RHEOLOGICAL, SENSORY AND SHELF LIFE STUDY OF TEXTURE-MODIFIED CHICKEN *RENDANG* FOR THE ELDERLY WITH DYSPHAGIA

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by

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LIST OF SYMBOLS

A	Values of storage modulus and loss modulus
a*	Redness
b (-)	Slopes of storage modulus and loss modulus
b*	Yellowness
cP	Centi Poise
D_T	D$ecimal\ reduction\ time\ at\ temperature$ 121.1 $°C$
K	Consistency index
K_{OC}	Casson yield stress
K_C	Consistency index
°C	Degree Celcius
η	Flow behaviour index
F_o	Time to destroy 90 % of Clostridium botulinum population at 121 °C and z is 10 °C
g	Gram
g/L	Gram per Liter
G′	Storage modulus
G″	Loss modulus
Hz	Hertz
L*	Lightness
MDA/kg	Malondialdehyde per kilogram
mg	milligram
mL	millilitre
MPa	Mega Pascal
N	Normality
Pa.s	Pascal-second

pH	A measure of the acidity (pH < 7) or alkalinity (pH > 7)
ppm	Parts per million
%	Percentage
rpm	Rotation per minute
s^{-1}	Per second
w/w	Weight per weight

LIST OF ABBREVIATIONS

ALEs	Advanced lipid peroxidation end-products
AOAC	Association of Official Agricultural Chemists
ANOVA	Analysis of Variance
BI	Browning index
CFR	Code of Federal Regulations
CFU	Colony forming units
CMC	Carboxymethyl cellulose gum
C.botulinum	*Clostridium botulinum*
CuFS	Cued Facial Scale
DNPH	2,4-dinitrophenylhydrazine
FDA	United States Food and Drug Administration
FEES	Fiber optic swallowing study
GI	Glycemic index
HCl	Hydrochloric acid
HI	Hydrolysis index
Hz	Hertz
IDDSI	International Dysphagia Diet Standardisation Initiative
LST	Line spread test
LVR	Linear viscoelastic range
MC	Modified corn starch
MDA	Malondialdehyde
MP	Myofibrillar protein
PPA	Porcine pancreatic alpha-amylase
S	Sago starch
SLP	Speech-Language Pathologists
T	Tapioca starch
TBA	Thiobarbituric acid
TBARs	Thiobarbituric acid reactive substances
TCA	Trichloroacetic acid
TMCR	Texture-modified chicken *rendang*
TVB-N	Total volatile basic nitrogen

UHT	Ultra high temperature
UV-vis	Ultraviolet-visible
VFSS	Videofluoroscopic swallow studies
WHO	World Health Organization
XG	Xanthan gum

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KAJIAN REOLOGI, SENSORI DAN JANGKA HAYAT RENDANG AYAM YANG TELAH DIUBAH SUAI TEKSTUR UNTUK WARGA TUA YANG MENGALAMI DISFAGIA

ABSTRAK

Kajian ini melibatkan analisis reologi, sensori dan jangka hayat rendang ayam yang telah diubah suai tekstur (TMCR) yang merupakan sebahagian daripada proses pembangunan bagi memperkenalkan makanan sedia dimakan untuk warga tua di Malaysia yang menghidapi disfagia. TMCR telah disediakan mengikut Tekstur C (puri halus) berdasarkan kepada standard negara Australia untuk makanan diubah suai tekstur. Bagi menambah baikkan konsistensi dan stabiliti TMCR, agen pemekat dalam bentuk jel kanji (10% w/v) dan larutan gam (5% w/v) seperti kanji jagung yang diubah suai (MC), kanji sagu (S), kanji ubi kayu (T), gam xantan (XG) dan gam karboksimetil selulosa (CMC) ditambah ke dalam TMCR pada lima jumlah berbeza (5, 10, 20, 30 dan 34 g). Untuk permulaan, ujian konsistensi menggunakan sudu dan pinggan telah dijalankan mengikut standard negara Australia dimana sampel mestilah mempunyai tahap kejelekitan yang mencukupi untuk mengekalkan bentuk di atas sudu apabila di kaut (tiada sebarang cecair yang meresap keluar daripada sampel apabila ianya diletakkan di atas pinggan). Daripada kesemua jumlah yang ditambah, TMCR yang mengandungi 30 g kanji pemekat dan 10, 20, dan 30 g gam pemekat didapati memenuhi kriteria ujian tersebut. Selanjutnya, sampel yang ditambah dengan 10, 20 dan 30 g agen pemekat telah di analisis secara reologi bagi menentukan jumlah tambahan yang optimum. Daripada ujian osilasi dan ujian ricihan mantap, jumlah optimum adalah didapati pada kadar penambahan 30 g, di mana TMCR menunjukkan kestabilan struktur yang tertinggi (dengan kata lain, nilai tertinggi untuk

kelikatkenyalan, kelikatan, sifat penipisan ricih, dan kejelekitan). Kestabilan struktur yang tertinggi itu terjadi disebabkan oleh kandungan zarah agen pemekat yang tinggi telah menghasilkan sistem yang dikemas secara padat, dengan ikatan yang kuat dalam kalangan zarah makanan tersebut. Seterusnya, kelikatan TMCR yang ditambah dengan 30 g agen pemekat telah dianalisis dengan kehadiran air liur tiruan. Diantara semua agen pemekat, didapati XG yang digabungkan dengan TMCR telah menghasilkan kestabilan struktur yang paling dikehendaki, dengan kesan terendah terhadap penambahan air liur tiruan. Ini disebabkan oleh ketegaran struktur seperti batang dan konformasi heliksnya yang menghasilkan rangkaian ikatan polimer yang sukar untuk diuraikan di dalam rumusan air liur tiruan. Dalam fasa kedua, kajian sensori yang melibatkan warga tua yang sihat dijalankan bagi menilai penerimaan TMCR yang ditambah dengan agen pemekat berbeza pada jumlah penambahan 30 g, kajian dari segi kemudahan menelan, penampilan keseluruhan, tekstur keseluruhan, niat untuk membeli, dan rasa sampel. Keputusan menunjukkan bahawa semua sampel mendapat penerimaan yang tinggi untuk kesemua atribut yang diuji. Tiada perbezaan signifikan di antara semua sampel di dalam bahagian *Cued Facial Scale*, kemungkinannya berpunca daripada penampilan rupa bentuk fizikal yang sama, disamping kemerosotan keupayaan fungsi sensori dalam kalangan warga tua. Selain itu, kesemua sampel yang ditambah agen pemekat didapati tidak meninggalkan sebarang sisa makanan selepas ditelan, disebabkan oleh tahap kejelekitan yang tinggi di antara partikel makanan yang dihasilkan oleh agen pemekat. Penambahan agen pemekat menunjukkan bahawa penyepaian mudah partikel makanan telah dihalang semasa dikonsumsi secara oral yang melibatkan ricihan diantara lidah dan lelangit dan pencampuran dengan air liur. Rasa kanji yang dikesan lebih dari 79% panelis ke atas kesemua sampel yang ditambah dengan agen pemekat bagaimanapun tidak mempengaruhi niat untuk membeli dan

juga penerimaan rasa terhadap produk yang dibangunkan, di mana masing-masing memperolehi lebih daripada 79% dan 85% tahap kesukaan. Ini menunjukkan bahawa panelis warga tua mempunyai tanggapan yang baik terhadap TMCR. Fasa terakhir merangkumi kajian kualiti jangka hayat dan kestabilan TMCR yang telah diproses sepanjang 6 bulan penyimpanan. Sepanjang tempoh simpanan, kedua-dua stabiliti dan kualiti sampel telah berkurangan dengan ketara, berlaku terutamanya disebabkan oleh pengoksidaan komponen makanan seperti pengoksidaan lipid dan protein. Walau bagaimanapun, TMCR telah didapati selamat untuk dimakan dengan tiada sebarang kehadiran bacteria aerob dan bukan aerob dan juga yis serta kulat, kesan dari proses retort disamping mengekalkan sifat reologi yang mudah serta selamat ditelan. Tambahan pula, nilai TBARs didapati berada di dalam lingkungan had boleh diterima iaitu (dibawah 1.5 mg MDA/kg) yang menunjukkan tahap ketengikkan yang rendah. Nilai TBARs yang rendah adalah disebabkan daripada kesan perlindungan oleh gam xanthan ke atas molekul-molekul lipid daripada terdedah secara langsung kepada agen pengoksidaan dan juga kesan penghambatan oleh rantaian sampingan gam xanthan (kumpulan bilangan piruvat yang bersebati dengan Fe^{2+} dan Fe^{3+}) sekaligus menghalang pembentukan radikal pengoksidaan. Secara amnya, penambahan gam xanthan dapat mengurangkan perubahan fizikal dan kimia yang mempengaruhi kedua-dua stabiliti dan kualiti sampel yang disimpan. Kesimpulannya, TMCR telah berjaya dibangunkan dengan menggunakan gam xanthan sebagai agen pemekat pada jumlah penambahan sebanyak 30 g dengan profil reologi yang sesuai dan ciri sensori yang boleh diterima agar ianya mudah dan selamat untuk dimakan oleh warga tua yang menghidapi disfagia.

RHEOLOGICAL, SENSORY, AND SHELF LIFE STUDY OF TEXTURE-MODIFIED CHICKEN *RENDANG* FOR THE ELDERLY WITH DYSPHAGIA

ABSTRACT

This study involves rheological, sensory, and shelf life analysis of texture-modified chicken *rendang* (TMCR) as part of the development process to introduce a ready-to-eat food for the elderly with dysphagia in Malaysia. TMCR was prepared according to Texture C (smooth pureed) as stated in the Australian standard for texture modified food. To improve consistency and stability of TMCR, food thickeners in the form of starch gel (10% w/v) and gum solution (5% w/v) such as modified corn starch (MC), sago starch (S), tapioca starch (T), xanthan gum (XG) and carboxymethyl cellulose gum (CMC) were incorporated into TMCR at five different amounts (5 g, 10 g, 20 g, 30 g and 34 g). Preliminarily, spoon and plate consistency tests were conducted following the Australian standard in which the sample should be cohesive enough to hold its shape on a spoon (when placed side by side, these consistencies would maintain their position without bleeding into one another). From all of the added amount, TMCR that contained 30 g starch gel and 10, 20 and 30 g gum solutions were seen to have fulfilled the criteria of the tests. Following this, sample that contained 10, 20, and 30 g of thickeners were further analyzed rheologically to determine the optimum amount of addition. From the oscillatory and the steady shear tests, the optimum amount was found to be at 30 g in which TMCR shown to have the highest structural stability (i.e. highest value of viscoelasticity, viscosity, shear-thinning property, and cohesivity). The highest structural stability was resulted from the higher content of thickener's particles had caused the system that is densely packed, with

strong interactions among the food particles. Following this, the viscosity of TMCR added with 30 g thickener was later analyzed with the presence of artificial saliva. Among all thickeners, XG shown to provide TMCR with the most desirable structural stability, the least affected by the artificial saliva. This was due to its rigid rodlike structure and its helical conformation which caused the entangled polymer chains difficult to be dispersed in the artificial saliva solution. In the second phase, a sensory study which consist of healthy elderly was conducted to evaluate the acceptability of TMCR added with different thickeners at 30 g addition, in terms of the ease of swallowing, overall appearance, overall texture, purchase intention, and flavour. Results showed that all samples were highly accepted for all attributes tested. The insignificant difference between all samples in the Cued Facial Scale part could be due to similar physical appearance as well as reduced sensory capability among the elderly. Besides, all thickened samples were found to be free from any food residues after swallowing, due to higher cohesion between food particles provided by the thickeners. Addition of thickeners shown to prevent easily disintegration of food particles during oral consumption which involved tongue and palate shear and mixing with saliva. Starchy taste perceived by more than 79% of the panellists in all thickened samples somehow did not affect purchase intention and flavour acceptance of the developed products, as both received more than 79% and 85 % likings respectively. This shows that the elderly panellists have a good impression on TMCR. The final phase involves shelf-life stability and quality study of the processed TMCR during 6 months' storage. Throughout storage duration, both stability and quality of the samples had reduced significantly, mainly due to the oxidation of food components such as lipid and protein oxidation. However, TMCR was found safe to be consumed with the absence of aerobic and anaerobic bacteria as well as yeast and mould due to the effect of retort

processing while maintaining easy and safe swallowing rheological properties. In addition, the TBARs value was found to be within the acceptable limit (under 1.5 mg MDA/kg) indicating low level of rancidity. The low TBARs value was resulted from the protective effect provided by XG on the lipid molecules from being directly exposed to the oxidizing agent and also due to the suppressing effect of XG side chains (pyruvate moieties chelates with Fe^{2+} and Fe^{3+}), thus hinders the formation of oxidizing radicals. Generally, the addition of XG was able to reduce physical and chemical changes which affects both quality and stability of the stored samples. In conclusion, TMCR was successfully developed by incorporating XG as thickening agent at 30 g addition with suitable rheological profiles and acceptable sensory properties for easy and safe consumption of the elderly with dysphagia.

CHAPTER 1

INTRODUCTION

1.1 Background

An increase in ageing population globally has led to various health-related issues for this particular segmented population. Besides the common age-related diseases, most elderly are prone to have reduced function in swallowing physiology, known as dysphagia (Aslam & Vaezi, 2013). The predominant complications of dysphagia include malnutrition and aspiration pneumonia which has a profound impact on the health of the patients and can be fatal if left untreated (Sura et al., 2012). Texture-modified food (TMF) has been used in many countries as a mean in managing patients with dysphagia (Cichero et al., 2013). TMF refers to any food that is texturally modified to provide a safe oral intake (Ullrich & Crichton, 2015). TMF is commonly prepared according to the standard for dysphagia diet modification available worldwide. Among the available standards are from the US, Australia, UK, and Japan, in which the degree of modifications and the descriptions on the texture modifications varies among each standard.

Basically, TMF can be categorized into several classifications based on the level of modification which ranged from the least (soft) to the most modified (puree). Amongst all classifications, puree is proven to be the most easily tolerated by dysphagic patients as evidenced by the fiberoptic endoscopic evaluation of swallowing (FEES), a method used in assessing the ability to swallow (Perlman et al., 2004). Based on the Australian standard for texture-modified food, puree texture should be smooth and lump free. Its consistency is similar to commercial pudding and should not be runny but may have grainy quality. These characteristics make chewing unnecessary for pureed food while providing a safe and easy swallow for those suffering from dysphagia. Numerous

studies have demonstrated its efficacy in slowing the rate of food bolus by providing both nerves and muscles a longer reflex response time to prepare for swallowing process (Mackley et al., 2013).

Currently, there are a few established companies which produce a range of commercial pureed products starting with the main course dishes to desserts that are available in the international market. These brands are the Simply Serve (Plymouth, Devon, England), Simply Puree (South Shield, Tyne and Wear, England), Thick-it (Muscatine, Iowa, USA), Thick & Easy (Austin, Texas, USA), Nutri (Yokkaichi, Mie, Japan). Similarly, studies on developing foods for dysphagia are also scanty. The types of pureed foods are the pureed salmon (Prabhu, 2018), pureed carrot and turkey (Ilhamto, 2012), pureed carrot (Sharma, 2015), and pureed green peas (Tobin, 2014).

In Malaysia, none of commercially prepared TMF products are available, which forces patients and caregivers to procure it from overseas which can be very costly. Therefore, TMFs are usually prepared individually at home, or by hospital and nursing home cooks. This practice can lead to inconsistencies of the quality and texture as the preparation method varies from one individual cook to another, due to the absence of a standardized food preparation procedure. Another issue that arises from the shortage of commercially available TMF products in Malaysian local market is in it's taste. Imported commercial TMF products are made for a different palette and may be unacceptable for local patients due to the difference in cultural background. Following to these issues, it is important to develop a TMF-based product that is suited to the local taste buds, that can also be sourced locally and sold at an affordable price. It is well known that any food that had been texturally modified would appear less appealing compared to normal textured food. In order to compensate the loss of its appealing, a stronger/intense flavoured food can be served to increase the appetite and to promote

salivation. Chicken *rendang* is famously known as a delicious and flavourful food to many people and undoubtedly very familiar among the elderly. Due to these advantages, chicken *rendang* was selected to be the flavour for TMF. In developing TMF, addition of thickeners is necessary to improve product's rheology and stability. However, their addition requires careful considerations as the type of thickener posses their own individual rheological characteristics resulted from their dissimilar structural properties which affects the food rheology. Similarly, the amount of thickener's added could also displayed different rheological results as higher amount leads to an increased number of particles in the food system (Razak et al., 2018). In determining the best thickener and the suitable amount of addition, this is when rheology plays a part to provide a comfortable and safe swallowing food for people suffering from dysphagia by characterizing the food behaviour during oral consumption (Brito-de la Fuente, Ekberg, & Gallegos, 2011; Seo & Yoo, 2013). There are several rheological methods and instruments that can be used to achieve this in which the choice of means and tools largely depends on types of samples and the purpose of the experiment (Rao, 2007).

Rheometer is used to determine the effect of different food compositions (such as thickener) when imposed under different conditions (e.g. oral and thermal processing, storage) on the rheological properties of the food product (Sharma, 2015; Zargaraan et al., 2013). Parameters such as viscoelasticity, viscosity, shear-thinning, as well as the cohesivity between food particles can be measured. These parameters are then used to characterize and measure the ease of swallowing of a particular TMF product (Nystrom et al., 2015).

During oral processing, food undergoes physical changes upon mixing with saliva, leading to an increased in fluidity. This condition possesses a risk to consumers as it increases the velocity of food during swallowing. Changes during oral processing

conditions, particularly during reaction with saliva could be monitored using an *in-vitro* method, followed with rheological analysis.

On the other hand, sensory analysis serves to study the acceptability of a newly developed TMF to a targeted group of consumer. Limitation of this study is on the selection of the right target group which is the elderly with dysphagia since they are more vulnerable to get choke or aspirate due to their frailty as well as presence of other health related conditions. Due to the extremely high risk, healthy elderly is usually chosen to be the participants as substitution to those with dysphagia (Ilhamto, 2012). During sensory analysis, the acceptability of the tested product is evaluated based on the participant's degree of liking. Elderly participants who generally tend to have reduced function in visual, communication, and or cognitive ability, a visual scale called the Cued Facial Scale (CuFS) can be presented to represent the degree of liking (Pelletier & Lawless, 2003). The CuFS consist of a set of emotional facial expression with a range of numbers has been proven to easily grab the attention of participants (Sawada & Sato, 2015).

A shelf life study is an integral part in determining the ability of any food to maintain its desired quality and stability in a specified storage condition and time. In conducting a shelf life study, the food must first undergo appropriate processing (i.e. thermal, high pressure, radiation), followed by packing and storing, of which the final product must be in a state that is ready for retail and consumption (Steele, 2004). A product's quality can be assessed experimentally based on its changes in pH, colour, nutrient content, and chemical compositions that are controlled by biochemical reactions (oxidation, Maillard reactions, enzyme activity). A microbiological profile is another important quality attribute in determining spoilage and acceptability. Typical tests such as the aerobic plate count, the anaerobic plate count and the yeast and mould

count serve as basic screenings in determining product's safety and also the efficacy of the sterilization process. For stability evaluation, it can be measured based on the form of physical changes (protein aggregation, coalescence, sedimentation) (Valero, Carrasco, & García-Gimeno, 2012).

1.2 Objectives

The main objective of this current study was to develop texture-modified chicken *rendang* (TMCR) that comply to the Texture C (Smooth pureed) from the Australian standard for texture-modified food. The specific objectives are as follows:

1) To prepare TMCR according to the Australian standard of Texture C with the addition of different types of thickeners (sago starch, tapioca starch, modified corn starch, xanthan gum, and carboxymethyl cellulose gum) at different amount of addition (5, 10, 20, 10, 30 and 34 g) and to select which amount that provides the characteristic of Texture C by conducting the spoon test and the plate consistency test.
2) To conduct rheological analysis on the selected thickener's addition and to study the effect of artificial saliva on the rheological properties of the optimized addition of thickeners.
3) To perform sensory analysis on the optimized addition of thickeners among the elderly people.
4) To study the shelf life stability and quality of TMCR added with the selected thickener.

PHASE 1

A. Optimization of TMCR Formulation

Thickeners : Sago starch, tapioca starch, modified corn starch, xanthan gum, carboxymethyl cellulose gum.

Added amount: 5 g, 10 g, 20 g, 30 g, 34 g.

- **Spoon and Plate Consistency tests**
- Hold its shape on a spoon.
- No bleeding when placed on a plate.

- **Rheological analysis (Oscillatory and Flow tests)**
- With and without the addition of the artificial saliva.
- Samples (Selected amount of additions for each thickener)

↓

PHASE 2

Product acceptability study (Sensory analysis)

Locations : Elderly home (Darul Hanan Pulau Pinang)
Participants : Healthy elderly (60 years and above)
Samples : Optimized formulation of each thickener (from Phase 1)
Test : Hedonic test
Attributes : Ease of swallowing, overall appearance, overall texture, purchase intention, flavour, residue after swallow, after taste.

↓

PHASE 3

Optimization of thickener upon retort processing

Sample **(**Optimized formulation of each thickener - from Phase 1)

- Rheological analysis (Flow test)

Shelf Life Stability and Quality Study

Sample (Optimized thickener from retort processing)

A. Stability study

- Rheological analysis (Oscillatory and Flow tests)

B. Quality study

- Microbiological tests
- Proximate analysis
- Thiobarbituric acid reactive substances test
- Colour
- pH

Figure 1.1 Flowchart on the overall research activities

CHAPTER 2

LITERATURE REVIEW

2.1 Aging Population

2.1.1 An Overview

Aging population refers to a shift in the age distribution (i.e. age structure) of a population towards older ages. It is measured by the growing percentage of elderly people that has retired. Definition of elderly varies from country to country. According to the World Assembly on Ageing organized by the United Nation back in 1982, people who age 60 years and above were regarded as the elderly. Malaysian government has followed this delimitation in planning for the local elderly (Chen, Ngoh, & Harith, 2012). World Health Organization (WHO) has projected that by 2050, the estimated number of people aged 60 years and above will be approximately 2 billion worldwide (World Health Organization, 2012). In 2018, a survey conducted by Department of Statistics Malaysia, reported that the number of elderly was 3.24 million, or around 10% out of 32.4 million of Malaysian population. It is expected to reach up to 5.6 million by 2035 ("Senior citizens", 2016; Department of Statistics Malaysia, 2018). This global phenomenon is contributed by the decrease of fertility rate as well as the significant increase in life expectancy (Keeratipongpaiboon, 2012). Aging population produces more dependent individuals than the working individuals. In line with the growing number of elderly population, many health and nutritional problems are also on the rise (Chen, Ngoh, & Harith, 2012).

2.1.2 Challenges

The Asian countries are projected to contribute about 60% of the world's elderly population in near future with 365 million in 2017 to over 520 million in 2027 (Allaudeen, 2017) in which Japan has the biggest proportion of about 17% (East-West Center, 2008). Comparing to the elderly population in the developed country like Japan (35.88 million out of 126.34 million population) ("Elderly citizen", 2019) and our highly populated neighbouring country Indonesia (23.4 million out of 260.87 million population) (Cahya, 2018), Malaysian proportion is considered small (3.24 million out of 32.4 million population) (Department of Statistics Malaysia, 2018). Somehow, concerns on health issues associated with this group is still alarming (Chen, Ngoh & Harith, 2012). Our health declines as we age. Higher occurrences of both physical and mental disabilities make the health care services for elderly becomes more complex in terms of technological, fiscal, and ethical perspectives compared to younger age group (National Research Council (US) Panel on a Research Agenda and New Data for an Aging World, 2001). In the coming years, it is expected that there will be higher demand in the health care system. This situation will cause great implications on the country's economy in which the government needs to think about improving financial sustainability of the pensioner, as well as allocating enough funds and resources to the health care system (United Nations, Department of Economic and Social Affairs, & Population Division, 2015). Between the year of 2010 and 2030, the proportion of workers are projected to increase tremendously as compared to retirees (UK Essays, November 2018). Total number of retirees are expected to be increased, hence with less number of tax payers from the working-age group, it will be hard for the government to enact policies proactively to cater the needs of the elderly group (United Nations et al., 2015).

2.2 Elderly with dysphagia

Dysphagia is a medical term used for difficulty or inability to swallow liquid, food, or medication (Whelan, 2001). In general, dysphagia resulted from the diverse functional and/or structural deficits in the oral cavity, pharynx, larynx or oesophagus (Matsuo & Palmer, 2008). However, in elderly, the high occurrences (14% to 35% in community-dwelling older adults and 51% in older adults in long-term care institutions) are mostly due to reduced functions of physiology such as loss of teeth and oral motor dysfunction (O'Rourke, 2014; Sura et al., 2012). Aging causes muscle mass and the elasticity of the connective tissue to declined and weaken the muscle (Fucile et al., 1998). Changes in the motor skills, gestures and, coordination leads to a slow reflex action (Kendall & Leonard, 2001) particularly in the area of laryngopharynx (Shin et al., 2016), therefore swallowing process tends to take longer time for elderly people (Hanson, O'Leary, & Smith, 2012). In addition, the reduced quantity of oral saliva also contributes to the swallowing difficulty among this group of people (Wendin et al., 2010). Besides, the age-related diseases also affect the swallowing mechanism which leads to dysphagia (Aslam & Vaezi, 2013). Examples of these common age-related diseases are stroke, neurodegenerative diseases (Alzheimer and Parkinson), cancers and metabolic disease (Armanios et al., 2015; Cabre et al., 2010). Signs of dysphagia can be observed from a person who leaked food or fluids during eating and drinking, coughing or choking during or after eating or drinking, food stuck in the oesophagus, acid reflux and pain during swallowing (Flynn et al., 2014).

Swallowing is a complex process that functions to transfer food and liquid through the oesophagus which acts as a passageway from the mouth to the stomach (Smithard, 2016). Swallowing happens either voluntary or involuntarily. The term complex refers to the coordinated action of nerves and muscles in the area of head and

neck. Swallowing activities occurs in three stages; oral, pharyngeal and oesophageal phase as depicted in Figure 2.1. In the oral phase, the food is chewed and moistened with saliva. When a bolus is formed, it will be transported to the oropharynx. During the pharyngeal phase, the food is being propelled into the oesophagus while at the same time the epiglottis closed the entrance of the airway. Finally, the oesophageal stage, the bolus passes down the oesophagus into the stomach with the help of peristaltic action as well as with the influenced of gravity (Matsuo & Palmer, 2008). Dysphagia can manifest at any of these three phases. For more understanding of the swallowing process, please refer to the animated video from the You Tube address, https://www.youtube.com/watch?v=YQm5RCz9Pxc by Alila Medical Media (2014).

Generally, properties of food during oral consumption depends on the types of the food consumed. For examples, in the oral and pharyngeal phases, thickened pureed food tend to form aggregated food bolus with some of the portion were dissolved in saliva, having both liquid and solid like phases (Matsuo & Palmer, 2009). Prior to swallowing, this two-phases food bolus was later pushed by the tongue and later, through contraction of the pharyngeal wall into the oesophageal phase and continues moving further down into the stomach. During this time, the leading edge of the food bolus (liquid component) would precede solid component. It occurs even before swallow initiation (Matsuo & Palmer, 2009; Saitoh et al., 2007).

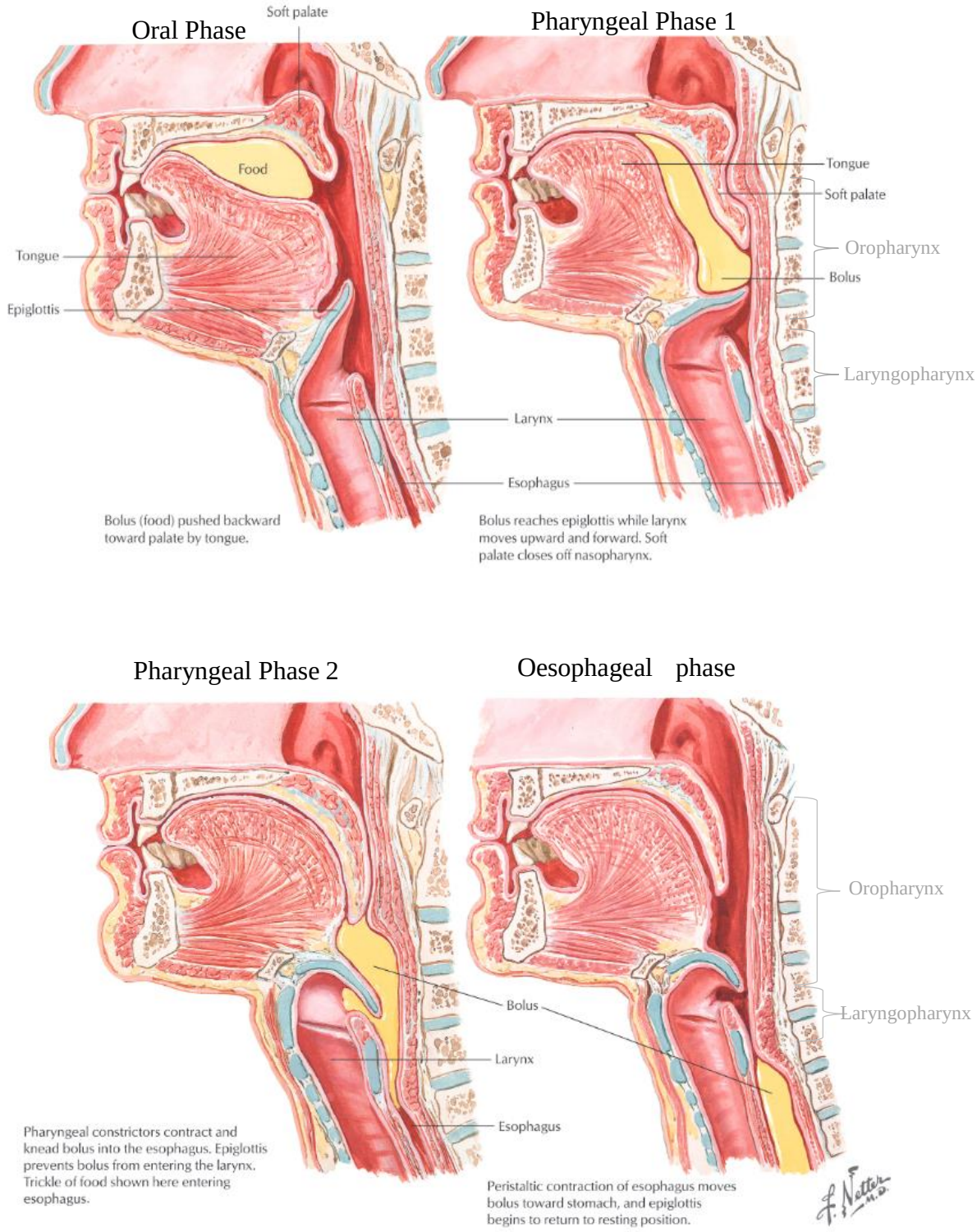

Figure 2.1 The 3 phases of swallowing

(Garcia & Chambers, 2010)

2.2.1 Prevalence of Dysphagia

The exact figure on the total number of individuals with dysphagia is unclear (Sura et al., 2012). Generally, the available statistics of reported dysphagia cases across countries are related to specific illnesses or conditions. For example, in Australia, 50% of stroke patients are among the sufferers. In the United Kingdom, it affects 60% of patients who were under acute care (Smithard, Smeeton, Wolfe, 2007). In the Asia region, around 52.7% of reported cases came from the South Korean's nursing home residents (Park et al., 2013), and in Taiwan, the incidence rate, was reported to be 51%, consisting patients in the long term care facilities, with and without tube feeding (Lin et al., 2002).

As for Malaysia, the established number of cases were reported to be from the area of West Coast peninsular, involving patients with stroke, supraglottic carcinoma (a type of head and neck cancer), or gastro-oesophageal reflux disease (GERD). Back in 1992, 33% of supraglottic carcinoma patients had been reported suffering from dysphagia (Sani, Said & Lokman, 1992), whereas in 2005, 7.3% of GERD patients were affected (Mahadeva et al., 2005). The latest reported study was in 2006, in which the prevalence was about 65.9% involving acute ischemic stroke patients. Undeniably, there are much more cases that go unreported, due to the fact that dysphagia has many possible causes, and the etiologies are sometimes hard to confirm (Anderson & Arnold, 2013; McGinnis et al., 2019). Besides, dysphagia can be either transient or permanent in which the cases can occur at a different level; mild, moderate or severe (Roden & Altman, 2013). Moreover, some individuals are underdiagnosed, while others did not even received treatment for dysphagia due to lack of awareness and/or understanding among the sufferers as well as among the health professionals in the hospitals regarding

the symptoms and treatments (National Foundation of Swallowing Disorders, n.d.; Xinyi, Ahmad & Vesualingam, 2018).

Conservatives estimation given by a team of the IDDSI experts suggested that 8% of the global population is experiencing dysphagia, and based on recorded data by the Population Reference Bureau, the number had reached to a staggering amount of 99 million people in the developed countries (Cichero et al., 2013). The growing number of dysphagia sufferers with each increasing year (The National Foundation of Swallowing Disorders, n.d), particularly among the elderly group (Aslam & Vaezi, 2013; Baijens et al., 2016; Bhattacharyya, 2014), has raised the demand for more research conducted in this area. This alarming issues cannot be taken lightly since dysphagia affects individual's quality of life, particularly to the elderly group, as they are more susceptible to suffer from serious health complications as discussed in the following section.

2.2.2 Consequences of Dysphagia

Individuals with dysphagia usually encountered a problem with aspiration where food or liquid entered the lungs by accident, thus causing serious health problem called pneumonia (Matsuo & Palmer, 2008). Aspiration is the misdirection of oropharyngeal or gastric contents into the larynx and lower respiratory tract (Marik & Kaplan, 2003). Failure in the airway protection will easily cause aspiration which could happen before, during, and even after swallowing (Matsuo & Palmer, 2008). Choking is another situation that is commonly faced by individuals with poor dentition or weak tongue strength where they are unable to properly masticate solid foods to form a bolus

(National Institute on Deafness and Other Communication Disorders, 2010) which causes the food to be stucked in the trachea (Queensland Government, 2019).

Apart from aspiration and choking, dysphagia sufferers can face other health complications such as dehydration and malnutrition that can diminish their quality of life (Hickson, 2006). Among all, malnutrition is always related to be the cause of frailty among the elderly due to reduced food intake (Morante et al., 2019; Sura et al., 2012). Malnutrition (i.e. undernutrition) can be defined as faulty or inadequate nutritional status in which can be characterized by insufficient dietary intake, poor appetite, muscle wasting and weight loss (Chen, Schilling, & Lyder, 2001). According to Morley (2012), generally, malnutrition refers to either protein-energy wasting or individual nutrient deficiencies. In the case of an older person, it is often referred to as "protein-energy malnutrition". Malnutrition can be detrimental to health in which the immune system is compromised, causing an increased risk of infections which further leads to a life-threatening situation (Hudson, Daubert, & Mills, 2000).

Malaysian elderly is vulnerable to malnutrition (Visvanathan, 2003). Factors such as economic and social status are the main contributors as most of them live in poverty, lonely, and comes from rural villages (Visvanathan, et al., 2005). Based on their high risk in getting malnourished and its serious consequences, therefore, an intervention using a protein-based diet associated with an impaired swallowing should be introduced to reduce the problem (Cichero, 2018).

2.2.3 Management of Dysphagia through Diet Modification

Management for dysphagia usually consist of the assessment as well as the intervention of the problem by Speech-Language Pathologists (SLP) and health

professionals (such as radiologist, neurologist, otolaryngologist, gastroenterologist, oncologist, physiatrist, and dietitian) (Cook & Kahrilas, 1999; Xinyi, Ahmad, & Vesualingam, 2018). The reasons behind this multidisciplinary approach are due to the complexity of symptoms (severe, stable or continuous neurological disorder) and the specificity of the underlying diseases or causes (side effect of medication, syphilis, Wilson's disease, connective tissue disease, Parkinson's disease, cleft palate and many other) in which most of it presents clear neurological disorders (Cook & Kahrilas, 1999; Farneti & Consolmagno, 2007).

Before going for examination by the SLP to determine the extent of the disorder, medical diagnosis would be performed by the general practitioner and subsequently, a referral then was made. During the assessment, the SLP will evaluate the patient using instrumental assessment tools such as ultrasound, endoscopy, manometry and videofluoroscopy (Martino et al., 2013). The evaluation results will be proceeded with feeding recommendations which includes an appropriate level of diet modification, amount of intake in a swallow, head and body position during intake, other helpful techniques, and swallowing exercises (Erlichman, 1989). On top of that, other measures need to be taken to avoid swallowing problem from getting worse such as their medication reviewed (some drugs are known to cause dry mouth and drowsiness), dental check for any infection, and for those with cognitive impairment, feeding position also needed to be checked (Smithard, 2016).

Basically, there are three methods in managing dysphagia; behavioural, medical and surgical. Diet modification, which fall under behavioural method is fundamental, and the easiest way to apply in dysphagia management (Logemann, 2007). This method allows an immediate swallowing efficiency and safety, instead of treating the swallowing disability (CASLPO, 2007; Ney, Weiss, Kind, & Robbins, 2009). For

individuals who are able to be fed orally, the objective of diet modification is to attain safe swallowing while supplying adequate nutritional and fluid intake. Safe swallowing refers to the absence of aspiration, choking as well as no food residues either in the mouth or between the pharynx and oesophagus (Kim, 2007). Diet modification is primarily a necessity rather than choice. This makes it a popular intervention to improve the safety of swallowing and to maintain the patient's nutritional needs orally (Dietitians Association of Australia & Speech Pathology Association of Australia Limited, 2007; Flynn et al., 2014).

2.2.3(a) Texture-Modified Food (TMF)

Diet modification can be divided into 2 categories; 1) thickened fluid and 2) texture-modified food (TMF). For thickened fluid, thickener is added to change the fluid viscosity so that the process of swallowing will be slower, hence reducing or eliminating the risk of aspiration (Dietitians Association of Australia Speech Pathology Association of Australia Limited, 2007). Meanwhile, TMF is defined as the normal texture food that has been physically modified in which thickener is usually incorporated to improve its texture and consistency, so that it requires less chewing and manipulation in the oral cavity (Penman & Thomson, 1998). Normal texture food is sometimes difficult to chew and swallow among the elderly people who have weak muscle strength. Thus, modification of the food texture, would certainly ease their trouble consuming the food. Besides, TMF also enables the orally prepared food to maintain as a cohesive mass during swallowing, avoiding unwelcome situations from occurring such as aspiration or choking (Ney et al., 2009). A study done by Wendin et al. (2010) have shown that the elderly from nursing homes tend to have higher food intake when served with TMF.

There are many established guidelines to prepare TMF; however, the levels of modifications vary from one country to another. In general, TMF texture ranges from the least modified (soft) to the most modified (puree) (Cichero et al., 2013).

The level of texture modifications is based on the individual's swallowing capability which requires the person's medical investigation (Wendin et al., 2010), re-evaluation, as well as an adjustment from time to time (Garcia & Chambers, 2010). Among all level of texture modifications, puree was found to be easily tolerated by those with dysphagia, as evidenced by the Fiberoptic Endoscopic Evaluation of Swallowing (FEES) analysis (Perlman et al., 2004). The optimal texture for pureed food shall be moist and semisolid, hence a cohesive bolus can be formed in the mouth (Dahl, Whiting, & Tyler, 2003). Optimal texture of pureed food can be obtained by incorporating hydrocolloids such as starch and gum to modulate the flow of the food bolus by decreasing the speed that flows down the pharynx (Funami, et al., 2012). In addition, hydrocolloids provide desirable consistency and cohesion to the pureed food while improving its water holding, shear thinning, as well as stabilizing its structure (Funami, 2011).

Improvement in both consistency and cohesivity of pureed food when added with hydrocolloid as a continuous medium are due to its fillers effect that occupies voids between particles. In the absence of hydrocolloids, the suspended particles are in a mobile state. Once added with hydrocolloids, the food system will have an increase in packing fraction thus creating interactions between hydrocolloids molecules with the suspended particles. This automatically leads to the reduction in the mobility of moving particles, providing higher consistency as well as cohesivity (Mongia & Ziegler, 2000; Tobin, 2014).

2.2.3(b) The use of starch and gums as food thickener

Starch and gums are examples of hydrocolloids commonly added in dysphagia food products as thickeners (Vallons, et al., 2015; Vilardell et al., 2016). Addition of thickeners can enhance safe swallow by improving viscosity and cohesivity between food particles (Tashiro, et al., 2010). Based on this reason, many clinicians recommend the use of thickeners in food during rehabilitation of individuals with dysphagia (Hanson et al., 2012). There are commercial thickeners marketed under different brand names. Some of the examples are "Thicken up" (modified corn starch), "Thick and Easy" (modified corn starch and maltodextrin), "Thick and Clear" (cellulose gum and maltodextrin), and "Simply Thick" (xanthan gum) (Balaghi, 2015). These commercial thickeners posesses distinct functional properties, as well as different therapeutic effects and are marketed to provide choices for individual preference (Macqueen, et al., 2003; Rofes, et al., 2014; Saha & Bhattacharya, 2010). Based on a previous study by Adeleye and Rachal (2007), dissimilar rheological properties were seen with the same type of thickener when added into different types of food matrices. According to Cho, Yoo, and Yoo (2012), the reason for these varying properties was mainly due to the interactions between thickener's macromolecules with the food components. Because of this, studying the efficacy of different types of thickeners in food products for easy and safe swallowing is therefore very important to avoid jeopardizing patient's health.

2.2.3(b)i Starch

Starch is one of the most widely used thickener in pureed food. Its popularity is due to its thickening ability, shear thinning behaviour, acceptable taste, lower price as well as its wide availability (Acton, 2013).

Basically, starch contains two types of polysaccharides (amylose and amylopectin) (Figure 2.2) (Azmi, Malek, & Puad, 2017). Amylose is a linear chain polymer that consist of alpha (1,4) linked glucopyranose units while amylopectin is an extensive branched polymer via alpha (1,6) linkages (Sharma, et al., 2017). The size of starch granules ranges between 2-100 µm depending on different sources (Sharma, 2015). Granules swelling marks dissimilar properties to the starch according to their source (examples: sago, tapioca, corn, rice, wheat) as well as their amylose content (Mandala, 2012).

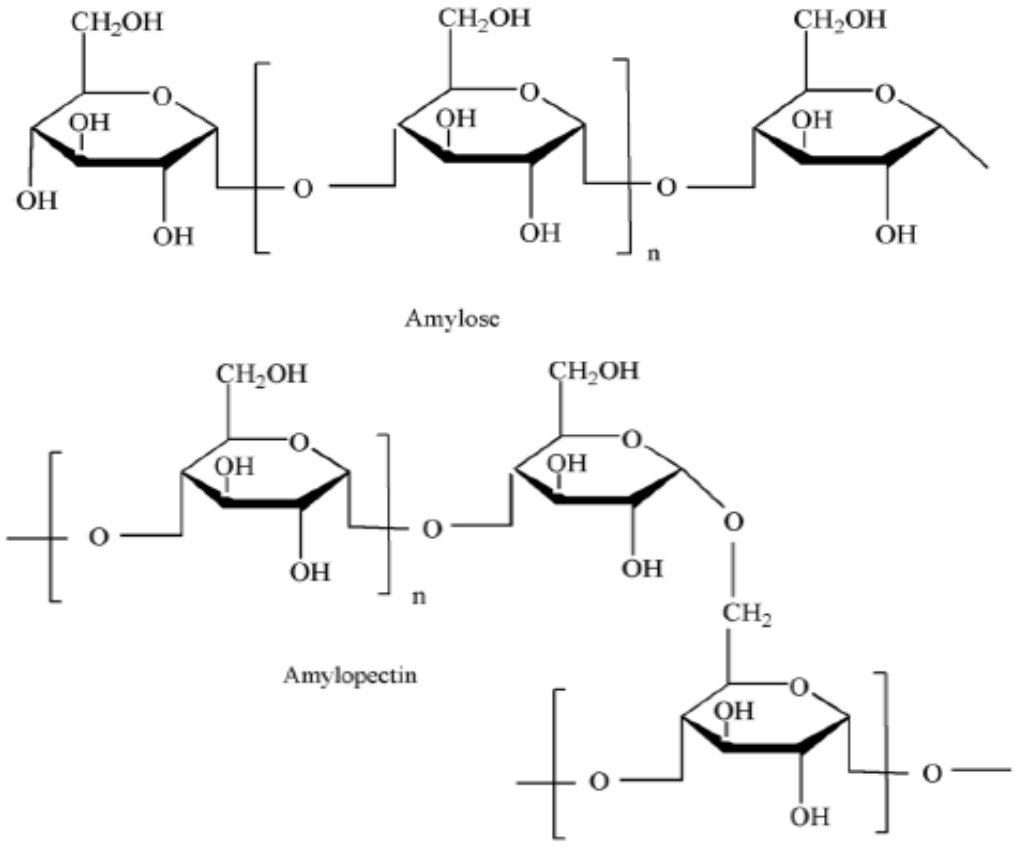

Figure 2.2 Structure of amylose and amylopectin in starch

(Tester, Karkalas, & Qi, 2004)

Meanwhile, commercial thickeners used for individuals with dysphagia are normally made of modified corn starch (McCallum, 2011). Corn starch becomes popular due to its wide availability and normally sold at a cheaper price (Basilio-Cortés et al., 2019). For dysphagia purposes, corn starch was normally modified to achieve certain properties such as the ability to thicken food without heating, with acceptable rheological (improved viscosity and stability) and sensory (colourless and flavourless) properties. The properties of modified starch would vary according to the types of modifications involved. For this type of commercial thickener (modified corn starch), the modification process might have been carried out through physical means such as the pregelatinization process. It is done by gelatinizing the starch, followed by drying the starch suspension (Lefnaoui & Moulai-Mostefa, 2015; Wang et al., 2019). This process produces starch with cold water solubility, higher viscosity, moisture sorption and swelling properties as compared to its native counterpart. These improved properties are caused by the leakage of amylose during the pregelatinization process, which facilitates the arrangement of starch molecules to form high strength gel network structure (Lefnaoui & Moulai-Mostefa, 2015). Upon the addition of modified corn starch into TMF, the food's internal structure would then have a coherent property, preventing fractional breakup during swallowing (Nishinari et al., 2019).

Research on the effect of modified corn starch on TMF is only limited to fruit and vegetable based (Stahlman et al. 2001; Ilhamto ,2012). Stahlman et al., (2001), studied on the effect of modified corn starch on pureed peach. The sensory study revealed that the peach and sweet flavour were diminished, however, a starchy taste was detected which leads to the low liking of the sample. Meanwhile, in another sensory study of pureed carrot, the sample was perceived to be more slippery and firmer in texture, with shinier and smoother in appearance compared to those added with rice

cereal and skim milk, as evaluated by trained sensory panellists (n=10). An acceptability study of the samples was further conducted among the regular consumers of pureed food (n=7) from the Elizabeth-Bruyere Hospital (Ottawa, Ontario, Canada) which then revealed no significant difference between modified corn starch thickened pureed carrot with the commercial pureed carrot. The author concluded that the prepared in-house pureed carrot was well liked as its commercial counterpart (Ilhamto, 2012). Insufficient study on meat based TMF could be due to the complexity of the food system which makes the analysis more complicated due to the combined effects of protein and/or lipids.

The fact that modified corn starch has long been used as dysphagia thickener is widely recognized (Garcia & Chambers, 2019; Ilhamto, 2012; Moret-Tatay et al., 2015; Payne et al., 2012). However, exploration on native starch such as sago and tapioca as an alternative thickener is rather compelling since both starch are widely available locally and sold at lower price (Karim et al., 2008; Pongsawatmanit, Temsiripong, & Suwonsichon, 2007). In addition, sago and tapioca starch prove to have improved physical and sensory properties when added in ground meat products (beef and chicken patties) and fish crackers (*keropok lekor*) (Chatterjee et al., 2018; Nur Liyana, Nor-Khaizura, & Ismail-Fitry, 2019). Karim et al., 2008; Pongsawatmanit, Temsiripong, & Suwonsichon, 2007).

Contrary to the modified starch, native starch requires heating to form viscous, cohesive and sticky pastes which later turn to gel upon cooling. Structurally, native starch gel is easily deformed when sheared, more susceptible to decomposition at high temperature, plus high tendency to undergo retrogradation and syneresis (Yousif, Gadallah, Sorour, 2012). Although native starch has some drawbacks, a heterogeneous system like TMCR which consist of other ingredients such as protein and lipid are able

to form complexes with carbohydrate molecules can ameliorate the said shortcomings properties. Hence, this present study aimed to investigate the possibility of using native starch to improve the rheology and sensory properties, as well as to prolong the shelf life of TMCR.

Therefore, the potential of using native sago and tapioca starch as thickener in TMF shall be explored.

2.2.3(b)ii Gums

Gums are the second most frequently used thickener after starch (Cichero, 2013). Rheologically, gums are more structurally stable than starch as gums are more viscous and require less amount to provide similar viscosity to starch (Saha & Bhattacharya, 2010). Moreover, gums have higher shear thinning property, providing greater extensibility thus allowing easier swallowing. Gums are also resistant towards enzymatic digestion, providing rheological stability by preventing disintegration of food particles that can lead to aspiration (Nishinari et al., 2019; Leonard et al., 2014). In processed meat, gums are used as a fat replacer that provides a lubricant mouth feel similar to the sensory perception of fat (McArdle, Hamill, & Kerry, 2011).

There are a wide variety of gums available for thickening purposes. Among all gums, xanthan and carboxymethyl cellulose have been formerly used in dysphagia diets (Sharma et al., 2017). Both are anionic polymer due to the presence of carboxyl groups on their side chains (BeMiller, 2008; Milani & Maleki, 2012). Effects of both xanthan gum and carboxymethyl cellulose gum when added into drinks and foods has been conducted previously, by looking at the viscoelasticity, viscosity, and also sensory measurements (Lopez et al., 2018; Ong, 2017; Sharma et al., 2017; Tashiro et al., 2010). Rheologically, both gums are quite similar except for their shear thinning behaviour in

which xanthan gum was found to be higher than carboxymethyl cellulose gum (Lopez et al., 2018; Tashiro et al., 2010). The high shear thinning behaviour of xanthan gum was further confirmed through sensory analysis based on the feeling of slippery and easier oral manipulation (Ong, Steele, & Duizer, 2018), while in another study, CMC was perceived to be greasy or oily attributed to the low degree of shear thinning (Lopez et al., 2018).

Aside from the rheological and sensory effects of gums, there are concerns on the bioavailability of drugs when taken with thickened food as the elderly often requires medication especially those who suffers chronic disease with life-long treatment (Jose, 2012). Issues regarding the delivery of drug in the right amount as well as at the right time to the targeted body parts need considerations to cure the disease. Certain gums are digested neither in the stomach nor in the small intestine (Ramasamy et al., 2011). During the digestive process, the drugs were shielded by the gums from being expose to the environment of the stomach and small intestine. Upon reaching the colon, the gums undergo assimilation by the colonic microflora (*Bacteroides*, *Bifidobacteria*, *Eubacteria*, *Clostridia*, *Enterococci*, *Enterobacteria*,), degradation by enzymes (β-glucuronidase, β-xylosidase, α-arabinosidase, β-galactosidase, nitroreductase, azoreductase, deaminase and urea dehydroxylase) and/or breakdown of the polymeric backbone caused by the high pressure and force induced by the peristaltic wave. These colonic conditions cause gum's molecular weight to be reduced, resulting to the loss of its mechanical strength (structural stability) which makes the gum unable to shield the drug, leading to its' release (Sinha & Kumria, 2001).

2.2.3(c) International Standards for categorizing TMF

There are many international standards established and used to categorize TMF. All of the available standards are depicted in Table 2.1. Despite the fact that there are many standards accessible throughout the world, the ambiguities in the names provided, inconsistencies in the degree of modifications as well as too many descriptions of each modified texture have created confusion and misinterpretations among the consumers as well as the professional groups. The confusions can compromise patient safety and have been acknowledged by the coroners as a contributing factor for the majority of death among the residents of the South Australian nursing home (Dietitians Association of Australia & Speech Pathology Association of Australia Limited, 2007).