DEVELOPMENT OF HYDROCOLLOIDS-COATED NOODLES FOR ENHANCED SALT RELEASE IN THE MOUTH

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DEVELOPMENT OF HYDROCOLLOIDS-COATED NOODLES FOR ENHANCED SALT RELEASE IN THE MOUTH

by

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LIST OF SYMBOLS AND ABBREVIATIONS

°C	Degree Celsius
ANOVA	Analysis of Variance
Cl^-	Chloride ion
DALYs	disability-adjusted life-years
FAAS	Flame Atomic Absorption Instrument
g	gram
GI	Glycemic index
GRAS	Generally recognizes as safe
h	Hour
HC	Hylon-coated
mL	Mililiter
MEC	Multiple Extrusion Cell
Na^+	Sodium ion
NaCl	Sodium Chloride
RS	Resistant starch
RS2	Resistant starch type 2
SEM	Scanning electron microscope
SC	Semperfresh-coated
TPA	Texture Profile Analysis
Work 1st	The amount of work done to breakdown the intact noodle during the first compression
YAN	Yellow Alkaline noodles
µS/cm	Micro siemens per centimetre
a*	Redness
b*	Yellowness
L*	Lightness
w_1	Contributions to the loss of energies per extrusion
w_{inf}	The work per extrusion after a large (infinite) number of extrusions
n_1	The decay rate of the work per extrusion with an increasing number of extrusions

PEMBANGUNAN MI TERSALUT-HIDROKOLOID UNTUK PELEPASAN GARAM YANG DIPERTINGKATKAN DALAM MULUT

ABSTRAK

Mi kuning (YAN) dengan kandungan garam yang rendah mempunyai sifat kekuatan tekstur dan mekanikal yang rendah. Akibatnya, YAN mudah pecah dalam struktur keseluruhannya apabila dimasak, iaitu menjadi lembut, lembik dan hancur kepada kepingan yang lebih kecil. Di samping kemunduran besar ini, kandungan garam yang rendah dalam YAN menjejaskan rasa dan persepsi garam oleh pengguna. Tambahan pula, YAN komersial mempunyai jangka hayat yang sangat singkat (sehingga 2 hari), walaupun di bawah simpanan peti sejuk. Kajian ini bertujuan untuk membangunkan YAN tanpa garam bersalut dengan penggunaan kanji jagung amilosa tinggi HylonVII™ (HC) atau campuran ester sukrosa asid lemak dan selulosa karboksimetil Semperfresh™ (SC). Mi dihipotesiskan mempunyai jangka, sifat tekstur, mekanikal dan deria hayat yang sama (atau lebih baik) serta mampu meningkatkan pembebasan garam dalam mulut daripada YAN. Sifat memasak dan mekanikal mi yang disalut dengan HC (10, 15, dan 20%) atau SC (2.5, 5, dan 7.5%) yang mengandungi julat garam pada 0 (Na0), 5 (Na5), 10 (Na10) dan 15% (w/v) (Na15) telah disiasat pada peringkat awal. Keputusan menunjukkan bahawa apabila aras garam meningkat, masa memasak dan kehilangan masak mi berkurang. Kedua-dua jenis salutan dan kepekatan garam pada 10% menunjukkan kekuatan tegangan dan keanjalan mi yang lebih baik. Oleh itu, kandungan HC15, SC5 dan natrium tambahan telah dipilih untuk analisis seterusnya. Kesan salutan terdiri daripada 15% HC dan 5% SC yang mengandungi pelbagai kepekatan garam (0, 10, 20, dan 30%) telah disiasat untuk sifat tekstur, mekanikal, memasak dan deria mi dalam Fasa 1. Kandungan garam

yang meningkat dalam salutan meningkatkan kandungan natrium dalam mi mentah dan mi masak bersama-sama dengan lebih banyak garam yang dibebaskan ke dalam air masak. Ia juga mengurangkan ($P < 0.05$) masa memasak dan kehilangan memasak mi dengan ketara. Kedua-dua jenis salutan dan kepekatan garam tidak mempengaruhi ($P > 0.05$) nilai pH, *CIE* a* (kemerahan) dan b*(kekuningan) mi. Namun begitu, aras garam yang lebih tinggi meningkatkan nilai *CIE* L* (kecerahan) mi. Mi HC-Na10 dan SC-Na10 menunjukkan nilai tertinggi dalam parameter tekstur dan mekanikal. Namun begitu, aras garam yang lebih tinggi meningkatkan nilai *CIE* L* mi. Mi HC-Na10 dan SC-Na10 menunjukkan nilai tertinggi dalam parameter tekstur dan mekanikal. Penambahbaikan struktur disokong dalam penilaian deria di mana HC-Na10 dan SC-Na10 dinilai sebagai mi paling keras dan paling anjal ($P < 0.05$). Walau bagaimanapun, apabila aras garam melebihi 10%, kesan perisai yang melampau dan penolakan merosakkan rangkaian gluten dan menjejaskan parameter mekanikal dan tekstur. Ahli panel deria menunjukkan peningkatan keutamaan rasa dan masin dengan peningkatan kepekatan garam dalam salutan mi. Pecahan struktur, mikrostruktur dan pembebasan garam *in vivo* dalam analisis mulut telah dijalankan dalam Fasa 2. Penambahbaikan struktur telah ditunjukkan kerana kedua-dua mi HC-Na10 dan SC-Na10 memerlukan jumlah kerja maksimum untuk dipecahkan. Selain itu, mikrograf SEM kedua-dua mi menunjukkan kemunculan yang mampat dan lebih padat dengan peningkatan dalam kesinambungan matriks dan dengan lompang dan rongga yang lebih sedikit. Walau bagaimanapun, permukaan pecah diperhatikan dalam mi yang disalut dengan 20% dan 30% garam. Walau bagaimanapun, permukaan pecah diperhatikan dalam mi yang disalut dengan 30% garam. Peningkatan pembebasan garam oleh salutan telah dibuktikan dalam analisis *in vivo*, di mana garam yang dibebaskan adalah pantas daripada salutan HC dan SC. Berdasarkan keputusan yang diperolehi, mi HC-Na10

dan SC-Na10 kelihatan sebagai formulasi yang paling menjanjikan untuk analisis jangka hayat (Fasa 3). Mi HC-Na10 dan SC-Na10 mempunyai jangka hayat lebih daripada 8 hari di bawah penyimpanan pada 4 °C, iaitu lebih daripada HC-Na0 dan SC-Na0. Penyimpanan penyejukan pada 4 °C melambatkan pertumbuhan mikrobiologi, perubahan pH dan nilai *CIE* L* dalam mi bersalut garam daripada yang disimpan pada suhu 25 °C. Kandungan kanji tahan dalam HC-Na10 ialah 0.85% dan ia boleh menyumbang kepada jumlah serat makanan dalam diet pengguna. Sebagai kesimpulan, mi HC-Na10 dan SC-Na10 mungkin merupakan formulasi yang sesuai untuk menggantikan YAN kerana mereka mempunyai parameter mekanikal dan tekstur yang tertinggi ($P < 0.05$), tekstur yang lebih kuat ($P < 0.05$), struktur mikro yang lebih padat, dan mempunyai kandungan natrium yang paling rendah ($P < 0.05$) berbanding mi bersalut garam yang lain.

DEVELOPMENT OF HYDROCOLLOIDS-COATED NOODLES FOR ENHANCED SALT RELEASE IN THE MOUTH

ABSTRACT

Yellow alkaline noodles (YAN) with low-salt content pose low textural and mechanical properties. Consequently, they collapse easily in overall structure upon cooking, i.e. become soft, soggy, and crumble into smaller pieces. In addition to this major setback, low salt content in YAN impairs the taste and saltines perception by the consumers. Furthermore, Commercial YAN have a very short shelf life (up to 2 days), even under refrigeration storage. This study aims to develop zero-salted YAN coated with using of high amylose corn starch HylonVII^{TM} (HC) or a mixture of sucrose esters of fatty acids and carboxymethyl cellulose Semperfresh^{TM} (SC). The noodles is hypothesised to have the same (or better) shelf life, textural, mechanical, and sensory properties, as well as able to enhance salt release in the mouth than YAN. The cooking and mechanical properties of noodles coated with HC (10, 15, and 20%) or SC (2.5, 5, and 7.5%) containing a range of salt at 0 (Na0), 5 (Na5), 10 (Na10), and 15% (w/v) (Na15) were investigated in the preliminary stage. The results showed that as the level of salt increased, the cooking time and cooking loss of noodles decreased. Both types of coatings and salt concentration at 10% showed improved tensile strength and elasticity of noodles. Thus, HC15, SC5 and additional sodium content were selected for the subsequent analysis. The effects of coatings consisted of 15% HC and 5% SC containing various salt concentrations (0, 10, 20, and 30%) were investigated for the textural, mechanical, cooking and sensory properties of noodles in the Phase 1. The increased salt content in the coating increased the sodium content in raw and cooked noodles along with more salt released into the cooking water. It also significantly ($P < 0.05$) reduced the cooking time and cooking loss of noodles. Both coatings and salt concentrations did not influence ($P > 0.05$) the pH, *CIE* a* (redness) and b*(yellowness) values of noodles. Nevertheless, the higher salt level increased the *CIE* L* (lightness) values of noodles. HC-Na10 and SC-Na10 noodles showed the highest values in textural and mechanical parameters. Structural enhancement was supported in sensory evaluation where HC-Na10 and SC-Na10 noodles were rated as the hardest and springiest ($P < 0.05$) noodles. However, when the salt level exceeded 10%, extreme shielding effect and repulsion damaged the gluten network and impaired the mechanical and textural parameters. The sensory panellist showed increasing preferences of taste and saltiness with increasing salt concentration in the coatings of noodles. Structural breakdown, microstructure and *in vivo* salt release in the mouth analysis were carried out in the Phase 2. Structural improvement was demonstrated as both HC-Na10 and SC-Na10 noodles required a maximum amount of work to be broken down. Moreover, SEM micrographs of these noodles showed a compact and denser appearance with an increase in the continuity of matrix and with fewer voids and hollows. However, ruptured surfaces were observed in noodles coated with 20% and 30% salt. The enhanced salt released by the coatings was evidenced in *in vivo* analysis, whereby that salt released was rapid from HC and SC coatings. Based on the results obtained, HC-Na10 and SC-Na10 noodles appeared to be the most promising formulations for shelf life analysis (Phase 3). HC-Na10 and SC-Na10 noodles had a shelf life of more than 8 days under storage at 4 °C, which is longer than HC-Na0 and SC-Na0 noodles. Storage at 4 °C decelerated the microbiological growths, changes in pH and *CIE* L* values in salt coated noodles than those storage at 25 °C. The resistant starch content in HC-Na10 noodles was 0.85% and it could contribute to the total dietary fibre in the diet of the consumers. To conclude, HC-Na10 and SC-Na10

noodles might be suitable formulations to replace YAN as they had the highest ($P < 0.05$) mechanical and textural parameters, stronger ($P < 0.05$) texture, denser microstructure, and pose the lowest ($P < 0.05$) sodium content than other salt-coated noodles.

CHAPTER 1

INTRODUCTION

1.1 Background

Noodles have been a famous traditional staple food in several Asian countries such as China, Japan, Indonesia, Malaysia and Thailand. Since ancient times, noodles have gained a reputation globally for their convenience, nutritional quality, and palatability (Li, Zhu, Peng, et al., 2014). Noodles are one of the staple food widely adopted into the local cuisine of Malaysian. Approximately 30% of the total flour used in Malaysia is used for processing noodles. The demand for noodles in Malaysia reached 1,570 Million serving in 2020 (Wina, 2021). Noodles are the staple food for most Chinese worldwide after the bread being number one (Li et al., 2017b). Nowadays, noodles can be served in many forms. Yellow alkaline noodles (YAN) are one of the popular forms of noodles. They consist of wheat flour, water, common salt and *kansui* (Fan, Ai, Chen, Fu, & Bian, 2018). Their extraordinary taste, flavour and chewiness draw more interests from people (Xing, Jiang, Guo, Yang, & Zhu, 2021).

Salt is added into YAN in 1 – 3% of flour weight. It is one of the crucial ingredients in noodles processing. Although the primary ingredient of YAN is wheat flour, salt plays a very vital role in noodle processing. The first function of salt is to strengthen the gluten network and improve dough stability. Rombouts, Jansens, Lagrain, Delcour, & Zhu (2014) reported that the salt addition at 0.5-2% enhanced the firmness of cooked noodles. Tan, Tan, & Easa (2018) stated that the hardness of the noodles increased when the salt was increased from 1% to 4%. Li, Sun, Han, Chen, & Tang (2018) discovered that NaCl induced a thread-like or fibrous gluten structure in fresh noodles and led to the development of a firmer and more rigid network in noodles. Next, salt improves the flavour and sensory perception of noodles by imparting a salty taste to the food. It also enhances other flavour constituents in the food. Li, Zhu, Guo, et al. (2014) reported that it inhibits microbial growth in fresh noodles and increases the shelf life of food products. Ma et al. (2020) stated that bacteria is the most typical spoilage microorganisms in raw and fresh wheat food, while molds and yeast are the second most common spoilage.

High salt intake is associated with cardiovascular diseases and hypertension, which are diagnosed in more than 26% of the adult in the global population (Kongstad & Giacalone, 2020). Hypertension is a significant risk of cardiovascular disease, myocardial infarction, stroke, renal failure, and premature death. Tan et al. (2020) reported that non-communicable diseases (NCDs) caused about three-quarters of premature death among Malaysians. The principal causes of death are ischemic heart disease and cerebrovascular disease. National Health and Morbidity Survey (NHMS) 2019 published that 6.4 million people in Malaysia, or 30% have hypertension and only half realised that they have hypertension. For the people below 30 years old, male possess the triple risk of hypertension than female. The prevalence of hypertension in adults (18 years and above) was 30% and it rises with age. WHO recommends < 2 g/day sodium (5 g/day salt) for adults, but most people consume 9-12 g of salt intake per day, mainly coming from processed food products (Beeren, Groves, & Titoria, 2019; Hashem, Pombo-Rodrigues, & Capewell, 2015). Malaysians' average daily salt intake is 8.7 g in a study involving health workers (Tan et al., 2020). Cappuccio, Beer, & Strazzullo (2019) reported that a significant reduction in blood pressure could be accomplished by consuming a moderate salt intake. Therefore, the most feasible option was suggested by WHO: a population option through non-pharmacological attempts which were diet and lifestyle. Ministry of Health Malaysia introduced the national strategies for decreasing the average salt intake in the population in the Salt Reduction Strategy 2015-2020 (Ministry of Health Malaysia, 2015).

The food industry has made significant improvements in providing low-salt options (Kloss, Meyer, Graeve, & Vetter, 2015). Salt reduction, salt replacement and physical alterations have been introduced to increase salt content in the mouth (Busch, Yong, & Goh, 2013). However, salt reduction gives unfavourable outcomes to consumer perception of food products. Therefore, a gradual and consistent salt reduction through a long period was proposed by Antúnez, Giménez, Alcaire, Vidal, & Ares (2019).

One of the salt reduction approaches is to replace (all or partial) salt with salt replacers. These salt replacers contain mineral salts like potassium chloride or flavour enhancers such as monosodium glutamate, yeast extracts, and 5nucleotides. However, some salt replacers do not possess the particular taste of sodium chloride. Partial replacement with potassium chloride has been extensively studied by researchers (van Buren, Dötsch-Klerk, Seewi, & Newson, 2016). However, potassium chloride, the main ingredient in salt substitute, can generally only substitute up to 30% of salt content in most food products. It has unpleasant taste qualities such as bitter and metallic when the amount used is high and it has a higher cost than salt (Sinopoli & Lawless, 2012).

In this study, Hylon™ VII and Semperfresh™ were selected as the salt-coatings for YAN. Since salt on the coatings is released more quickly during chewing, the distribution of YAN’s matrix is no longer needed. The salt incorporated in the salt coated-YAN plays similar roles as the salt found in the traditional YAN formulation i.e. without coating.

1.2 Problem statements

Fresh YAN have high moisture content, high pH values and abundant nutrient composition. YAN with a lower salt content possess lower textural properties due to the weakened gluten network and inability to form an elastic and extensible dough. These problems cause difficulties in handling and cooking. Besides, the consequent loss in texture affects the sensory appeal. The salt reduction affects consumer perception of food products as salt impairs the taste and saltiness of food. YAN are highly liable to spoilage and typically have 1-3 days of shelf life due to high water content and rich nutrients. Refrigeration is required to store the fresh YAN to deter deterioration. The higher rate of deterioration of YAN increases food wastage and limits its utilization beyond households and restaurants. With a reduced content of salt, YAN achieve spoilage at a higher rate.

1.3 Hypothesis

It was hypothesized that formulating coatings with selected hydrocolloids would help to improve or maintain the mechanical, sensory attributes and shelf life of YAN with low salt content and enhance the salt release in the mouth. The hydrocolloids selected for consideration were high amylose corn starch and edible mixture of sucrose esters of fatty acids and carboxymethyl cellulose. Despite the potential use of these hydrocolloids to meet the various requests of food processing, salt coatings have not been explored in YAN.

Starch is abundant, easy availability, easy processing, higher yield, high nutritional value, low cost, biocompatibility, biodegradability and edible (Shah, Naqash, Gani, & Masoodi, 2016). High amylose corn starch (> 50%) can form a transparent, odourless, and tasteless membrane matrix with good mechanical and barrier properties (Kim, Jane, & Lamsal, 2017; Sifuentes-Nieves et al., 2019). The coatings exhibit higher stress to fracture values and better tensile strength, firmness and elasticity values than those obtained from regular starch (Menzel et al., 2015; Sifuentes-Nieves et al., 2019). Some researchers also reported that incorporating high-amylose flour enhances noodle hardness and reduces noodle springiness and cohesiveness (Kaur et al., 2016; Li et al., 2021). Bresciani et al. (2021) incorporated high amylose corn starch into pasta to produce pasta with high resistant starch and better cooking and nutritional quality. Incorporating high amylose corn starch into noodles could potentially improve fibre intake in populations.

An edible coating is a thin layer of edible material formed as a coating on a food product (Tavassoli-Kafrani, Shekarchizadeh, & Masoudpour-Behabadi, 2016). Edible fruit coatings material is made from food-grade and can be safely consumed together with the food product (Tavassoli-Kafrani et al., 2016). Edible coatings are prepared in liquid solutions to be applied on the surface of a product by spraying, brushing or dripping (Andrade, Skurtys, & Osorio, 2013). The odourless and tasteless coatings are remarkably welcomed by consumers. The coating is able to reduce quality losses by creating a semi-permeable protective coat on the surface of the fruit that controls moisture, solute and gaseous exchange between the fruit's internal and external environment (Ncama, Magwaza, Mditshwa, & Tesfay, 2018). Edible coatings are also an efficient post-harvest treatment to preserve fruit quality by reducing spoilage and microbial contamination (Tavassoli-Kafrani et al., 2016).

1.4 Research objectives

The aim of this study is to develop coatings with salt on noodles with the same and/or better shelf life, textural, mechanical, sensory properties and enhanced salt release in the mouth than yellow alkaline noodles (YAN). The general objective is to investigate the feasibility of using Hylon and Semperfresh as coatings on zero-salted noodles to carry a certain amount of salt. The specific objectives of this study are listed as below:

1. To investigate the effects of Hylon and Semperfresh coatings with selected salt concentrations on cooking, pH, colours, textural, mechanical, sensory properties of zero-salted YAN
2. To investigate the effects of Hylon and Semperfresh coatings with selected salt percentage on microstructure, structural breakdown properties and salt release in the mouth
3. To investigate the effects of Hylon and Semperfresh coatings with selected salt percentage on shelf life of YAN.
4. To investigate the amount of resistant starch on raw and cooked Hylon-coated noodles.

CHAPTER 2

LITERATURE REVIEW

2.1 Noodles

2.1.1 Background of noodles

Asian noodles are a significant component of the daily diet in Southeast Asia (Khorshidi, Hatcher, Page, & Scanlon, 2018). Noodles consumption continues to expand quickly with a 7 % yearly growth (Karim & Sultan, 2015). Zhang & Ma (2016) reported that noodles started in the Han dynasty with more than 4,000 years of history and was called *cake* and *soup cake* (noodles with soup). Various shapes, sheets and strips of noodles were available. The noodles were prepared by forming the sheets from the dough and cooked in a pot. The cultural traditions and customs of China are represented by noodles, which stands for “human nature” and “worldly common sense”. Noodles steadily gained in popularity in Japan, Malaysia, Indonesia, Thailand, Burma, and India. Noodles contribute an average 20 - 50% of total wheat flour consumption in most Asian countries. India, the United States, Brazil, Russia, Nigeria, and Mexico are in the top 15 instant noodle consumption countries in which noodles were not in their traditional food (Hou, 2020).

Noodles are famous in Malaysian food. Noodles processing occupies about 30% of total flour consumption in Malaysia. One of the leading food manufacturing industries in Malaysia includes the noodles factories, and most of the noodles are used for local consumption (Karim & Sultan, 2015).

2.1.2 Classification of noodles

The preferences of the communities such as eating aspect and patterns, colour, texture, size, taste, shape, development in technology are the factors that influence the various forms and shapes of noodles eaten. Noodles are usually categorised into numerous types according to their origins, such as Chinese, Japanese, Korean, Italian and Thai bamee noodles. From there, they are classified into white and yellow noodles according to their colour. Besides, they are categorised according to flour types, namely wheat and rice noodles. Furthermore, the differences in processing methods and conditions lead to four subclassifications of noodles which are fresh, dried, boiled and steamed noodles (Fan et al., 2018; Hou, 2020).

Wheat flour noodles are the most common in Asian noodles. The essential ingredients are wheat (*Triticum Aestivum*) flour, water and salt. Asian wheat flour noodles can be categorized into two major classes according to the ingredients: white salted noodles (made from salt) and yellow alkaline noodles (YAN) (made from *kansui*, a mixture of sodium and potassium carbonates) (Tao et al., 2019). Their typical formulas are shown in 2.1.

Table 2.1 Typical noodle formulations of white salted noodles and yellow alkaline noodles

Ingredients	White Salted Noodles	Yellow Alkaline Noodles
Flour (%)	100	100
Water (%)	32 - 40	28 - 34
Salt (%)	2 - 5	1 - 1.5
Potassium Carbonate (%)	0	0.5
Sodium Carbonate (%)	0	0.5

(adapted from Hou, 2010)

2.1.3 Yellow alkaline noodles (YAN)

Yellow alkaline noodles (YAN) are usually eaten in Malaysia and various forms like Cantonese and Hokkien noodles. Wheat flour, water, salt and *kansui* are the essential ingredients of YAN. YAN are parboiled and usually sold in wet form. Their high moisture content (50-60%) and nutrient substances restrict their shelf life to 1 − 1.5 days and 3 - 4 days with suitable processing and packaging. Therefore, refrigeration is usually needed for storage to avoid quick deterioration and discolouration. Some significant features of YAN include unique aroma and flavour, bright and yellow colour, firmer and elastic texture. The addition of *kansui* yields a distinctive yellow colour, firm texture, alkaline flavour and high pH ranging from about 9 to 11. The typical *kansui* applied in YAN is sodium carbonate or mixtures of sodium and potassium carbonate. The amount of *kansui* added to fresh YAN is usually at 1.0-1.5% of the weight of flour for fresh YAN. The amount of water added is 28-35% of flour weight (Fan et al., 2018; Hou, 2020; Man Li, Ma, Zhu, Guo, & Zhou, 2017).

2.1.3(a) Basic ingredients of YAN

The essential ingredients of YAN include wheat flour, water, salt (sodium chloride) and *kansui*. Each ingredient plays a vital role in YAN quality. The amount of essential ingredients is crucial as they can affect end-use quality.

2.1.3(a)(i) Wheat flour

Wheat is the primary and most essential raw ingredient of noodles. It is typically categorised into soft and hard wheat because of its distinct utilisation. Hard wheat flour is used to make the majority of Asian noodles, and they have a wide range of protein content levels depending on the types of noodles and local choices (Cato & Li, 2020).

The flavonoid pigments (xanthophylls) in wheat flour are colourless at acidic pH levels but change to yellow at alkaline pH levels. The flavonoid apigenin-C-diglycosides compounds in wheat flour determine YAN's yellow colour with xanthophylls (Asenstorfer, Wang, & Mares, 2006). A white or creamy white colour is desirable for WSN, while a bright yellow colour is desirable for YAN (Yeoh et al., 2014).

The protein content of wheat flour is negatively correlated to noodles' colour, brightness and surface smoothness, while it has a positive relationship with the hardness and elasticity of noodles. Noodles made from low-protein flours are usually darker than those made from high-protein flour (Park & Baik, 2002, 2004b). Protein quantity and quality are essential for excellent cooking quality. The protein content of YAN flour is in the range of 11-13.5%. Most of the proteins in wheat flour derive from gluten proteins (monomeric gliadins and polymeric glutenins). Gliadins and glutenins produce a viscoelastic network by intermolecular disulfide bonds (Li et al., 2021). Gliadins are connected to the viscosity and extensibility, while glutenins are associated with the hardness and elasticity of the network (Rombouts et al., 2014).

Some researchers reported that the cooking qualities of noodles, such as cooking loss, cooking yield, optimum cooking time and textural properties of noodles, were affected by the protein. The cooking time of noodles decreased when the protein content of flour reduced. Water absorption decreased when flour protein content increased. Significant surface rupture appears on the noodles made from low-protein flour and leads to higher water absorption of starch and shorter cooking time of noodles. Low protein wheat flour produces a network with poor compactness and elasticity. High gluten makes the noodle dough too hard and increases difficulties in rolling and sheeting (Cato & Li, 2020; Li, Sun, & Zhu, 2017).

Wheat dough is formed when gluten interacts with water molecules to form a specific three-dimensional network filled with starch granules (Li et al., 2021a). The three-dimension network is equalised by S–S and non-covalent bonds (Li et al., 2021b).

Starch represents the primary component of wheat flour at about 75%. The dietary energy provided from starch is around 70% of the total energy from YAN. The functions of starch in food products include bulking, thickener, stabiliser and texture modifier. The starch consists of two major components that are amylose and amylopectin. Amylose shows α-1,4-linked d-glucose units with a linear structure and few branches. The branched amylopectin contains significantly higher levels of α-1,6-linked d-glucose unit (Junjie Guo, Yang, Wang, Lian, & Liu, 2021). The amylose and amylopectin regulate the functional properties of starch, for example, water absorption, gelatinisation and retrogradation characteristics. The gelatinization and retrogradation process in starch in wheat flours influence the textural and cooking qualities of noodles (Man Li, Zhu, Guo, et al., 2014)

2.1.3(a)(ii) Water

Water is an essential ingredient that is added during mixing for gluten formation—the gluten proteins in the flour exhibit viscoelastic properties with support from water. All the water-soluble ingredients are dissolved in water before mixing. An appropriate amount of water is essential to ensure the optimum flour hydration and formation of a uniform dough sheet. Too much water yields sticky dough with low viscosity and causes difficulty in handling.

Moreover, it also increases the extension of the noodles strips and cooking losses. On the contrary, insufficient water produces a dry, hard and stiff dough that inhibits the flour components from mixing. Incomplete gluten development produces cooked noodles with weak and soft textures (Karim & Sultan, 2015).

The development of a continuous gluten matrix in dough requires 28% to 35% of the water content of the dough. Approximately 28–35 % of water absorption level based on flour weight is recommended for noodle processing. The dough strength can be monitored by manipulating the water level. The numerous ingredients in the formulation, processing instruments, processing factors, and noodles features determine the level of water used in commercial manufacturing (Karim & Sultan, 2015). Water absorption of noodle dough is negatively related to flour protein content (Park & Baik, 2002). The water addition amount to the flour influences dough consistency, which varies according to the flour's biochemical content (Baudouin et al., 2020).

Water possesses a high specific heat capacity. Hence, little water can influence the thermal properties of flour extensively and thus affect the heat behaviour of the material (Wang et al., 2021).

2.1.3(a)(iii) Kansui

Kansui is an essential ingredient in making YAN. It is comprised of sodium/potassium carbonate or bicarbonate or a mixture of any or all of these salts. Sodium hydroxide or sodium silicate can be added. The manufacturers decide the variety and ratio of *kansui*. The type of *kansui* used and their ionic strengths form noodles with pH ranging about 9 to 11. The *kansui* addition is at the level of 0.5–3.0% (w/w) with a ratio between 1:9–9:1.

The effects of *kansui* on protein and starch is presented in Table 2.2.

Table 2.2 Effects of *kansui* on protein and starch

Study	Effects of *kansui*
Jia et al. (2019)	modified the hydrophobic and/or electrostatic interactions induced the three-dimensional polymeric network formation strengthen the internal structure improved the overall quality of the cooked noodles
Rombouts et al. (2014)	promoted gluten network development during cooking facilitated intermolecular disulfide bond formation
Tao et al. (2019)	increased gelatinisation and the viscosity of the starch paste
Li et al. (2018)	promoted starch gelatinization and increased cooking loss induced more protein aggregates during cooking induced a fibrous gluten structure
Fan et al. (2018)	improved the aroma of YAN

The incorporation of *kansui* into the noodles increases the yellow intensity when the endogenous flavonoids are going through a chromophoric shift and change to yellow in alkaline conditions. The type and the amount of alkaline reagent used determine the yellowness intensity in alkaline noodles (Ding et al., 2021; Fan et al., 2018).

2.1.3(a)(iv) Salt (sodium chloride)

2.1.3(a)(iv).1 *Effects of salt on YAN*

Salt (table salt or sodium chloride) is an ionic compound with Na^+ and Cl^-. Salt plays a vital role in noodle processing. Salt addition is usually 1-3% of flour weight. Salt at 8% can be added to Udon and several hand-made noodles (Fu, 2008). Salt addition at 2% was recommended by Morris, Jeffers, & Engle (2000) for the excellent quality of YAN. Ye et al. (2009) suggested salt addition from 0 to 2%, and the optimum salt concentration is 1%.

Salt shields the negative charges on the gluten protein by bonding between ion Na^+ and the negatively charged gluten protein and allows a slower wheat flour hydration. Salt strengthens the gluten network by the interaction between gliadins and glutenins through intermolecular hydrogen bonds and ion bonds. As a result, dough with higher elasticity and stronger is produced (Tan et al., 2018)

Salt enhances the textural of noodles by promoting protein-protein interactions and aggregation of gluten proteins. Man Li et al. (2018) report that salt formed a fibrous gluten structure in noodles.

The gluten proteins carry an overall net positive charge under their isoelectric point (pH 7.5) in a dough system. Repulsion occurred among the charged proteins and is followed by hydration of protein. The interactions among the proteins are reduced, and the mixing time is shortened. Thus, dough with high stickiness is formed. Salt could shield the negative charges on the gluten protein by bonding between ion Na^+ and the negatively charged gluten protein. Salt could eliminate the repulsion between the protein by neutralising the overall charge. Thus, it enables interaction and aggregate of protein through hydrophobic interaction. Therefore, the hydration of protein is reduced, and the dough structure becomes stronger and more compact (Avramenko, Tyler, Scanlon, Hucl, & Nickerson, 2018; Tan et al., 2018).

Rombouts et al. (2014) reported that the salt addition decreased the degree of gluten polymerisation and enhanced the firmness of cooked noodles (0.5- 2% salt). Tan, Tan, & Easa (2018) stated that the hardness of the noodles increased when the salt was increased from 1% to 4%. Li et al. (2018) discovered that NaCl induced a thread-like or fibrous gluten structure in fresh noodles and led to a firmer and more rigid network in noodles.

Salt could enhance the flavour by inducing a desirable salty taste when it changes to ions. The ions Na^+ dominates the taste buds stimulation and the ions Cl- produces the salty taste (Roper, 2015). Besides imparting the pure salty taste from the food, it could produce a sweet taste and cover bitter or metallic taste (Beck, Jekle, & Becker, 2012)

In addition, salt is used for inhibiting enzyme activities and the growth of microorganisms in fresh noodles, thus extending their shelf life. For these reasons, salt is a necessary additive in noodle production (Li, Zhu, Guo, et al., 2014). Li et al. (2017) reported that the proliferation of bacteria was the most rapid during storage of 72 hours and responsible for the spoilage of fresh noodles. Mold and yeast growth slightly increased and maintained the same order of magnitude.

2.1.3(a)(iv).2 *Effects of consumption of salt on human health*

Hypertension is a major risk of cardiovascular disease (CVD), myocardial infarction, stroke, renal failure, and premature death. The risk of these diseases increases incrementally with increasing hypertension. According to the Global Burden of Disease 2016, 124.1 million disability-adjusted life-years (DALYs) among men and 89.9 million DALYs among women suffered from ischemic heart disease and stroke that resulted in high systolic blood pressure (Tan et al., 2020). Heart and pulmonary circulation ailments (16.1% of total deaths) and hypertension and stroke (8.4% of total deaths) account for two of the five primary causes of mortality in Malaysian government hospitals. These diseases occupy one-quarter of all medically approved deaths in Malaysia. According to National Institutes of Health, Ministry of Health (2019), National Health and Morbidity Survey (NHMS) 2019 shows that 30% or 6.4 million people in Malaysia suffer from hypertension. Only half are aware that they have hypertension. Approximately 90% of them are on medication, and 45% control their blood pressure successfully. Men below 30 years old suffer the triple risk of hypertension than women. Moreover, they reported that the total prevalence of hypertension in adults (18 years and above) in this study was 30%, and it increased with age.

A blood pressure value of over 140/90 mmHg is categorized as high blood pressure. Cappuccio (2013) reported that a 4.2/2.1 mmHg reduction in blood pressure could be achieved by reducing 4.4 g daily dietary intake of salt. He also stated that extensive studies reported a correlation between salt intake and blood pressure. In addition, he wrote that 5 g per day higher salt intake (2000 mg of sodium) could increase 17% risk of total cardiovascular disease and 23% risk of stroke. Besides, salt (sodium) intake is positively related to urinary calcium excretion. An increase in urinary calcium of 1 mmol is increased by the rise of 100 mmol of sodium in dietary. Furthermore, a high salt intake leads to high urinary calcium losses, elevated levels of parathyroid hormone, 1,25-dihydroxy-vitamin D, and serum osteocalcin (a marker of bone formation), along with urinary cyclic AMP and urinary hydroxyproline (a marker of bone resorption). Numeral studies show that the autoimmune system can be damaged by high salt intake and lead to autoimmune encephalomyelitis (Sharif, Amital, & Shoenfeld, 2018) and lupus (Lawrence et al., 2011). Moreover, high salt yields excessive reactive oxygen species (ROS) and causes liver fibrosis (Wang et al., 2016).

According to World Health Organization (Who, 2012), most people consume 9-12 g of salt per day. High salt intake is connected to an increased risk of hypertension, cardiovascular diseases and kidney disease. In a study involving health workers, Malaysians' average daily salt intake was 8.7 g (Tan et al., 2020). A salt consumption reduction to < 2 g/day sodium (5 g/day salt) for adults was proposed by WHO, which is half of the average daily dietary salt intake (Lawrence et al., 2011). Cappuccio, Beer, & Strazzullo (2019) reported that a significant reduction in blood pressure could be accomplished by consuming a moderate salt intake.

Nevertheless, most of the death caused by CVD and diseases related to hypertension appeared at sub-optimal blood pressure levels between 120 and 140 mmHg systolic. Many people had these blood press readings, and clinical guidelines did not treat them with drugs. Hence, WHO proposed the most workable alternative, a population approach through non-pharmacological efforts such as diet and lifestyle. More than 70% of daily salt intake was generated from processed foods (Beeren et al., 2019; Hashem et al., 2015). Thus reducing salt content in the food formulation is one of the significant interests of health-conscious consumers.

2.1.3(b) Salt reduction in food

Reducing sodium content in food products has become an essential topic for the processed food industry. The modification of sensory characteristics followed by decreased consumer acceptance is part of the significant implications of salt reduction in food (Lawrence et al., 2011).

Numerous different approaches have been taken by food manufacturers to decrease the salt amount in their foods (Kongstad & Giacalone, 2020). Some food manufacturers reduced a significant amount of salt added to the food. However, substantial salt reductions negatively affected consumer perception of various food products. Thus one of the approaches to reduce salt in food is the gradual and persistent reduction of the salt amount over a long duration (Antúnez et al., 2019).

In addition, potassium chloride is the main ingredient in salt substitutes and is frequently used in reducing sodium content in food. According to Kongstad & Giacalone (2020), 10–40% of partial salt replacement by potassium chloride is suitable because the consumers overlook its impact on the flavour. However, its metallic-bitter after-taste is undesirable.

Various combinations of mixtures consisting of other inorganic salts, organic acids, amino acids, peptides, protein hydrolysates, or other salt-enhancing substances such as monosodium glutamate have been proposed to replace salt. Food products with monosodium glutamate often use mushrooms, tomato, onion, soy sauces, and cheese (natural sources of umami) to replace salt because they have saltiness enhancing function and excellent acceptability by consumers. Some researchers reported that consumers accepted food taste with up to 50% salt reduction in a particular food. Still, some salt replacers did not carry the unique pure salt taste of sodium chloride (Kongstad & Giacalone, 2020; Pflaum, Konitzer, Hofmann, & Koehler, 2013).

The structure of lipoprotein foods was engineered to increase sodium release and delivery (Kuo, Ilavsky, & Lee, 2016). The benefits of designing food and salt structure included improving sodium transport to the receptors in the mouth, enhancing the sensory perception of saltiness, and sodium reduction (Sun et al., 2021).

The other approach included altering the physical form of the salt to increase its availability to the taste buds to reduce the salt requirement. The researchers concluded that optimizing salt content and particle size could improve the saltiness of low sodium food without using additives and influence the sensory acceptability (Emorine, Septier, Thomas-Danguin, & Salles, 2014).

Some researchers employed sodium replacement and biopolymer encapsulation to decrease sodium absorption. They reported that the combined technology could produce sodium-reduced sausage, excluding the bitter taste (Jung, Jin, & Hur, 2018).

Spray drying and electrohydrodynamic atomized drying techniques were adopted to alter the size and structure of common salt. The nano-size salt particles could improve sodium delivery in the oral cavity with a quicker dissolution rate and thus optimize the saltiness perception (Vinitha, Leena, Moses, & Anandharamakrishnan, 2021).

However, there is no information on salt reduction in noodles by using coating as an application.

2.2 Noodles processing

The steps of making Asian noodles are generally similar. Adequate skills and knowledge are necessary to achieve the optimum quality of noodles with consumer acceptance. There is a slight difference between the processing of YAN at-home scale and industrial manufacturing (Karim & Sultan, 2015). The outline of noodles processing is shown in Figure 2.1.

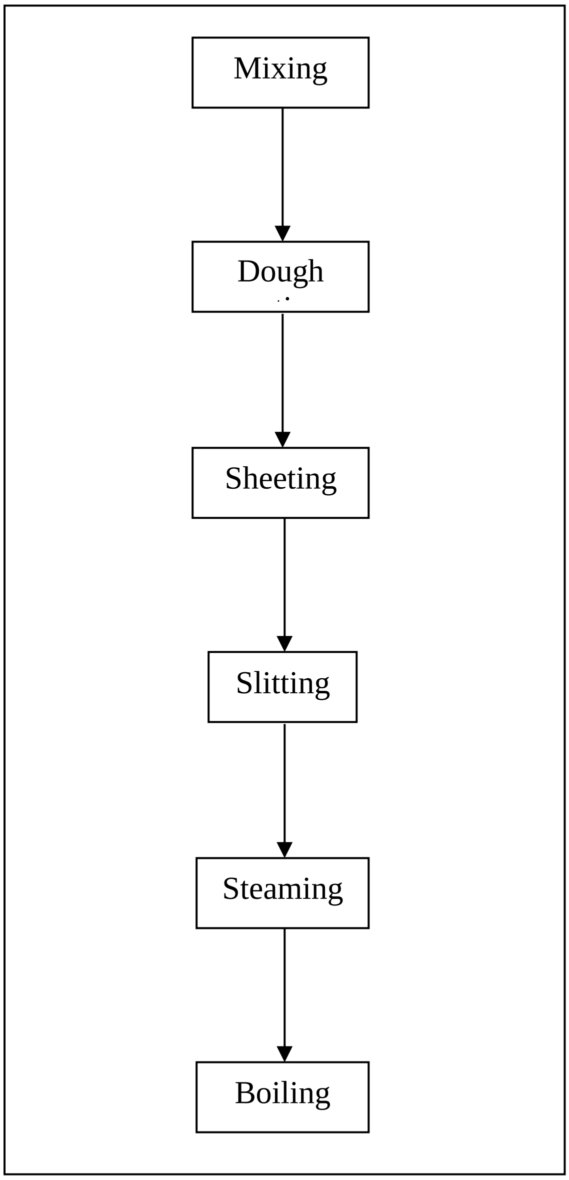

Figure 2.1 Outline of noodles processing

2.2.1 Mixing

Mixing raw ingredients is the initial step in noodle processing. Dough mixing accomplishes two purposes that are flour particles hydration and disruption, followed by gluten shearing and stretching. Wheat proteins receive mobility with water and swell, allowing them to retaliate to mechanical stress (Baudouin et al., 2020). Nevertheless, mechanical mixing is compulsory in dough development, along with hydration. Microscopic observations of dough display that the distortion of the water-insoluble gluten proteins into oriented sheets or filaments was caused by mixing (Boitte, Hayert, & Michon, 2013). Optimal dough mixing was induced by expanding the gluten fibrils into a three-dimension network enveloping the whole dough mass (Boitte et al., 2013). The three-dimension network is stabilized by S–S and non-covalent bonds. These interactions may be induced by glutenin macropolymer and secondary protein structures. These interactions also determine the rheological properties of dough, especially the strength and extension properties (Li et al., 2021a).

Mixing time primarily affects the dough performance and end-product quality. Inadequate mixing yields unbalanced wheat flour hydration and incomplete gluten development. Over mixing could overdevelop gluten, destroy the well-developed gluten network, and produce high dough temperature, which could denature the protein (Liu et al., 2015).

2.2.2 Dough resting

Dough resting is typically essential in noodle preparation and significantly affects both noodle quality and performance in production. The crumbly mixture rest for some time to further facilitate flour particles' hydration and disperse water within the dough system (Liu et al., 2021). Longer resting time induces more excellent modification in dough rheology. Dough resting time impacts the elasticity of the doughs (Jha, Chevallier, Cheio, Rawson, & Le-Bail, 2017).

2.2.3 Sheeting

Sheeting constructs the dough into a uniform and compact sheet by the roller and regulates the thickness and quality of the dough. The majority of gluten networks are constructed by the mechanical work of the roller (Shi et al., 2021).

The gluten matrix in the machine-sheeted dough is coordinated with the sheeting direction. The sheeting direction (longitudinal direction) of the dough sheet is varied from that perpendicular to the sheeting direction (transverse direction). Consequently, the gluten network structure can be formed in all directions in the dough (Liu et al., 2021). The organized rearrangement of the gluten lamellae is enhanced among structural units and the interaction between protein macromers and starch granules (Shi et al., 2021).

2.2.4 Slitting

The dough sheet is cut into the noodle strands by a cutting machine when it meets the desired thickness. The cutting rolls affect the width and shape of the noodle strands. Rectangular, square and round are accepted for the form of a noodle strand cross-section (Fu, 2008).

2.2.5 Steaming

Steaming is energy-efficient and typically used in the production of instant noodles. Pregelatinization of starches occurs during steaming and decreases the cooking time before serving (Luo, Guo, & Zhu, 2015). The initial moisture of the noodle, the amount, pressure and temperature of the steam, and steaming time determines the degree of cooking. Dough with high water absorption is essential in making excellent quality steamed noodles. Therefore, the degree of cooking during steaming is vital. The optimum moisture content of steamed noodles is 59–61% (Fu, 2008). The steamed noodles had a dry, hard and half-cooked texture due to the low gelatinization and moisture (Hormdok & Noomhorm, 2007). There are many steamed noodle products in Chinese cooking tradition. Examples are chow mein, marinated noodles, and noodles are consumed with soy sauce (Siah & Quail, 2018).

2.2.6 Boiling

Boiling is typically employed in cooking (Wang, Zhang, Xu, & Zhang, 2020). The optimal cooking time is usually used for cooking the noodle to achieve excellent eating quality. Boiling yields competitive and argumentative starch gelatinization and protein polymerization, which are crucial in influencing the texture of cooked noodles (Luo et al., 2015). Boiling is performed in boiling water, and subsequently, gelatinization of starch and thickening of noodles occur. High water content was formed on the outer noodle strand, and low water content was developed on the inside as it became more smooth and elastic (Wang et al., 2020). Excessive boiling water and overheating are detrimental to the noodles because of the increased friction between boiling water and noodles. The optimum temperature of boiling is 98 °C. The size of the noodle strands and the types of noodles determine the optimum cooking time (Fu, 2008). Cooking time should be monitored closely because overcooked noodles are too soft, weak, and rupture easily, leading to difficulty in handling (Park & Baik, 2004a). Short cooking time is preferable for all noodles (Hou, 2010). The quality of noodles could be enhanced by boiling and steaming, and the needs of different types of noodles can be fulfilled (Lü et al., 2014).

Zhai et al. (2020) reported that Ca^{2+} and HCO_3^- in water underwent a thermal decomposition reaction during boiling of water. Thus, precipitation of $CaCO_3$ and volatilization of CO_2 occurred. Consequently, the concentrations of Ca^{2+} and HCO_3^- of the water reduced rapidly during boiling. Furthermore, Ca^{2+} and SO_4^{2-} in water precipitated during boiling due to their low solubility. Thus, the concentration of SO_4^{2-} also reduced. In addition, NH_4^+ and HCO_3^- in water underwent a reaction during boiling, in which volatilization of HN_3 and CO_2 appeared. Thus, the concentration of NH_4^+ was reduced.

2.3 High amylose starch

2.3.1 Structure and function

Starch is the major carbohydrate storage component in many plants and the second biggest natural biopolymer besides cellulose. Starch is primarily composed of 2 polymers of D-glucose amylose and amylopectin with various molecular masses, degrees of branching and physicochemical properties. The linear amylose contains a small number of long glucan chains, and the highly branched amylopectin has numerous clusters of short chains. It mainly consists of amylose (20%–30%) and amylopectin (70%–80%) (Wang et al., 2021).

The starch structure, gelatinization temperature, intrinsic viscosity, glass transition temperature, gel texture, rheological properties, solubility, and swelling power of starch are greatly affected by the molecular weight and chain length distribution (Zortéa-Guidolin et al., 2017). Amylose is vital for starch gel formation, while amylopectin influences retrogradation, gelatinization, acid hydrolysis, enzymatic hydrolysis, and rheological properties of starch granules (Sun et al., 2021).