UTILISATION OF MATURED GREEN BANANA (*Musa Paradisiaca var. Awak*) FLOUR AND OAT BETA GLUCAN AS FIBRE INGREDIENTS IN NOODLES

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by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PUBLICATIONS & SEMINARS

1.1 Effect of green banana flour (*Musa paradisiaca*) and oat beta-glucan in yellow alkaline noodle on nutritional properties and sensory evaluation. Paper submitted for 10th ASEAN Food Conference, August 2007, Kuala Lumpur, Malaysia.

1.2 The Effect of Incorporation of Banana Flour on the Quality of Noodles. Paper presented at 9th ASEAN Food Conference, August 2006, Jakarta, Indonesia.

1.3 Influence of Partial Substitution of Wheat Flour with Banana (*Musa Paradisiaca var. Awak*) Flour on the Physico – Chemical and Sensory Characteristics of Doughnuts. Paper presented at Malaysian Science & Technology Congress, 18 – 20 April, 2005, Cititel Midvalley, Kuala Lumpur

1.4 Bronze Medal I – TEX 2004
15th Invention, Innovation & Industrial Design Technology Expo 2004, 20 – 22 May 2004, Midvalley Convention Hall, Kuala Lumpur

PENGGUNAAN TEPUNG PISANG MATANG (*Musa Paradisiaca var. Awak*) DAN OAT BETA GLUCAN SEBAGAI INGREDIEN BERGENTIAN DI DALAM MI

ABSTRAK

Kajian ini bertujuan untuk mempertingkatkan kandungan gentian dietari dan memperbaiki nilai nutrisi untuk mi kuning beralkali (YAN). Dalam kajian ini, tepung pisang (BF) diproses daripada pisang awak hijau matang (*Musa paradisiacal var. Awak*) dan oat β-glucan telah ditambah ke dalam YAN sebagai sumber gentian. Kesan penambahan peratusan BF secara meningkat (dari 20% ke 50%) dan 10% oat β-glucan dikaji dari segi sifat fisikal, kimia, sensori dan jangka hayat. Penggantian tepung gandum dengan peningkatan peratusan BF dan penambahan 10% oat β-glucan telah meningkatkan dengan bererti ($p<0.05$) nilai proksimat (termasuk kandungan lembapan, protein, gentian kasar, abu dan lemak), gentian dieteri total (TDF), kanji rintang (RS) dan beberapa jenis mineral penting. Mi yang ditambah dengan peningkatan peratusan BF mengandungi amilopektin dan kanji total yang lebih banyak dan ini telah menyekat keupayaan membengkak mi, seterusnya memberi kesan terhadap sifat 'pasting' dan kualiti memasak mi. Sebaliknya, mi ditambah dengan 10% oat β-glucan menunjukkan kemampuan mengikat air yang lebih baik. Mi yang dihasilkan mempunyai tekstur yang kurang teguh tetapi lebih melekit. Penggantian peningkatan peratusan BF menyebabkan mi yang dihasilkan berwarna lebih gelap (keperangan) dan intensiti warna mi juga didapati lebih rendah. Penambahan oat β-glucan dan langkah memasak dapat membantu meningkatkan kecerahan (L*) mi. Keputusan SEM menunjukkan bahawa mikro-struktur dalaman mi ditambah dengan 30%BF adalah lebih padat berbanding dengan sampel kawalan. Mi ditambah dengan oat β-glucan pula menunjukkan mikro-struktur yang lebih poros berbanding mi tanpa oat β-glucan Peringkat optimum BF yang sesuai diganti ke dalam mi ialah 30%. Adalah didapati 30% BF dapat memperbaiki sifat berfungsi mi secara signifikan ($p<0.05$) dari segi sifat pengoksidaan (kandungan total fenolik, aktiviti anti pengoksidaan dan perencatan peroksidaan) dan kesan 'postprandial Glycemic Index

(GI) dan kadar penghadaman karbohidrat. Mi yang digantikan dengan 30% BF dan ditambah dengan oat β-glucan menunjukkan sifat pengoksidaan yang paling tinggi, GI yang paling rendah dan kadar penghadaman karbohidrat yang paling rendah antara semua sampel. Selain itu, kualiti mi 30% BF adalah setanding dengan mi diperbuat daripada tepung gandum dalam ujian sensori. Penilaian jangkat hayat menunjukkan bahawa mi kawalan dan mi 30%BF adalah selamat dimakan dalam jangka 3 hari. Selepas 3 hari penyimpanan pada 4 ^{o}C, hitung plat aerobik (APC) dan muatan kulat dan yis dalam mi didapati melebihi had keselamatan. Suhu pengeringan tinggi (80^{o}C) didapati menghasilkan mi kering yang lebih tahan terhadap pecahan.

UTILISATION OF MATURED GREEN BANANA (*Musa Paradisiaca var. Awak*) FLOUR AND OAT BETA GLUCAN AS FIBRE INGREDIENTS IN NOODLES

ABSTRACT

The purpose of this study was to increase the dietary fibre content and enhance the nutritional values of yellow alkaline noodle (YAN). In this study, banana flour (BF) from mature green banana (*Musa paradisiacal var. Awak*) and oat β- glucan were incorporated as sources of fibre in YAN. The effects of adding increasing level (20% to 50%) of BF and 10% oat β- glucan on the physical, chemical , sensory and shelf-life properties of YAN were investigated. The replacement of wheat flour with increasing level of BF and additional of 10% oat β-glucan resulted in significantly higher ($p<0.05$) proximate parameters (moisture, protein, crude fibre, ash, and fat content), total dietary fibre (TDF), resistant starch (RS) and some essential minerals. Noodles incorporated with increasing level of BF contained higher amylopectin and total starch which restricted the swelling power and consequently affected the pasting properties and cooking quality of the noodles. However, noodles with additional of 10% oat β-glucan showed greater water holding capacity and thus produced less firm but stickier texture noodles. Incorporation of increasing level of BF resulted in darker noodle (brownish) and decreased the colour intensity of noodle. However, addition of 10% oat β-glucan and the boiling step increased the lightness (L*) of noodles. The optimum level of BF incorporated into noodle is 30%. It was found that 30% BF could significantly ($p<0.05$) improved the functional properties of the noodles in terms of the antioxidant properties (total phenolic content, antioxidant activity and inhibition of peroxidation), effect of postprandial Glycemic Index (GI) and carbohydrate digestibility. Noodle incorporated with 30% BF and with added oat β-glucan showed greatest antioxidant properties, lowest GI and rate of carbohydrate digestibility among all samples. SEM results indicated that the interior microstructure of 30% BF-incorporated

noodles were more compact than the control sample. Noodle added with oat β-glucan showed more porous microstructure than noodle without oat β-glucan. Besides that, the quality of the 30%BF-incoprorated noodle was well comparable to the control sample as evaluated by sensory test. After the third day, the aerobic plate count (APC) and mould and yeast count of noodles was shown to exceed the safety limit. High drying temperature (80^{o}C) resulted in noodle which was more resistant to fracture.

CHAPTER 1: INTRODUCTION

Economic development is normally accompanied by improvement in country food supply and gradually eliminates the problem of nutrient deficiency. Therefore, the world is seeing a dramatic increase in problem of over-nutrition, especially among children in many western and developing Asian countries. According to WHO (2005), 300 million people all over the world are obese (BMI >30) while 1 billion of the people are overweight (BMI >25) in 2005. In Malaysia, prevalence of obesity and chronic energy deficiency (CED) in adult are 4.7% and 7.9% for male and female, respectively. This prevalence is projected to increase by 29% and 56% for male and female, respectively in 2015 (WHO, 2005).

The main reason for higher density diet is due to the increasing consumption of added sugar, fats, oils and animal products but reduction in the intakes of complex carbohydrate and dietary fibre. This over-nutrition diet had associated to diet – related chronic diseases, which account for more than half of the world’s diseases, which included obesity, cardiovascular disease, type-2 diabetes, as well as constipation. According to WHO (2005), 35 million people die from chronic disease in 2005 and an estimation of 388 million people will die from these diseases in the next 10 years. Besides, WHO (2005) reported that in year 2000, 171 million people worldwide have diabetes and approximately 47 million are from South East Asia.

An increase in the dietary fibre content in human diets is being encouraged and advocated. This is because dietary fibre plays a major role in determining the health and disease conditions by prevention of colon cancer, coronary heart disease, obesity, diabetes and gastrointestinal disorder (Azizah and Yu, 2000; Anderson *et al.,* 1994). According to American Dietetic Association (ADA), the current recommended fibre intakes for adults range from 20 to 35g/day or 10 to 30g/1000 Kcal (Marlett *et al.,* 2002) for American while recommended intake for Malaysian is 20 – 30g per day for all age group. However, 77% of the world's population failed to meet this nutritional target. For example the average American's daily intake of dietary fibre is only 14-15 g/day. Besides, Malaysian only consumes 13 – 16 g/day of dietary fibre which is far below WHO recommendation.

To meet ADA recommendation 20 – 35 g of TDF, fibre are used in the diet so as to remain healthy. The tendency of increase intake for cereal foods or fibre-enriched food products in the daily diet has brought up the concept of functional food. Functional food provided potentially beneficial effect on the health when consumed, such as reduced risk for diseases. Examples of functional foods include foods that contain specific minerals, vitamins, fatty acids or dietary fibre, foods enriched with biologically active substances such as phytochemicals, antioxidants or probiotics cultures. Moreover, functional foods should be in the form of normal foods and must demonstrate their effects in amounts that can normally be expected to be consumed in the diet. To respond to consumer demand for healthful food supply, many new functional foods are being developed by the food industry.

Noodle products are staple food in many parts of Asia, especially throughout South East Asia. Almost 40% of wheat products in Asian countries are consumed in the form of noodles (Miskelly, 1993; Crosby, 1991). Traditional noodle is made from simple ingredients (wheat flour, water and salt) can be a complete meal since it contains carbohydrates, protein and trace amount of saturated fatty acids. Besides, noodles are often used as a convenience food due to its simple preparation, low cost and fast cooking characteristics. However, composition of noodles appears to have limited attention and there is little data available on nutritional value of noodle products (Waliszewski *et al.,* 2003; Kachru *et al.,* 1995). Moreover, some reports even claimed that noodle is lack of other essential nutritional composition such as dietary fibre, vitamins (especially B group vitamins) and minerals which were lost during wheat flour refinement (Maberly, 2003; Watanabe and Ciacco, 1990; Dexter *et al.,* 1982). Thus, noodle products which represent a major end-use of wheat, are suitable for enhancing health – by promoting the health as functional food.

Noodle products enriched with dietary fibre might be in demand in the future food trend. Besides fibre, nutritional values of noodles can be enhanced by adding other essential nutritional composition such as antioxidant, protein, vitamins and minerals. Incorporation of composite flour into noodles will result in high quality and healthy noodles. Researches have been carried out by incorporating legume flour (peanut flour: Chompreeda *et al.,* 1987; garbanzo bean flour: Lee *et al.,* 1998; rye flour: Kruger *et al.,* 1998), barley flour enriched with β-glucan (Knuckles *et al.* (1997) and pumpkin powder (Lee *et al.,* 2002) in the production of pasta and noodle products. Besides, Collado and Corke (1996) also reported that sweet potato, potato and waxy corn have been used to improve eating quality of white salted noodle (WSN) is common practice in Japan. However, there was no available literature on the study of yellow alkaline noodle (YAN) using fruit fibre as source of fibre.

Green banana (*Musa paradisiaca* var. Awak) flour is an ideal fibre ingredient in noodles as the source of fibre. Banana flour can be produced from green *Musa paradisiaca* var. Awak which belongs to a type of plantain. *Musa paradisiaca* var. Awak is abundant in Malaysia and the world production of banana in 2003 was 102 million MT of which approximately 32 million MT was plantains (FAO, 2003). However, about one-fifth of the harvested bananas are spoiled and rejected. In order to increase the utilisation of culled bananas, few researchers had identified the potential of converting green banana into flour and starch (Sunthralingam and Ravindran, 1993).

Mature green banana especially plantain is very rich in starch and is one of the promising substitutes for the starch industry (Mota *et al.,* 2000). Raw banana starch is resistant to α- amylase and glucoamylase due to its high degree of crystalline intrinsic structure (Zhang *et al.,* 2005, Faisant *et al.,* 1995, Eggleston *et al.,* 1992, Cummings and Englyst, 1991). Therefore, isolated banana starch is suitable to be used to produce starchy food. Green banana is also high in total dietary fibre content (18%, Plaami *et al.,* 1992), especially in hemicellulose (6.08%, Kayisu *et al.,* 1981b) which is higher than most fruits and vegetables. The high fibre content, particularly in soluble fibre can lower glycemic response by forming a physical barrier to enzymatic hydrolysis of starch. On the other hand, insoluble fibre is important because it act as bowel cleanser which prevent intestinal cancer and also been utilised in reduced calorie diets. Apart from dietary fibre, bananas contain high amount of essential minerals such as potassium, and various vitamins such as A, B_1, B_2 and C. According to Gasster (1963), bananas are recommended for obese and geriatric patients because of its low in lipid content but high in energy value. Due to the high nutritional values contributed by green banana, the application of banana starch and flour in bakery and snack food products have been explored by many researchers.

Soluble fibre has prompted interest among researchers and food manufacturer for the health effect rather than the insoluble fibre. The soluble fibre has shown to have positive effects on glycemic, insulin and cholesterol responses to foods. Beta glucan (β – glucan) derived from oat (*Avena sativa* L.) is a type of water – soluble non-starch polysaccharide which could form viscous solution in digestive system. β-glucan is consider as fibre because no enzyme in the human body can hydrolyze the β-glucosidic linkage. This fibre has been studied for its effectiveness in preventing coronary diseases and diabetes. Food and Drug Administration (FDA) had claimed that foods containing 0.75 g beta-glucan or 1.7 g of soluble fibre per serving can reduce the risk of heart disease (FDA, 2001). Besides, oat β-glucan is also specifically included in recent National Cholesterol Education Program American Heart Association guidelines (NIH-NHLBI, 2001). Therefore, β-glucan is regarded as a potential functional food ingredient in food industry.

OBJECTIVES:

The primary objective of this study is to develop a high fibre noodle with potential health benefits and functional properties by incorporation of green banana flour and oat β-glucan as the fibre source. Other specific objectives are:

1. To determine the feasibility of using green banana flour as a source of fibre in noodles in term of its chemical, physical and sensory attributes.
2. To evaluate the effect of added oat β-glucan in noodles in term of its chemical, physical and sensory attributes.
3. To study the functional effect of added of green banana flour and oat β-glucan on carbohydrate digestibility, glycemic indexes and antioxidant properties of noodles.
4. To study the effects of added green banana flour and oat β-glucan on the shelf – life of noodles.
5. To study the effect of different drying temperature on the fracturability of dried noodles strands

This project was also aimed at better utilisation of underutilised local fruit - *Musa paradisiaca var. Awak* in the processed food industry.

CHAPTER 2: LITERATURE REVIEW

2.1 *Musa*

Banana belongs to the family Musaceae, genus *Musa* and is a general term embracing a number of species or hybrids in this genus. The name *Musa* is from the Sanskrit, *Moca*, via its Arabic counterpaert, *mauz*. Bananas descended from two wild ancestors: *Musa acuminate* and *Musa balbisiana* (Lehmann *et al.,* 2002; Robinson, 1996; Stover & Simmonds, 1987a), which are native from Southeast Asia. By now, 700 varieties of *Musa* are known and 100 varieties from them are cultivated.

There are three common species of *Musa,* which include *Musa Cavendishii, Musa paradisiaca* and *Musa sapientum. Musa cavendishii* is pure triploid acuminate (AAA group) and is type of dessert banana. Cavendish is one of the most important fruit grown commercially in large scale for world export trade. *Musa paradisiaca* is a type of plantain, which is normaly, cooked before eaten while *Musa sapientum* known as true banana is usually eaten raw at maturity. Both *Musa paradisiaca* and *Musa sapientum* belong to AAB group (Stover & Simmonds, 1987b) and are characterized by the higher starch concentration.

Bananas and plantains are the developing world's fourth most important food crop after rice, wheat and maize. This crop is grown in 120 countries throughout the tropics and sub-tropics. The worldwide production of bananas in 2001 was 66.5 million tones and increased to 102 million MT of which 68% as banana and 32% plantain by 2002 (FAO, 2003). Besides, world banana exports are projected to reach almost 15 million tones in 2010. More than 85% of global banana production is produced by small-scale farmers, providing an important source of food and income. The world's leading banana exporter is Ecuador, followed by Costa Rica and Colombia.

Musa is one of the cheapest food crops to produce and the cost of production is less than most other staples. Besides been used primarily as dessert, banana fruit may be processed into pulp-liquid fruit, canned slice, deep-fried chips, toffees, fruit bars, brandy and etc. (Kachru *et al.,* 1995; Morton, 1987). In addition, the by-products of banana such as the leaves, fibres and pseudostem extract have been reported to have some commercial value such as animal feeds, medicines and crafts. India, with rich bio-diversity of banana and plantain, is the largest producer and consumed of banana in the world with an estimated production of 16 million tones of bananas annually.

2.1.1 Plantains

Plantains are a major food crop in the tropical and subtropical zones of the world. World production of plantain in 2003 is shown in Table 2.1. In West and Central Africa, plantains provide the major staple food for the population with an annual production of more than 10 million tones (INIBAP, 2003). Plantain produces fruit throughout the year but is harvested between the harvests of other starchy staples such as cassava and yam.

Table 2.1: World production statistics of plantain in 2003

Country	***Production (x 1000 MT)***
South America	6362
Colombia	2925
Peru	1600
Ecuador	860
Venezuela	760
Central America and Caribbean	2261
Cuba	797
Asia	1040
Sri Lanka	610
Total	**32,974**

Source: FAO (2003)

Plantains are very similar to the unripe dessert bananas outwardly in appearance. The fruit of plantain is larger, coarser and less sweet. Complete matured green plantain contains 50% flesh and 50% peel. Pulp content in the range of 55% - 60% is considered commercially acceptable (Morton, 1987). The green plantains are usually dried, ground fine and roasted. Plantain powder or flour has been used widely as an ingredient in the food industries (Morton, 1987).

2.1.2 Nutritional values of *Musa*

Banana is a well known source of carbohydrates and dietary fibre. Bananas have long been recommended as dietary supplements for individuals suffering from digestive disorders. According to Mota *et al.* (2000), green banana fruit contain higher hemicelluloses content (6.08%) than most fruits and vegetables. Apart from dietary fibre, green bananas contain high amount of essential minerals such as potassium, and various vitamins such as A, B_1, B_2 and C (Chandler, 1995).

The amount of nutrient in banana and plantain is similar except for plantain which is much starchier than banana because plantain contains 17% starch while banana contains less than 5% starch (Ketiku, 1973). Both bananas and plantains contain significantly high in potassium (400mg/100g pulp) and trace amount of sodium (1mg) and iron (Stover, 1987a). They also have similar levels of B vitamins thiamine, niacin and riboflavin. Plantain has greater amount of vitamin A than bananas (Chandler, 1995). Plantains are rich in vitamin C, providing approximately 20mg for every 100g of flesh which is higher than banana (10mg/100g) (Chandler, 1995).
Because of the low lipid and high energy value, bananas are recommended for obese and geriatric patients (Gasster, 1963). Bananas are useful for persons with peptic ulcer, for treatment of infant diarrhea, in celiac disease and in colitis (Seelig, 1969). Many studies proven that dried unripe plantain or banana pulp powder was anti-

ulcerogenic against aspirin-induced ulceration and was effective in prophylactic treatment and in healing ulcers (Dunjic *et al.,* 1993; Goel *et al*, 1989; Mukhopadhyaya *et al.,* 1987; Best *et al.,* 1984). Bananas are also useful for the treatment of infant diarrhea, celiac disease and in colitis (Seelig, 1969).

2.1.3 Banana Flour

Banana and plantain can be produced in many different ways, such as frozen puree, juice, figs, jams and canned banana slices (Thompson, 1995). Seasonal gluts and perishability of ripe bananas and plantains caused great economic losses and therefore there is tremendous interest in the development of modes of processing and preserving these fruits.

A novel way of utilizing these green bananas is to process the fruit into flour. In the flour form, the shelf life can be extended and provide easy storage. Banana or plantain flour is made domestically by sun-drying the slices of unripe banana and pulverizing. Commercially, it is produced by spray-drying, or drum-drying the mashed fruits. The plantain cultivars 'Saba', 'Tundoc' and 'Latundan' are very suitable for making flour (Morton, 1987).

Banana flour is rich in starch granules and this biopolymer constitutes an excellent raw material which modifies the texture and consistency of food. Consequently, banana flour appears to have some commercial potential by itself or as bases with other foods such as in baby weaning foods, puddings, soups and gravies.

Table 2.2: Nutritional values for the plantain and banana (per 100g edible portion)

	Banana				Plantain			
	Ripe	**Green**	**Dried**	**Flour (green)**	**Ripe**	**Ripe (cooked)**	**Green**	**Dried (green)**
Calories (kcal)	65.5-111	108	298	340	110.7-156.3	77	90.5-145.9	359
Moisture (g)	68.6-78.1	72.4	19.5-27.7	11.2-13.5	52.9-77.6	79.8	58.7-74.1	9.0
Protein (g)	1.1-1.87	1.1	2.8-3.5	3.8-4.1	0.8-1.6	1.3	1.16-1.47	3.3
Fat (g)	.016-0.4	0.3	0.8-1.1	0.9-1.0	0.1-0.78	0.10	0.10-0.12	1.4
Carbohydrates(g)	19.33-25.8	25.3	69.9	79.6	25.50-36.81	18.1	23.4-37.61	83.9
Fibre (g)	0.33-1.07	1.0	2.1-3.0	3.2-4.5	0.30-0.42	0.2	0.40-0.48	1.0
Ash (g)	0.60-1.48	0.9	2.1-2.8	3.1	0.63-1.40	0.7	0.63-0.83	2.4
Calcium (mg)	3.2-13.8	11	-	30-39	5.0-14.2	-	10.01-12.2	50
Phosphorus (mg)	16.3-50.4	28	-	93-94	21.0-51.4	-	32.5-43.2	65
Iron (mg)	0.4-1.50	0.9	-	2.6-2.7	0.40-0.11	-	0.56-0.87	1.1
B-Carotene (mg)	0.006-0.151	-	-	-	0.11-1.32	-	0.06-1.38	45
Thiamine (mg)	0.04-0.54	-	-	-	0.04-0.11	-	0.06-0.09	0.10
Riboflavin (mg)	0.05-0.067	-	-	-	0.04-0.05	-	0.04-0.05	0.16
Niacin (mg)	0.60-1.05	-	-	-	0.48-0.70	-	0.32-0.55	1.9
Ascorbic Acid (mg)	5.60-36.4	-	-	-	18-31.2	-	22.2-33.8	1
Tryptophan (mg)	17-19	-	-	-	8-15	-	7-10	14
Methionine (mg)	7-10	-	-	-	4-8mg	-	3-8mg	-
Lysine (mg)	58-76	-	-	-	34-60mg	-	37-56mg	-

Source: Morton (1987)

2.2 Wheat Flour Noodle

Noodle is one of the main staple foods consumed in East and South East Asian countries. It is believed that noodles originated in the north of China as early as 5000 B.C. With widespread Chinese migration and emigration, increased travel and trade, noodle was taken across the country and spread into these areas. According to Miskelly and Gore (1991), the similarities of the generic words for noodles [*mian*, *mien* or *mi* (China); men (Japan); *mie* (Indonesia); and *mee* (Thailand, Singapore and Malaysia)], support this common origin. Besides, the importance of noodle products throughout South East Asia can best be summarized by the fact that they account for 30 – 40 percent of most countries total wheat flour consumption (Miskelly, 1993).

The terms *pasta* and *noodles* are often used interchangeably. However, the two products are very different in term of their raw materials and method of manufacture (Hou and Mark, 1998). Pasta is made from coarse semolina milled from durum wheat while noodles are generally made from hexaploid or common wheat. According to Crosbie *et al., (*1992), Asian noodles are commonly classified according to:

1. size of the noodle strands
2. the nature of the raw materials used in their manufacture
3. the method of preparation
4. the presence of alkaline salt in formula

Asian noodles consist of strands that vary in shape, width, and length, prepared from various flours, such as wheat flour, rice flour, potato flour, soybean flour, and mung bean flour. Some Asian noodles are made with eggs but many do not contain any eggs. Asian noodles vary in colours, such as translucent white, opaque white, cream yellow, tan and brown. The noodle is available in the market in the dry or wet form. Asian noodle is eaten hot or cold, and is used in soups, salads, stir-fries, and other Asian dishes. Generally, noodles can be broadly classified into three main groups: a) white-salted noodles, b) yellow-alkaline noodles and c) instant noodles. Due to their short cooking requirement and availability, noodle is often used as convenience food.

2.2.1 Alkaline Noodle

Although it is believed that noodles based on simple flour and water dough were developed in the north of China, the addition of alkaline salts appear to have originated in south-eastern China. Alkaline noodles disseminated from China and were soon adopted by many South East Asian countries (Burum, 1985).

Yellow-Alkaline noodle is essentially made from flour (100 parts), water (32-35 parts), and solution of alkaline salts known as *kansui* or lye water (1 part). There are many several types of Asian noodles which contain alkaline salt. Chinese wet noodles, Hokkien noodles, Cantonese noodles, Japanese chukka-men, Thai bamee and instant noodles fall under the yellow alkaline noodle category and they are vary mainly in the final stages of manufacture. The most popular types of noodles are the fresh, dried and ‘wet’ or boiled noodles. Boiled noodle is popular in Malaysia, Singapore and Indonesia, which is also known as ‘Hokkien noodles’.

Hokkien noodle is boiled for 1 – 2 minutes during processing, leaving a fine ungelatinized core in the centre (Moss, 1982). The moisture content is generally between 50 – 60% (Karim, 1990). Hokkien noodle is quickly re-cooked by boiling or frying prior to consumption.

Table 2.3: Noodle Formulation and Processing in the Laboratory

	Type of Noodle in Asian					
	Chuka - Men	**Cantonese Noodle (wet-type)**	**Malaysia Hokkien Noodle**	**Japanese Udon**	**Instant Noodle or Ramen**	**Thailand Bamee**
Flour	100	100	100	100	100	100
Water	32	32	30 – 33	32	34 – 37	28
Salt	1	2	2	2	1.6	3
Potato Starch	-	-	-	-	0 – 1.2	-
Sodium Hydroxide	-	-	0.5	-	-	-
Sodium Carbonate	0.4	0.45	-	-	0.1	1.5
Potassium Carbonate	0.6	0.45	-	-	0.1	-
Eggs	-	-	-	-		10
Guar Gum	-	-	-	-	0 – 0.2	-
Polyphosphates	-	-	-	-	0 – 0.1	-

(Hou and Kruk, 1998)

2.2.2 General Noodle Processing Technology

Noodle production is a simple process (Figure 2.1) involving mixing of flour, water and various salts into crumbly dough, which is then sheeted through roller and cut into strings to produce raw noodles. Further processing is required to produce the other noodle types. Nowadays most noodles are mass produced by mechanical means. The noodle-making process is remarkably constant from the smallest scale machine production to the largest scale factory.

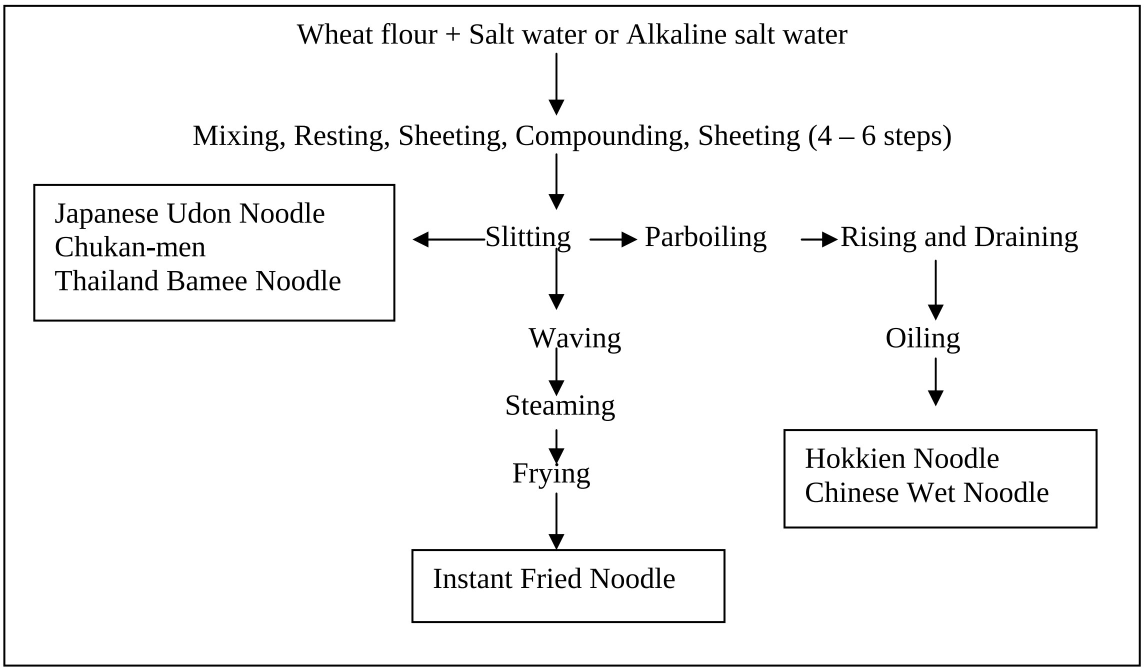

Figure 2.1: Noodle making process (*Source: Hou and Kruk, 1998*)

Mixing: The main aim of mixing is to uniformly distribute the ingredients and hydrate flour particles and protein to form low- moisture crumbly dough. There is little gluten development during the mixing stage in the low water content noodle dough.

Compression: The crumbly dough is sheeted between steel rollers in a noodle machine. During this stage, although the visual appearance of the dough is quite uniform, dough development is still not complete (Moss *et al*., 1987).

Dough Resting: Resting or aging is accomplished by storage of dough in a plastic bag for 30 minutes. Resting the dough before sheeting is beneficial in all production. It produces a smoother dough sheet as it helps to improve starch gelatinization and assists in the even hydration of flour particles promoting better gluten development. Resting of dough also produces cooked noodles with firmer eating quality (Moss *et al.*, 1987).

Sheeting: The compressed dough sheet is reduced stepwise in thickness by successive passes through a roller, with reduction in the gap setting. Roll gap is normally reduced by up to 30% each pass and usually accomplished with six or seven sheeting passes. The function of sheeting is to form a sheet of dough with a uniform thickness and gluten development. During the reduction stage, gluten is fully developed to obtain a uniform protein matrix in noodle.

Cutting: The finished dough sheet is passed through a pair of slotted cutting rolls to produce noodle strands. Typically, the width of noodles can vary from 0.6 – 6.0mm, depending on the type of noodle being made. For Hokkien noodles, the width is about 2.5mm.

2.2.3 Assessing Noodle Quality

Quality of noodle is evaluated in term of colour (Miskelly, 1984), texture (Ross *et al.,* 1997; Lii and Chang, 1982) and cooking characteristic (Oh *et al.,* 1985a). Qualities of the noodles are determined by the raw materials, ingredients and process technology in which starch and protein play the major roles.

2.2.3.1 Colour

The colour of noodle is one the most important quality parameter perceived by consumer (Mares and Campbell, 2001). Each type of noodle has its own unique colour and the preference varies with the region (Shelke *et al.,* 1990). For example, Chinese-type noodle (ra-men, chukka-men) required a bright yellow colour while Japanese noodle is creamy white and for buckwheat or soba noodle, light brown or grey is desirable.

Although preferences vary according to region, generally noodles require good brightness and retain a stable colour for 24–48 hours after preparation is desirable (Hou and Kruk, 1998). Brightness and yellowness are the two distinct aspects in colour evaluation of alkaline noodle. Brightness value (L*) higher than 60, with a maximum value of 100 is desired for yellow noodle. It also should also show high positive b* that indicate a desirable yellow colour. In contrast, redness (+a*) value is undesirable hue in alkaline noodles.

Noodle colour is contributed by several factors such as flour colour, flour extraction rate, protein and ash content in flour and also the presence of alkaline salts in noodle preparation. In contrast to the noodles containing only salt which are cream or white in colour, alkaline noodle are yellow. The natural yellow colour of noodle is attributed to the presence of xanthophylls (Mares *et al.,* 1997) and apigenin-glycosides (type of natural flavones) in flour (Mares, 1992). The latter compounds are colourless at neutral or acid pH but turned yellow at higher pH as lye water (type of alkaline salt) is added). The degree of yellowness in noodles is depending on the type of alkaline salt used in formulation (Miskelly, 1984), content of yellow pigment and other flavonoid component such as tricin found in wheat flour.

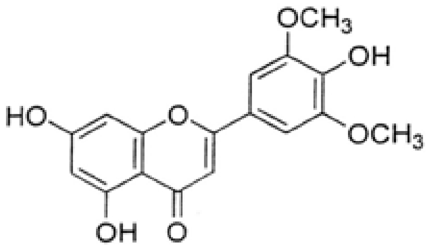

Figure 2.2: Structure of a flavonoid pigment (tricin) from wheat flour (*Source: Hudsan, et al., 2000*)

2.2.3.2 Texture

Texture is one of the critical characteristics in quality evaluation of noodle. Elasticity, adhesiveness and firmness are the main parameters that are measured in texture evaluation of noodle (Crosbie *et al.,* 1990; Miskelly and Moss, 1985). In Japan, noodle should be smooth, soft and elastic in texture while noodle with firmer texture is preferred in China and Korea (Konik and Miskelly, 1992). Table 2.4 described the general texture characteristics for each type of noodle. Both protein (Oh *et al.,* 1985a, b) and starch (Crosbie, 1990; Toyokawa *et al.,* 1989; Oda *et al.,* 1980; Nagao *et al.,* 1977) play a major role in governing the textural properties of noodle but varies with noodle type. For instance, starch pasting quality is the primary trait to determine the eating quality for Japanese and Korean noodles whereas protein quantity and strength are very important to Chinese-type noodle (Huang and Morrison, 1988).

For alkaline noodle, high score are allocated to noodle with smooth surface, firm and elastic texture (Ross *et al.,* 1997; Kim *et al.,* 1996; Shelke *et al.*, 1990; Moss *et al.,* 1987). Thus, Cantonese noodle, Chuka-men, Malaysian hokkien noodle and Thailand bamee noodle are usually made from high protein flour which contributed firmer bite for noodles. Excellent quality of yellow alkaline noodle can be produced by using wheat flour with 10 – 12% protein. Besides, lye water added in alkaline noodle also helps to improve the texture of noodle. Lye water helps in delaying the hydration of gluten and prevents development of gluten during mixing and resting dough steps and thus gives a continuos matrix to noodle dough which then produced noodle with firm and smooth surface noodle (Rho *et al.,* 1988).

Table 2.4: Asian noodle texture evaluation

Noodle type	Texture requirement
Japanese Udon	Soft bite and elastic; good mouthfeel; stable texture in hot water
Cantonese noodle	Good bite, chewy and elastic; less sticky; stable texture in hot water
Malaysian Hokkien	Good bite, chewy and elastic; less sticky;
Chuka-men	Good balance of softness and hardness; elastic; smooth; less texture deterioration in hot water
Thailand Bamee	Good bite, springy and smooth texture

Source: Hou and Kruk (1998)

2.2.3.3 Cooking characteristic

Cooking quality includes water gain, cooking loss, surface characteristic and tolerance to overcooking. According to Moss *et al.,* (1987) and Huang and Morrison (1988), addition of alkaline salt in noodle formulation had prolonged the optimum cooking time (60 – 120 seconds). A higher value of gain weight will produce higher yields and more profits for the processor.

2.2.4 Dried Noodle

Fresh noodles have a limited shelf life and are prone to enzymatic darkening due to the activity of enzyme polyphenoloxidase. Thus, dried noodle is produced to extend the shelf life and retain the bright colour when of noodle during storage.

Dried noodles had a long history as an industrial product in China (Huang, 1996). They are the most popular commercially produced noodles. Dried noodles have the advantages in terms of economy, longer shelf life, ease of transport, and easy to cook. In dried noodles, colour and opaqueness are major factors to determine the quality. To obtain optimum quality, the key step in dried noodle production is the controlled drying process.

Dried noodles are hung to dry, either in the sun or in a special controlled temperature and humidity drying chamber, to about 8 – 10% moisture (Oh *et al.,* 1985b; Corke and Bhattacharya, 1999). Many of the pasta drying technology, included high (HT) and very high (THT, trés haute temperature) appear applicable to noodle production (Pollini, 1996). However, rapid drying using high temperature is known to be troublesome. It caused noodle cracking and deformation due to the limited strength to withstand the internal stress (Inazu *et al.,* 2002). Thus, drying process is divided into three steps in noodle industry. In the first stage, low temperature is used to remove the surface moisture. In the second or main drying stage, internal water from noodle strand is removed by using higher temperature and controlled humidity. The main drying stage which occupies the longest drying time will governs the product quality. In the final stage, the product is further dried using cool air. In dried noodles, colour and opaqueness are major quality factors. Thus, to obtain optimum quality, the key step in dried noodle production is the controlled drying process.

2.3. Dietary Fibre

Dietary fibre (DF) is defined as non-digestible carbohydrate and lignin from the edible fraction of plant that resistant to hydrolysis, digestion and absorption in small intestine of human digestive tract (Prosky, 1999; Mugford, 1991; Southgate *et al.,* 1978; Trowell *et al.,* 1976). However, according to Charalampopoulos *et al.*, (2002) and Prosky (1999), fibre is not totally unavailable but portion of dietary fibre is fermented to volatile fatty acids in human large intestine. According to America Dietetic Association (ADA), the recommended fibre intake for Malaysian is 20 – 30g/day (25 – 30g/day for insoluble fibre and 10 – 13g/da for soluble fibre) for for all age group. However, the British Nutrition Foundation has recommended a minimum fibre intake of

12 – 24g/day for healthy adults while in developing countries range is 60 – 120g/day (Fuchs *et al.,* 1999).

Total dietary fibre (TDF) is divided into two categories, which are water-soluble and insoluble fibre. They are characterized in term of the water solubility in water at 100^{o}C and pH6 – 7 of the fibre fraction (Grigelmo-Miguel and Martin-Belloso, 1999). Both the water-soluble fibre and insoluble has beneficial effects towards human health but have distinct chemical characteristic and provides different therapeutic effects.

Soluble dietary fibre (SDF) is water-soluble food material that resists the hydrolysis by alimentary tract enzymes but form viscous solution and will be highly fermented by microflora in human large intestine. SDF mainly consists of β-glucan, pectins and variety source of gums (Howarth *et al.,* 2001; Prosky and DeVries, 1992). By forming a viscous gel matrix, soluble fibre has been shown to be able to bind bile salts which may reduce blood cholesterol levels. It also may slow the absorption of glucose from the intestine, thereby requiring less insulin secretion. Therefore, SDF is effective in delay gastric emptying (Howarth *et al.,* 2001), reducing serum cholesterol (Gallaher *et al.,* 1999; Prosky and DeVries, 1992), insulin contents and prostprandial blood glucose (Pick *et al.,* 1996) in human body. Consequently, help to reduce the risk of colon cancer, diverticulosis diabetes and coronary heart disease (Prosky and DeVries, 1992).

Insoluble fibre (IDF) is enzymatic indigestible plant material in human alimentary system and is not soluble in hot water. IDF components include cellulose (major amount), hemicellulose, lignin, cutin and plant waxes. IDF is mainly related to intestinal regulation and is better for alimentary system dysfunctions, such as reduce rates of constipation, hemorrhoids and also protect against colorectal cancer (Prosky and DeVries, 1992).

2.3.1 Hemicellulose

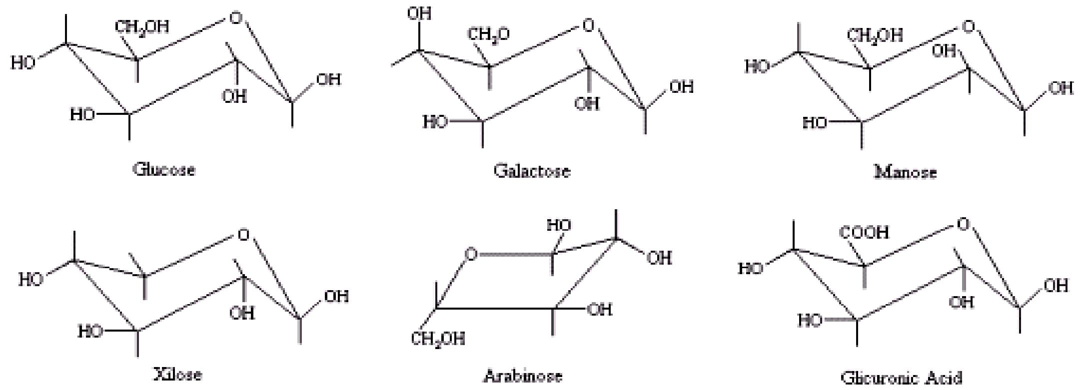

Figure 2.3: Chemical structures of the main components of hemicellulose (*Source: Resende, 2005*).

Hemicelluloses are made up of relatively short chain xylose (xylan polymer) or of a mixture of glucose and mannose (glucomannan polymer) bonded in β-1-4 linkage configurations. Attached to this main structure are side chains of glucose, arabinosa, galactose, mannose, galacturonic and glucuronic acid (Wisker *et al.,* 1985). Side chains of hemicelluloses can be produced by hydrolysis and the chain structure varies in different plant origin. Distinguish from cellulose; hemicellulose is easily hydrolyzed by dilute acid or base and in water. This is because hemicellulose has a random, amorphous structure with little strength. According to Southgate (1976) and VanSoest and Robertson (1977), among most fruit and vegetable, the content of hemicellulose in banana is higher.

2.4. Resistance Starch (RS)

Resistant starch has been defined as the fraction of starch, which escapes digestion in the small intestine but be digested in the large intestine after 5 to 7 hours of consumption (Muir *et al.,* 1995; Englyst and Cummings, 1992). Resistant starch is naturally found in cereal grains or form when starch or starch-containing foods are heated. According to Haralampu (2000); Eerlingen *et al.*, (1993), and Englyst and Cummings (1992), these indigestible starch fractions commonly are classified into four categories as follow:

i. RS1 corresponds to the physically inaccessible to digestion by entrapped in a cellular matrix.
ii. RS2 are native starches with B-type crystal in raw botanic such as potatoes and green banana.
iii. RS3 is mainly consisting retrograded amylose or high amylose starches.
iv. RS4 consists of chemically modified starches.

Recently, numerous nutritional studies have elucidated the chemically and physiological benefits of resistant starch. RS is quantified as part of the insoluble fraction in many fibre assays; however, it behaves physiologically similar to soluble and fermentable fibre (Haralampu, 2000). RS is also known as a type of functional fibre which can be added to food, and would be listed as an ingredient on food lables. A wide range of short-chain fatty acid (SCFA), primarily acetate, propionate and butyrate is produced during fermentation of RS by colonic microflora (Kritchevsky, 1995; Phillips *et al.,* 1995; Silvester *et al.,* 1995; Muir *et al.,* 1994). SCFA is an important substrate to reduce the ulcerative colitis and colon cancer but promoting the lipid and cholesterol metabolism. Present of SCFA also increase the absorption of magnesium and calcium in human body. The physiological importance of RS has been investigated in relation to reduce the glycemic index and insulinemic responses, which beneficial in the management of diabetes (Garcia-Alonso *et al.,* 1999; Kabir *et al.,* 2002). This is because RS is slowly absorbed and association of RS with an increased malabsorption of starch in small intestine (Haralampu, 2000). According to Yue and Waring (1998), in addition to its therapeutic effects, including RS in food products do not cause pronounced sensory alterations. Consequently, RS provide better appearance, texture and mouthfeel than conventional fibres to food products (Martinez-Flores *et al.,* 1999).

2.5 Oat Beta (β) Glucan

Beta Glucan (β-glucan) is the major component in the endosperm of oat (*Avena sativa* L.). Chemically, it is referred to of a heterogeneous water-soluble cell-wall polysaccharides consisting of (1→3, 1→4)-linked β-D-glucopyranosyl monomer. In the native state, the molecular weight of oat β-glucan is up to 3 million Daltons, consisting about 20000 glucosidyl units. Relative to other cereal grains, oat contains significantly higher amount of β- glucan (3 – 5%) (Drzikova *et al.,* 2005; Wood, 2002; Asp *et al.,* 1992) and some oat cultivars even contain as much as 6 - 8% (Ganβmann, 1998; Miller *et al.,* 1993; Welch and Lloyd, 1989). However, oat bran contains considerably proportion of β-glucan (about 50%) as compared to the whole groats of oat (Asp *et al.,* 1992; Aman and Graham

Many studies had shown that consumption of food containing β-glucan or β-glucan-enrichment fractions have positive effects on human health. When β-glucan is ingested in the stomach, it swells and gradually dissolves in water and form gel-like solution. By forming viscous solution, β-glucan delays gastric emptying, slow down the intestinal transit rate and also reduces plasma cholesterol, glucose and insulin concentrations in human. Also, according to Drzikova et al. (2005), β-glucan is able to affect bile acid binding and fermentation in vitro. Moreover, β-glucan had high apparent viscosity, water holding and emulsion stabilizing capacities. It is postulated that these specific properties of β-glucan enable it to be used as fat replacer and thickening agent in food products such as bread (Knuckles *et al.,* 1997), mayonnaise (Worrasinchai *et al.,* 2006) and cheese (Konuklar *et al.,* 2004; Volikakis *et al.,* 2004).

2.6 Antioxidant

Antioxidants are found abundant in several types of plant materials such as vegetables, fruits, cereal crops, spices and herbs (Table 2.5). Most of these substances are polyphenol components, types of secondary metabolites of plants (Walton *et al.* 1999). Therefore, consumption of diet high in fruits and vegetables can significantly increase the antioxidant capacity in human plasma and have strong protective effects against major disease risks.

Polyphenol components play important roles as reducing agent, hydrogen donor, metal chelators and singlet oxygen quenchers, which are attributed by their scavenging properties (Rice-Evans *et al.,* 1995). Thus, antioxidants can neutralize the free radicals and oxygen radicals produced in biological systems. According to Moskovitz *et al.,* (2002), free radicals have been associated with etiology and progression of diseases and ageing.

On the other hand, in food industries, antioxidants are usually used in inhibition of lipid oxidation in red meat, poultry, fish (Tang *et al.,* 2001a; McCarthy *et al.,* 2001) and also bakery products. Antioxidants help to inhibit rancidity and prolong the shelf life of food products. However, compared to natural antioxidants, synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisol (BHA) and propyl gallate (PG) are widely used in food industries. Due to carcinogenic and toxic components which will be released during degradation (Ito *et al.,* 1985), natural antioxidants including catechins, epicatechin, gallocatechin, and α- tocophenol can be used as alternative in food.

Recently, many epidemiological studies have found that there is a significant positive effect of antioxidant intake towards human health. These included improve