PHYSICO-CHEMICAL PROPERTIES OF SPONGE CAKE MADE FROM WHEAT FLOUR INCORPORATED WITH MANGO (*Mangifera Indica var.* Chokanan) PULP AND PEEL FLOUR

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by

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LIST OF ABBREVIATIONS

AA	Ascorbic acid
APC	Aerobic plate count
BHA	Butylated hydroxyanisol
BHT	Butylated hydroxytoluene
Cm	Centimeter
CFU	Colony forming unit
°C	Degree celcius
DPPH	1,1-Diphenyl-2-picrylhydrazyl
EA	Emulsifying activity
ES	Emulsion stability
FRAP	Ferric reducing antioxidant power
FC	Foaming capacity
GAE	Gallic acid equivalent
GOD-PAP	Glucose oxidase peroxidase
GI	Glycemic index
G	Gram
Ha	Hectares
H	Hour
HI	Hydrolysis index
IDF	Insoluble dietary fibre
Kcal	Kilocalorie
Kg	Kilogram
kJ	Kilojoule

LGC	Least gelation concentration
L	Liter
MR	Maillard reaction
MRPs	Maillard reaction products
MPeF	Mango peel flour
MPP	Mango peel powder
MPuF	Mango pulp flour
µg	Microgram
µl	Microliter
µm	Micrometer
mM	Milimolar
Mg	Milligram
Ml	Milliliter
Min	Minute
M	Molar
Nm	Nanometer
%	Percentage
Oz	Ounce
PaO	Pheophorbide-a-oxygenase
PDA	potato dextrose agar
PPO	Polyphenol oxidase
pGI	Predicted glycemic index
PG	Propyl gallate
QE	Quercetin equivalent
RDS	Rapidly digestible starch

Rpm	Rate per minute
RNS	Reactive nitrogen species
ROS	Reactive oxygen species
RS	Resistant starch
s	Second
SCFA	Short chain fatty acids
SDS	Slowly digestible starch
SDF	Soluble dietary fibre
SEM	Scanning Electron Microscope
TPA	Texture profile analysis
TPC	Total phenolic content
TS	Total starch
$TEAC_{DPPH}$	Trolox equivalent antioxidant capacity for 1,1-diphenyl-2-picrylhydrazyl
$TEAC_{FRAP}$	Trolox equivalent antioxidant capacity for ferric reducing antioxidant power
v/v	Volume per volume
a_w	Water activity
WRC	Water retention capacity
w/v	Weight per volume
WF	Wheat flour

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PENILAIAN FIZIKO-KIMIA DALAM KEK SPAN TEPUNG GANDUM YANG DIGANTIKAN DENGAN TEPUNG ISI DAN KULIT MANGGA (*Mangifera Indica* var. Chokanan)

ABSTRAK

Objektif kajian ini adalah untuk mengkaji sifat-sifat fiziko-kimia, pemakanan dan organoleptik kek span yang disediakan dengan penggantian-separa tepung gandum dengan tepung isi dan kulit mangga (MPuF dan MPeF, masing-masing) pada peratusan yang berbeza (kawalan, 5, 10, 20 dan 30%). Dalam kajian ini, komposisi kimia, kompaun antioksidan dan sifat-sifat fungsi bagi MPuF dan MPeF telah dikaji. Berbanding dengan tepung gandum (WF) komersial, MPuF dan MPeF mempunyai kandungan lembapan dan protein yang lebih rendah secara signifikan ($p<0.05$), tetapi tinggi dalam kandungan gentian kasar dan abu. MPuF dan MPeF mempunyai keseimbangan dalam perkadaran gentian dietari larut (SDF), dietari tidak larut (IDF), adalah antara 29 hingga 35% dan 65 hingga 70% daripada jumlah gentian dietari (TDF), masing-masing. MPuF dan MPeF juga mempunyai kandungan antioksidan lebih tinggi berbanding WF. Kapasiti penyerapan air (WAC) dan kapasiti penyerapan minyak (OAC) bagi MPuF dan MPeF adalah antara 0.54 hingga 0.87 g/kg dan 0.20 hingga 0.22 g/kg, masing-masing. Keputusan kajian ini menunjukkan bahawa MPuF dan MPeF merupakan sumber gentian dietari yang kaya dengan antioksidan dan mempunyai sifat-sifat fungsi yang sesuai digunakan sebagai bahan berfungsi dalam penyediaan kek dan produk-produk lain untuk meningkatkan nilai pemakanan dan kualiti makanan. Penambahan MPuF dan MPeF dalam kek span telah meningkatkan kandungan IDF, SDF, TDF dan kanji rintang (RS) secara signifikan ($p<0.05$), manakala menurun kandungan lemak dan nilai kalori. Selain itu, adalah didapati MPuF dan MPeF dapat mempertingkatkan kandungan pemakanan kek span secara signifikan ($p<0.05$) dari segi sifat pengoksidaan (kandungan total polifenol, vitamin C, karotenoid, antosianin, flavonoid dan aktiviti anti pengoksidaan) dan kesan ‘postprandial respon glisemik dan kadar penghadaman kanji. Penambahan 30% MPeF dalam kek span mempunyai sifat pengoksidaan yang paling tinggi, dan paling rendah dari segi hidrolisis indek (HI), anggaran glisemik indek (pGI) dan kadar penghadaman kanji *in-vitro*. Penggantian peningkatan peratusan MPuF dan MPeF dalam kek span telah mempengaruhi kesan isipadu, kekerasan, warna secara signifikan ($p<0.05$). Analisis penilaian deria mendapati 10% MPuF dan 10% MPeF kek span menunjukkan penerimaan keseluruhan yang paling tinggi. Penambahan optimum MPuF dan MPeF yang sesuai diganti ke dalam kek span adalah 10%. Keputusan analisis mikrobiologi menunjukkan bahawa hitungan plat aerobik (APC) dan hitungan yis dan kulat dalam kek span melebihi 10^3 CFU/g selepas tiga hari penyimpanan pada suhu ambien (25^{o}C). Kajian penstoran menunjukkan bahawa jangka hayat biasa kek span adalah selama tiga hari dan kini telah boleh dilanjutkan sehingga lima hari pada suhu penyimpanan yang rendah (<4°C).

PHYSICO-CHEMICAL PROPERTIES OF SPONGE CAKE MADE FROM WHEAT FLOUR INCORPORATED WITH MANGO (*Mangifera Indica var.* Chokanan) PULP AND PEEL FLOUR

ABSTRACT

The objective of this research was to determine the physico-chemical, nutritional and organoleptic attributes of sponge cake by partial substitution of wheat flour with mango pulp and peel flour (MPuF and MPeF, respectively) at different levels (control, 5, 10, 20 and 30%). In the present study, the chemical composition, antioxidants and functional properties of MPuF and MPeF were evaluated. Compared to the commercial wheat flour (WF), the MPuF and MPeF were significantly ($p<0.05$) low in moisture and protein, but high in crude fibre and ash content. The MPuF and MPeF showed a balance in soluble and insoluble dietary fibre (SDF and IDF) proportions, ranging from 29 to 35% and 65 to 70% of total dietary fibre (TDF) content, respectively. The MPuF and MPeF exhibited high values for antioxidants as compared to WF. The water and oil absorption capacity (WAC and OAC) of MPuF and MPeF ranged from 0.54 to 0.87 g/kg and 0.20 to 0.22 g/kg, respectively. Results showed that MPuF and MPeF is a rich source of dietary fibre with good antioxidant and functional properties which can be a value-added ingredient utilized in the preparation of cake and other bakery products to improve nutritional qualities. Addition of MPuF and MPeF in sponge cake significantly ($p<0.05$) increased the IDF, SDF, TDF and resistant starch (RS) content, but decreased the fat content and calorie value. Furthermore, it was also found that MPuF and MPeF could significantly ($p<0.05$) improve the nutritional properties of the sponge cakes in terms of the antioxidant properties (total polyphenol, vitamin C, carotenoid, anthocyanin and flavonoid content, antioxidant activity), effect of postprandial glycemic responses and starch digestibility. Sponge cake incorporated with 30% MPeF showed the greatest antioxidant properties, lowest hydrolysis index (HI), predicted glycemic index (pGI) and *in-vitro* starch digestion rate among all samples. Increasing the levels of MPuF and MPeF in sponge cake had significant impact on the volume, firmness and colour. Sensory evaluation showed sponge cake formulated with 10% MPuF and 10% MPeF to be the most acceptable. The optimum level of MPuF and MPeF incorporated into sponge cake is 10%. Results from microbiological analyses showed that aerobic plate count (APC) and yeast and mould count of sponge cakes were more than 10^3 CFU/g after three days of storage at ambient temperature (25^{o}C). Result from storage studies indicated that the shelf life of sponge cake usually ranged for three days and can now be extended to five days by low temperature (<4°C) storage.

CHAPTER ONE

1.0 INTRODUCTION

Mango (*Mangifera Indica* L.) is one of the most important tropical fruits in the world with regard to production and consumers acceptance. Currently, mango is ranked fifth in the total production among the major fruit crops of the world (FAO, 2004). In Malaysia, there are only a few potential varieties that are marketable, and Chokanan variety is one of the most popular and commonly consumed mango. Thus, in this study, the Chokanan variety was selected in this study due to its pleasant flavour and a unique sweet taste. Besides, it is also recommended for commercial planting both for processing (to prepare jam, candy, nectar, pickle, canned slice and chutney etc) and for direct consumption. However, mango being a highly perishable seasonal fruit; significant post-harvest wastage occur during its peak season due to deficient post-harvest handling procedures employed. According to Djantou *et al*. (2007), poor post-harvest technology is one of the major constraints for reduction in the annual production, which accounts for nearly 60-80% of loss. Processing the surplus mango fruits into flour with an intention to be used as a functional ingredient in various food formulations seem to be a good preserving method, thus ensuring its extended consumption and reduce wastage.

Mango is reported to be a good source of antioxidant/bioactive compounds such as polyphenol, vitamin C, carotenoid, anthocyanin, flavonoid and exhibited good antioxidant activity (Larrauri *et al*., 1996; Ajila *et al*., 2007a; Vergara-Valencia *et al*., 2007) which posses various beneficial effects on human health. Earlier, studies also have reported that mango pulp and peel contains high dietary fibre (DF) (Ajila *et al.*, 2007b; Ajila *et al.*, 2008). DF plays an important role in many physiological processes in the prevention of illnesses such as constipation, hypertension, liver cirrhosis, diabetes, cancer, and others (Champ *et al*., 2003). The soluble fibre has been reported to have a positive impact on improving blood glucose and cholesterol levels (Prosky and DeVerie, 1992). The importance of DF in the diet has generated new studies looking for new sources of DF that may be used as ingredients by the food industry. Nowadays, the most widely consumed DF products are of cereal origin (Bunzel *et al*., 2001). However, the amount of DF that comes from cereal-based products differs greatly depending on the source and the processing methods used (Rodríguez *et al*., 2006). In general, DF from fruit has a better nutritional quality than those found in cereals. Fruits DF have significant amounts of bioactive compounds and a more balanced in composition, such as greater total and soluble dietary fibre (TDF and SDF) contents (Griguelmo-Miguel and Martin-Belloso, 1999) and exhibit good functional properties [water absorption capacity (WAC) and oil absorption capacity (OAC)].

Mango could be seen as potential source of ingredient with many practical applications in food industry. There has been growing interest in the impact of mango and extract of mango on health. Studies on the use of green and ripe mango pulp and peel flours as a starting raw material to produce high dietary fibre powder was previously conducted in our preliminary work (Noor Aziah *et al*., 2011). The results of the study had indicated that green mango peel and pulp flour as a rich source of dietary fibre with good functional properties. Hence, with these properties the flours have great potential to be incorporated as a functional ingredient into human food products. Mango pulp and peel flour of Chokanan variety and their use in bakery products such as in the sponge cake have not been studied. The results of this research will provide new information on the potential applications of these flours in the bakery industry.

In general, cakes are well liked by all age groups. However, they have high amounts of fat, sugar and calorie; thus, they can be considered as one of the factors that cause obesity and dental disease. Moreover, some reports have even claimed that most cake formulations are lacking in certain essential nutritional components, such as DF, vitamins and minerals, which are lost during wheat flour refinement (Heiniö *et al*., 2003; Rodríguez *et al*., 2006). Thus, sponge cakes are the most suitable conventional foods to be studied and developed as a source of dietary fibre and antioxidant which provided functional properties.

With increasing health-consciousness among consumers, there is growing demand for health-promoting foods and fibre-enriched foods (biscuit, bread, sponge cake etc.). In recent years, several studies have reported that different sources of fruit fibre can be used to replace wheat flour in the preparation of bakery products. Toma *et al*. (1979) tested potato peel, a by-product from potato industry and used as a source of DF. Vergara-Valencia *et al*. (2007) used fibre concentrate from mango fruit as a bakery product ingredient. Sudha *et al.* (2007) studied the effect of apple pomace by-product, as a source of dietary fibre and polyphenols in cake making. Bilgiçli and Akbulut (2009) incorporated apricot and watermelon pekmez into cake formulation to improve the nutritional value and extend the shelf life of cake. Sponge cakes fortified with various nutrients had become an important commodity in food industry. Generally, the great efforts are mainly in improving sponge cake quality and creating novel types sponge cakes.

1.1 Objectives of Study

The major aim of the present work was to develop a healthy sponge cake by partial substitution of wheat flour with mango pulp and peel flour. Other specific objectives are:

1. To determine the chemical compositions, antioxidant compounds and functional properties of the mango pulp and peel flour.

2. To investigate the effects of different percentage levels of mango pulp and peel flour on the physico-chemical and organoleptic attributes of sponge cake.

3. To study the functional effect of partial substituted mango pulp and peel flour on *in-vitro* enzymatic starch digestion-glycemic indexes and antioxidant properties of sponge cakes.

4. To evaluate the effect of partial substitution of mango pulp and peel flour on the shelf-life of sponge cake at different storage temperature.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Mango

Mango belongs to the genus of *Mangifera*, consists of numerous species of tropical fruiting trees in the flowering plant family Anacardiaceae. *Mangifera Indica* L. is the most important and widely distributed species. The common name of mango (*Mangifera Indica* L.) is as interesting as the origin of the species itself, this also gives some hints to the place of its origin. The fact that the local South Indian names for mango, as *Man-kay* or *man-gas* in Tamil language; are also used in Malaya, attests that the superior races of mango were introduced into Malaya from India (Singh, 1960). Mango fruit comes in a variety of shapes, sizes, flavour, texture and colour. This fruit gives off a distinctive sweet smell, attractive colour, and delicious taste with high nutritional value (Rajkumar *et al.*, 2007).

Currently, mango is the world's fifth most important food crop (FAO, 2004), and over 90 countries produced mangoes. This crop is commonly cultivated in many tropical and sub-tropical regions. Asia accounts for around 77% of total mango production, and America and Africa account for around 13% and 9%, respectively. In India (Negi, 2000), it is grown extensively and particularly in south-east Asia such as Philippines, Indonesia, Thailand, Malaysia and others (Singh, 1960). Table 2.1 indicates the worlds' top ten mango producing countries, which account for approximately 85% of the world's mango production. Between 1996 and 2005, production grew at an average annual rate of about 2.6%. In 2005, world production of mango showed a smooth increase to 28.51 million tonnes as compared to 27.61 million tonnes recorded in 2003. Among countries, India is the largest producer of mangoes, accounting for 38.6% of world production from 2003 to 2005 (FAOSTAT, 2007). There are over a 1000 varieties of mango worldwide, which have been identified (Djantou, 2007). In Malaysia, there are only a few potential varieties and clones that are marketable such as Chokanan and Masmuda, Harum Manis, Foo Fatt/Golek, Melele, Nam Dok Mai and others. Chokanan is one of the most popular and commonly eaten varieties of mango among all (MARDI, 2010). This clone was popular in Perak, Melaka, Selangor, Sarawak and few other states. There was about 9,375 hectares (ha) of mango area in 2009 with total production of 24,500 metric tonnes. The largest mango growing and production area in Malaysia was located at Jasin district in Melaka (463 ha) followed by Alor Gajah district in Melaka (419 ha) and Kuching district in Sarawak (271 ha) (Anem, 2010).

Chokanan is a fast grower and is able to bear fruit throughout the year. It bears fruits continuously and prolific even during rainy season. During hot summer months of May and June, Chokanan mango is flowering with the fruits maturing in August and September (Floresca, 2005). The mango fruit has green colour skin and turn to golden yellow when fully ripe (Figure 2.1a and 2.1b). The flesh was golden yellow in colour with soft fibre (Anem, 2010). The average weight is 0.5 kilogram per fruit. This fruit is one of the sweetest mangoes in the world and it is also a favorite for eating as green mango because it is not sour. Therefore, it’s gaining popularity in the local market and has the potential to substitute imports. It is recommended for commercial planting both for fresh eating and for processing due to its pleasant flavour and unique taste (MARDI, 2010).

Table 2.1: World's top ten mango production statistics (1996- 2005)

Countries	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2003-2005 (%)
	(1,000 metric tons)										
India	11,000	11,000	10,230	9,780	10,500	10,060	10,640	10,780	10,800	10,800	38.58
China	2,074	2,410	2,562	3,127	3,211	3,273	3,513	3,571	3,582	3,673	12.90
Thailand	1,181	1,198	1,088	1,462	1,633	1,700	1,700	1,700	1,700	1,800	6.20
Mexico	1,189	1,500	1,474	1,503	1,559	1,577	1,523	1,362	1,573	1,679	5.50
Indonesia	783	1,088	600	827	876	923	1,403	1,526	1,438	1,478	5.29
Pakistan	908	914	917	916	938	990	1,037	1,035	1,056	1,674	4.48
Brazil	593	508	469	456	538	782	842	1,254	1,358	1,000	4.30
Philippines	898	1,005	945	866	848	882	956	1,006	968	985	3.53
Nigeria	653	689	731	729	730	730	730	730	730	730	2.61
Egypt	203	231	223	287	299	325	287	319	375	380	1.28
Others	3,248	3,230	3,347	3,656	3,597	3,731	4,001	4,327	4,242	4,308	15.34
World total	22,733	23,773	22,584	22,584	24,730	24,973	26,634	27,609	27,822	28,508	100

Source: FOSTAT (2007)

Figure 2.1a: Green mango fruit in the variety of Chokanan

Figure 2.1b: Ripe mango fruit in the variety of Chokanan

2.1.1 Mango Peel and Pulp

Mango is basically divided into three major parts such as exocarp (11-18%), mesocarp (60-73%) and endocarp (14-22%) as shown in Figure 2.1. The fruit is a laterally compressed, fleshy drupe, containing mesocarp (mango pulp). Its edible part is pulpy, firm to tender, and has its own characteristic flavour. The mango pulp is protected by a peel which, under normal temperature and pressure conditions, ensures perfect food safety. It's resinous and varies considerably in size, shape, length, colour, taste, flavour, fibre presence and several other characters (Singh, 1960). Fruit shape varies from rounded to ovate-oblong to elongate or in the immediate forms involving two of these shapes. Fruit length ranges from 2.5 to 30 cm, depending on the variety. The flavour of mango varies from turpentine to sweet (Litz and Mukherjee, 2009).

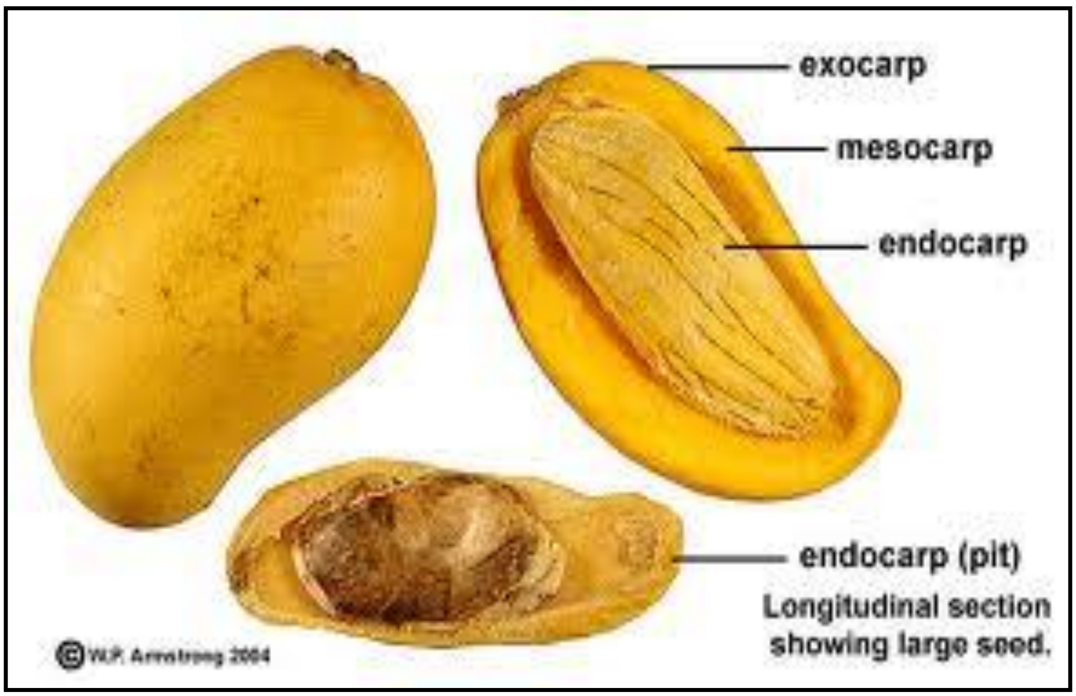

Figure 2.2: Anatomy of mango fruit (Source: Armstrong, 2004)

A good quality mango must have a moderately small kernel and the pulp of the fruit is delicate and smooth. While selecting the best quality of mango, one must make sure that the fruit is fresh, fleshy, and firm to touch. In general, the most important physical test of the fruit on its flavour. The most characteristics feature of the mango fruit is the formation of a small conical projection, beak that develops laterally at the proximal end of the fruit. The endocarp (mango kernel) is inedible, woody, thick and fibrous, which the fibres in the mesocarp arise from the endocarp.

The exocarp also known as the mango peel is inedible, thick and glandular. The mango peel is gland-dotted and its colour exhibits different mixture of green, yellow, orange and red. The peel is generally contains of a mixture of green, yellow and red pigments which present in the fruit such as chlorophyll, anthocyanin, carotenoid and so on (Litz and Mukherjee, 2009). In general, the colour changes in peels are obviously attributed to the cultivar and time of ripening. At maturity, peel of the fresh mango fruit changes from green to yellow due to the choloroplasts in the peel become chromoplast, which contain yellow and red pigments. Furthermore, some of the mangoes have a red blush is due to the presence of anthocyanins. In ripe mango fruit, the pulp carotenoids also vary with respect to cultivar (Mitra and Baldwin, 1997).

2.1.2 Uses and Nutritional Value

Mango is a commercially important tropical seasonal fruit and having a heavy demand in world market. However, quality, taste, physical appearance and postharvest shelf life of fruit are dependent upon its maturity at harvest. For instance, when fruits are harvested before maturity; they do not ripen uniformly and may present excessive shrinkage and high levels of sourness due to the reason of ethylene or acetylene cannot induce complete ripening with proper aroma, flavour, and taste in unripe fruits (Jha *et al.*, 2007). On the contrary, if fruits harvested at maturity stage will result in reduced shelf life with greater susceptibility to disease and infection by microorganism (Mitra and Baldwin, 1997) owing to high perishability of the ripe fruits (Kansci *et al.*, 2008).

In general, mangoes are physiologically ripened for 6 days at 24°C and 98% relative humidity (Tovar *et al.*, 2001). During peak season, the bulk of mango produce has had to be consumed as fresh fruit, fresh from the harvest site, due to its poor keeping quality and the difficulties of long-distance transport (Singh, 1960); consequently, the efforts have been made to preserve the natural qualities of the fruit by cold storage. In general, storage of mango at ambient temperature (25 to 35°C) results in rapid degradation, whereas freezing is usually accompanied by enzymatic browning (Campbell and Campbell, 1983). Furthermore, the whole mango fruits showed chilling injury symptoms stored at temperature below 13°C for several days (Tovar *et al.*, 2001). Hence, large quantities of this valuable fruits are wasted as a consequence of deficient post-harvest handling (Bello-Perez *et al.*, 2009).

Poor post-harvest technology is the major constraint to annual production which accounts for 60-80% of mango loss (Temple, 2001). In order to avoid this wastage, attempts have been made to find ways and means to utilise this surplus fruit in as many forms as possible, based upon popular needs and tastes. Presently, the unripe fruits of local varieties of mango are used for preparing various traditional products like raw slices in pickles, chutneys, amchur, curries, cold drinks (*panna* or *panha*) and so on. Ripe fruits are preserved and processed into puree for re-manufacturing into products such as nectar, marmalades, jams, jellies, candies, syrups, canned slices (Ajila *et al.*, 2007a). Besides, it can serve as a flavouring agent and major ingredient used in juice, smoothies, ice cream, fruit bars, sorbets and etc (Singh, 1960). Processing of mango into all sorts of products will help to reduce postharvest loss and increase consumption of the fruits.

After industrial mango processing, by-products such as peel and kernel are generated in large quantities. Peels are the major by-products obtained during processing, as they constitute about 15–20% of the total weight of the fruit (Beerh *et al.*, 1976). The peel is typically considered inedible because it contains substance called urushiol. This substance causes in itching of the skin, skin rashes called urushiol-stimulated contact dermatitis or even dermal irritation; consequently, it is not advisable to consume the peel as allergic conditions such as a painful rash and swelling may appear on the lips and face (Singh, 1960). For this reason, mango peel is not currently being utilized commercially in any way and ends up being discarded as a waste (Negro *et al.*, 2003), though they may be rich in biologically active substances (Ajila *et al.*, 2007b). A novel way of utilizing the surplus mangoes is to process the fruit into a shelf stable product such as sterilized pulp or dried flakes and flours (Saxena and Arora, 1997; Srinivasan *et al.*, 2000) for consumption. The processing technology enables to reduce postharvest losses and to ensure its extended consumption.

Preservation of the mango is important as the fruit is rich in nutritional value such as DF and carbohydrates content. Besides, it also contains acids, proteins, fats, essential vitamins (A, B and C), dietary minerals (copper and potassium), trace minerals (magnesium, manganese, selenium, calcium, iron, and phosphorus), and others. The composition of raw mango is listed in Table 2.2 (USDA Nutrient database) based on United States Department of Agriculture (USDA, 2006). Raw mango with 100g (3.5oz) serving has 65 calories and about half the vitamin C found in oranges. It also contains more vitamin A than most fruits. Furthermore, mangoes contain higher amount of carbohydrate such as starch, which is converted into sugar as the fruit ripens.

According to several researchers (Beerh *et al.*, 1976; Larrauri *et al.*, 1996; Larrauri, 1999; Ajila *et al.*, 2007b; Vergara-Valencia *et al.*, 2007), mango peel and pulp have been confirmed to have health benefits as they are rich in a variety of phytochemicals and bioactive compounds such as DF, polyphenol, carotenoid, enzyme, vitamin C and E and others, which provide beneficial effects for human health and protection from diseases such as cancer. Furthermore, Ajila *et al.* (2008) reported that the mango peel shows high values of antioxidant activity.

Table 2.2: Composition of raw mango pulp

Nutritional value per 100 g	
Energy	272 kJ (65 kcal)
Carbohydrates	17.00 g
Sugars	14.8 g
Dietary fibre	1.8 g
Fat	0.27 g
Protein	0.51 g
Vitamin A equiv.	38 μg
Beta-carotene	445 μg
Thiamine (Vit. B_1)	0.058 mg
Riboflavin (Vit. B_2)	0.057 mg
Niacin (Vit. B_3)	0.584 mg
Pantothenic acid (B_5)	0.160 mg
Vitamin B_6	0.134 mg
Folate (Vit. B_9)	14 μg
Vitamin C	27.7 mg
Calcium	10 mg
Iron	0.13 mg
Magnesium	9 mg
Phosphorus	11 mg
SPotassium	156 mg
Zinc	0.04 mg

Source: USDA Nutrient Database (2006)

2.1.3 Mango Pulp and Peel Flour

The mango is very popular due to its nature of high nutritive value, delicious taste and excellent flavour. Mango are generally consumed either raw or ripe and also can be processed into all kinds of products such as juice, jam, jelly, candy, nectar and so on. Mango is a highly perishable seasonal fruits which has higher moisture content (85%) and has a very poor keeping quality which cannot withstand to any adverse climatic conditions during storage (Rajkumar *et al.*, 2007). Large quantities are wasted during the peak season due to poor postharvest handling procedures applied. According to Thind (2002), seasonal perishability of ripe mango caused great economic losses, almost 30 per cent in every year.

To overcome the wastage problems, the most commonly techniques used is dehydration. Commercially, the modern techniques such as spray drying, freeze drying, drum drying, hot air drying and others can be applied. Among these methods, hot air drying is the optimal method because of its high productivity, cost-effective and resulted in a more uniform, hygienic, high quality and attractively coloured dried product (Doymaz, 2004). Drying can control the moisture content of the fruit by removing the moisture or reducing its water activity, so that the food becomes less susceptible to both microbial and chemical deterioration (Boudhrioua *et al.*, 2002). Processing flour can modify the hydration properties of food product which would affect the further application in real food system (Chantaro *et al.*, 2008). Hence, processed mango flour that implies good stability and quality of mango products will create demand in the food industry.

With increasingly health conscious consumers seeking food products that meet health, nutrition and quality needs. For this reason, it is important to develop new nutritional food, maximize their nutrient content in both processing and storage and extend the shelf-life, thus to meet the requirement of the market. In this regard, the information on nutrient change in processing and storage will be of great importance. Blanching prior to drying process was recommended to improve the physico-chemical quality of the final product. Chantaro *et al.* (2008) reported that dried blanched samples had slightly higher total phenolic content (TPC) as compared to the dried unblanched ones. This is because degradation and enzymatic browning did not take place during drying in the case of blanched samples. Moreover, blanching also improved the TDF yield and insoluble: soluble dietary fibre (IDF: SDF) ratio and also enhanced the water retention capacity (WRC), which is important for food applications.

Mango flours can be used as a source of dietary fibre and antioxidant in a variety of formulated foods and as an ingredient in bakery products such as cookie, biscuit (Ajila *et al.*, 2008), bread (Vergara-Valencia *et al.*, 2007), macaroni (Ajila *et al.*, 2010) and others. The mango flour is considered as a good source of DF and starch granules and with these biopolymer constitutes are an excellent raw material which modifies the texture and consistency of food. Consequently, mango flour appears to have some commercial potential by itself or as bases with other foods such as in baby weaning foods, puddings, soups, gravies. It is also commonly used for certain food products like ice cream, yoghurt, mango fruit bar, mango cereal flake, mango cake and mango for their production (Rajkumar *et al.*, 2007).

2.2 Dietary Fibre

Dietary Fibre (DF) is defined as non-digestible carbohydrate and the edible fraction of plants which are resistant to the hydrolysis, digestion and absorption in small intestine of the human gastrointestinal tract (Prosky, 1999; Mugford, 1991; Southgate *et al.*, 1978; Trowell *et al.*, 1976). According to Charalampopoulos *et al.* (2002) and Prosky (1999), fibre is not totally unavailable but portion of the DF is fermented to volatile fatty acids in human colon. DF consists of a diverse group of plant substances, celluloses, hemicelluloses, lignins and other non-starch/non-cellulosic polysaccharides (Narayan Prasad *et al.*, 1995).

DF has well-documented beneficial effects on human health. High consumption of DF is associated with a reduced incidence of disorders and diseases common in developed societies such as chronic bowel disorders, obesity, diabetes, cardiovascular disease and cancer (Johnson, 2004; Kris-Etherton *et al.*, 2002). DF is categorized into two groups, insoluble and soluble dietary fibre (IDF and SDF). Both DF have beneficial effects towards human health but have distinct chemical characteristic and provides different therapeutic effects.

SDF mainly consists of β-glucan, pectins and variety source of gums (Howarth *et al.,* 2001; Prosky and DeVries, 1992). SDF dissolves in water to form a viscous gel matrix. The gel holds onto substances such as carbohydrate and reduces the amount absorbed thorough the gut. This helps in slowing the absorption of glucose from the intestine and preventing the spikes in blood glucose level, 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 postprandial blood glucose (Pick *et al.*, 1996) in human body. DF also helps to reduce the risk of colon cancer, type-2 diabetes and coronary heart disease (Prosky and DeVries, 1992).

IDF components include cellulose (major amount), hemicellulose, lignin, cutin and plant waxes. IDF is an enzymatic indigestible plant material and is not soluble in hot water. It possesses passive water-attracting properties which help to increase bulk, soften stool and reduce the transit time through the intestinal tract. 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).

In 2006, the American Dietetic Association (ADA) recommended a minimum DF intake is 20-35g a day g/day (25-30g/day for IDF and 10-13g/day for SDF) for a healthy adult while in developing countries the recommended DF intake ranges from 60-120 g/day (Fuchs *et al.*, 1999). Research in Germany has indicated that increasing DF intake of 25g a day for adults; it helps to reduce the risk of developing diabetes by a quarter compared to people who consuming DF at 12-14g/day (Sarah *et al*., 2010). However, a DF daily intake for most Malaysians ranged from 13-16 g/day (Ng, 1997).

The importance of DF in the diet has initiated new studies on new sources of DF that can be used as ingredients for the food industry. DF is mostly found in fruits, vegetables, whole grains and legumes. The most widely consumed DF products are those derived from cereals (Vergara-Valencia *et al.*, 2007). However, the amount of DF that comes from cereal-based products differs greatly depending on the source and the processing method. Most of the DF is lost during wheat flour refinement (Rodríguez *et al.*, 2006). Fruit DF has better nutritional quality than that found in cereals because it has higher proportion of SDF (Gorinstein *et al.*, 2001; Griguelmo-Miguel and Martin-Belloso, 1999) and associated bioactive compounds (flavonoid and vitamin C) with antioxidant properties which provide an additional health promoting effects (Benavente-Garcia *et al.*, 1997; Marin *et al.*, 2002). A good DF is not only desirable for their nutritional value but also for their functional and technological properties too (Thebaudin *et al.*, 1998). Thus, it has all the characteristics required to be considered as a potential ingredients in the formulation of functional foods and it can also be utilised in the preparation bakery products to improve nutritional properties.

2.3 Resistant Starch

Starch is the carbohydrate constituent in plant materials. Most of the starch is naturally found in cereal grains, maize, potato and rice starches are of commercial value. Little is known about the structural and molecular characteristics of starch from unconventional source, such as green mango fruits (Espinosa-Solis *et al.*, 2009). Higher starch content (70-80%) present in this fruit is at unripe state, it makes the fruits become a potential source of starch for various applications (Bello-Perez *et al.*, 1999) because of its lack of flavour, while being relatively different from starches of other plants.

The digestibility of starch in food varies widely, therefore a nutritional classification system of dietary starch has been taken into account both the kinetic component and the completeness of the starch's digestibility and is comprised of rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) (Sandhu and Lim, 2008). RS has been defined as the fraction of starches that escape digestion in the small intestine but are digested in the large intestine after five to seven hours of consumption (Muir *et al.*, 1994; Englyst *et al.*, 1992) and it has functional and nutritional properties in common with DF. According to Eerlingen *et al.* (1993), these indigestible starch fractions are commonly classified into four categories such as RS1 which corresponds to the physically inaccessible to digestion by entrapped in a cellular matrix, RS2 which is the native starches with B-type crystal in raw botanic such as potatoes and green banana, and RS3 which mainly consisted of retrograded amylose or high amylose starches and RS4 which consists of chemically modified starches.

Numerous nutritional studies have elucidated the chemically and physiological benefits of RS. 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 labels. A wide range of metabolic end products such as the short chain fatty acids (SCFA), primarily acetate, propionate and butyrate that is not hydrolyzed and absorbed in the small intestine but later fermented by the colonic microflora (Kritchevsky, 1995; Phillips *et al.,* 1995; Muir *et al.,* 1994; EURESTA, 1993), which produces several acetic, propionic and butyric and the gases like carbon dioxide, hydrogen and methane (Macfarlane and Cummings, 1991). SCFA may have many beneficial physiological effects on colon health. 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 could increase the amount of indigestible matter in that it moves the matter through to the colon. Thus, it is slowly absorbed and association of RS with an increased absorption of starch in small intestine (Haralampu, 2000). Colonic fermentation, bacterial growth, faecal bulking, transit time, and energy value of food are all influenced by the presence of RS. Consequently, RS provide better appearance, texture and mouth-feel than conventional fibres to various food (Martinez-Flores *et al.,* 1999) and dietetic products, and since then use in functional foods has increased research interest.

2.4. Antioxidants

Antioxidants are abundant in vegetables, fruits, and are also found in cereals, herbs and other plant materials. Plants provide a wide range of redox-active secondary metabolites (i.e. antioxidants) (Serrano *et al.,* 2007). Consumption of diet high in fruits and vegetables increased significantly the antioxidant capacity of human plasma (Cao *et al.*, 1998) and has strong protective effects against major disease risks. Antioxidants are substances that delay or prevent the oxidation of cellular oxidisable substrates. Many studies have shown that free radicals cause oxidative damage to different molecules such as lipids, proteins and nucleic acids (Ubando-Rivera *et al.,* 2005; Yen and Chen, 1998). According to Moskovitz *et al.* (2002), free radicals have been associated with progression of diseases and ageing. Thus, antioxidant act by exerting free radicals effect by scavenging reactive oxygen species (ROS) and reactive nitrogen species (RNS) as well as preventing the generation of ROS/RNS (Halliwell, 1996).

The importance of antioxidants in the maintenance of health and prevention from cancer and health chronic diseases; thus, recently is attracted considerable interest in food industry as the trend of the future is moving toward functional food with specific health effects. Antioxidants have been used in the food industry to prolong the shelf life and inhibit rancidity in red meat, poultry, fish (McCarthy *et al.,* 2001) and also bakery products; thereby improve the quality and nutritional value of food products. Nowadays, the addition of synthetic antioxidant compounds such as butylated hydroxytoluene (BHT), butylated hydroxyanisol (BHA) and propyl gallate (PG) are commonly used in processed food (Wong *et al.*, 2006). However, the use of these synthetic antioxidants has been questioned due to their potential health risk and toxicity which will be released during degradation (Kalt *et al.*, 1999). Hence, the search for natural antioxidant received more attention as it is presumed safe and has potential nutrition and therapeutic value compared to synthetic antioxidant compounds.

The interest in natural antioxidants has resulted to the attention in fruits since they are rich in phenolic compounds (Robards *et al.*, 1999; Kalt *et al.*, 1999). Polyphenol compounds play important roles as reducing agent, hydrogen donor and metal chelators which are attributed by their scavenging properties (Rice-Evans *et al.*, 1995). Thus, it can neutralize the free radicals and oxygen radicals produced in biological systems. Free radicals are generated in the body on account of oxidative metabolism, disease, smoking, environmental poison, alcohol and ionizing radiation (Stangeland *et al.*, 2009). Recently, many epidemiological studies have reported that there is a significant positive effect of antioxidant intake towards human health in prevention of cancer, ageing, neurodegenerative diseases, coronary heart diseases and diabetes (Zaveri, 2006; Kaur and Kapoor, 2002; Saura-Calixto and Goni, 2006). As a result, phenolic compounds with antioxidant activity can be considered as functional food ingredients in food industries.

Mango is a popular tropical fruit all over the world with valuable dietary source of many phytochemical compounds which impart a characteristics colour and flavour to the fruit (Grundhofer *et al.*, 2001). Among these compounds, polyphenolics are widely distributed as secondary metabolites. It serves as the predominant antioxidant compounds that are present in fruits. Earlier studies reported that mango pulp and peel are found rich in polyphenolics compounds, carotenoids, flavonoids, ascorbic acid and other compounds (Berardini *et al.*, 2005a; Berardini *et al.*, 2005b; Schieber *et al.*, 2000).

Phenolic compounds and pigments are the main group of compounds contributing to the antioxidant activity. Solvent of 80% acetone was proven for maximum extraction amount of phenolic compounds from the mango peel (Ajila *et al.*, 2007a). The antioxidant activity of phenolics is due to the reactivity of phenol moiety which is the hydroxyl group on aromatic ring. The ability to scavenge free radicals is via hydrogen donation or electron donation as reported by Shahidi and Wanasundara (1992). The quantification of polyphenols was carried out using Folin-Ciocalteu whereby phenols form the blue coloured phosphomolybdic-phosphotungstic-phenol complex in alkaline solution as elaborated by Singleton and Rossi (1965). Carotenoids are widely distributed in nature and are liposoluble antioxidants. A small amount of carotenoids comes from chlorophyll *b* and a negligible amount from chlorophyll *a*. Carotenoid compound can vary even though it is the same tested variety with a slight modification in the extraction method used. Carotene content in mango peel extracts ranged from 74-436 µg/g peel and it was found abundantly in ripe mango peels as compared to raw peels (Ajila *et al.*, 2007a).

Antioxidant activities are measured through the measurement of reducing power and free radical scavenging activity. The reducing power of the mango peel extract was compared with synthetic standard Trolox. Increased absorbance of the reaction mixture will indicate higher reducing power. The reducing power of a compound is related to the electron transfer ability and serves as a significant indicator of the compound antioxidant activity. It was reported that phenolics, carotenoids and anthocyanins present in mango peel deemed as good electron donors and reduce ferricyanide complex (Fe^{3+}) to ferrous form and thus indicates the antioxidant activity (Chung *et al.*, 2002; Yen and Chen, 1995). On the other hand, the scavenging activity of acetone extracts mango peel is measured using DPPH. This chemical is a stable free radical and the antioxidants react and convert DPPH into 2, 2-diphenyl-1-picrylhydrazine. Van Gadow *et al.* (1997) also reported that the degree of discolouration indicates the scavenging potential of the antioxidant due to the hydrogen donating ability.