrogradation - review. Food Chemistry, 71(1): 9- 36.

Nicosia, M.A., 2007. A planar finite element model of bolus containment in the oral cavity. Computers in Biology and Medicine, 37(10): 1472- 1478.

Richman, J.W., M.S. Ferraco and S.J. Davis, 1994. Chapter 1. Managing the dysphagia patient. Pureed foods with substance and style. Gaithersburg, MD: Aspen Publishers.

Steffe, J.F., 1996. Rheological methods in food process engineering. 2nd Edn., Michigan, U.S.A.: Freeman Press. East Lancing.

Tornberg, E., 2005. Effect of heat on meat proteins- implications on structure and quality of meat products. Meat Science, 70(3): 493- 508.

Wattanachant, S., M.S.K. Syed, H.D. Mat and R.R. Abd, 2002. Suitability of sago starch as a base for dual modification. Songklanakarin Journal of Science and Technology, 24(3): 431-438.

Wendin, K., S. Ekman, M. Bülow, O. Ekberg, D. Johansson, E. Rothenberg and M. Stading, 2010. Objective and quantitative definitions of modified food textures based on sensory and rheological methodology. Food and Nutrition Research, 54: 1-10.

Zargaraan, A., R. Rastmanesh, G. Fadavi, F. Zayeri and M.A. Mohammadifar, 2013. Rheological aspects of dysphagia- oriented food products: A mini review. Food Science and Human Wellness, 2(3-4): 173- 178.

Zhang, L. and S. Barbut, 2005. Effects of regular and modified starches on cooked pale, soft and exudative: Normal and dry, firm and dark breast meat batters. Poultry Science, 84(5): 789- 796.