UTILIZATION OF PEELED AND UNPEELED PUMPKIN FLOUR AS A VALUE-ADDED INGREDIENT IN CRACKERS

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UNIVERSITI SAINS MALAYSIA

2013

UTILIZATION OF PEELED AND UNPEELED PUMPKIN FLOUR AS A VALUE-ADDED INGREDIENT IN CRACKERS

by

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Thesis submitted in fulfillment of the requirements for the degree of Master of Science

July, 2013

ACKNOWLEDGEMENT

My supervisor…the real superwoman… Professor Dr. Noor Aziah Abdul Aziz. Her guidance, criticism, and advices were the source of power that drives throughout the research…

My family…the most precious treasure I found on the day I was born. Their undying love and unlimited support were my greatest strength along this journey…

My other half…the most wonderful magic ever happened to me. His overwhelming affection and care were my source of inspiration…

My daughter…the most valuable gift that I ever received. Her tears and smiles were the ultimate motivation for me to complete this thesis…

My friends…the most reliable guides. Their kindness and willingness to share were the biggest assistance for me to complete the research.…

And for all other individuals who contributed directly or indirectly to the completion of my research and thesis. ..my utmost gratitude to them for their helping hands…

Last but not least… the supreme power of God… whose blessings made everything possible, up to this point of my life….

"…And this dissertation is dedicated to my beloved parents, Mr. and Mrs. Chanmal Anantham Saraswathy, my dearest husband, Mr. Vignes and my lovely daughter, Ms Yoshanaa…"

KOMATHI A/P CHANMAL ANANTHAM

May, 2012

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LIST OF ABBREVIATIONS

Abbreviation	Caption
ANOVA	analysis of variance
AUC	area under curve
a_w	water activity
BHA	butylated hydroxyanisole
BHT	butylated hydroxytoluene
DNA	deoxyribonucleic acid
DPPH	2,2-diphenyl-1-picrylhydrazyl
GI	glycemic index
GOD-PAP	glucose oxide-peroxidase
HCl	hydrochloric acid
HI	hydrolysis index
IDF	insoluble dietary fibre
KCl	potassium chloride
MDA	malondialdehyde
OHC	oil holding capacity
PCA	plate count agar
PDA	potato dextrose agar
PPF	peeled pumpkin flour
PRP	peeled raw pumpkin
RS	resistant starch

RVA	rapid visco analyzer
SDF	soluble dietary fibre
SEM	scanning electon microscopy
TBA	thiobarbituric acid
TCA	trichloroacetic acid
TDF	total dietary fibre
TEP	1,1,3,3-tetraethoxypropane
UPF	unpeeled pumpkin flour
URP	unpeeled raw pumpkin
UV	ultraviolet
WHC	water holding capacity

PENGGUNAAN TEPUNG LABU TANPA KULIT DAN TEPUNG LABU BESERTA KULIT SEBAGAI BAHAN TAMBAH NILAI DALAM KRAKER

ABSTRAK

Tujuan kajian ini adalah untuk menghasilkan suatu makanan yang ditambah nilai daripada tepung labu tanpa kulit (PPF) dan tepung labu beserta kulit (UPF) yang ditambahkan dalam kraker pada tahap 5 % , 10 %, 15 % dan 20 % daripada berat tepung gandum. Sifat fiziko-kimia PPF dan UPF telah ditentukan dengan menggunakan tepung gandum sebagai kawalan. Sifat fiziko-kimia, tekstur, sensori dan kestabilan penyimpanan juga telah dikaji untuk semua jenis kraker, dengan menggunakan kraker yang disediakan daripada 100 % tepung gandum sebagai kawalan,. PPF dan UPF didapati mempunyai keupayaan memegang air (WHC) dan keupayaan memegang minyak (OHC) yang tinggi secara signifikan ($p \leq 0.05$). Kandungan abu dan gentian kasar yang tinggi secara signifikan ($p \leq 0.05$) serta kandungan lembapan dan aktiviti air yang rendah secara signifikan ($p \leq 0.05$) turut didapati pada PPF dan UPF. Gentian diet larut (SDF), gentian diet tidak larut (IDF) serta jumlah keseluruhan gentian diet (TDF) dalam PPF dan UPF didapati tinggi secara signifikan ($p \leq 0.05$). Aktiviti antioksida serta kandungan kanji rintang (RS), β-karotena dan fenolik juga didapati tinggi secara signifikan ($p \leq 0.05$) dalam PPF dan UPF. Bagi kandungan mineral, didapati PPF dan UPF tinggi secara signifikan ($p \leq 0.05$) dalam kandungan kalsium dan magnesium. Walaupun kandungan amilosa PPF dan UPF adalah rendah, didapati kedua-duanya mempamerkan suhu pempesan, kelikatan 'breakdown' dan nilai 'setback' yang rendah secara signifikan ($p \leq 0.05$).Kelikatan akhir yang tinggi secara signifikan ($p \leq 0.05$) turut

didapati pada PPF dan UPF. Parameter warna didapati berubah secara signifikan ($p \leq 0.05$) bagi kraker yang ditambahkan dengan peratusan PPF dan UPF yang berbeza. Kandungan gentian kasar meningkat secara signifikan ($p \leq 0.05$) bagi kraker PPF pada semua peratus penambahan, dan hanya pada 15 % dan 20 % bagi kraker UPF. Kandungan TDF dan IDF didapati tinggi secara signifikan ($p \leq 0.05$) dalam kraker PPF pada 15 % dan 20 % penambahan. Keputusan yang sama turut diperolehi untuk kraker UPF, termasuk kandungan SDF yang tinggi secara signifikan ($p \leq 0.05$) pada semua peratus penambahan. Kandungan RS, β-karotena dan aktiviti antioksidatif didapati tinggi secara signifikan ($p \leq 0.05$) dalam kraker PPF dan UPF. Kandungan fenolik yang tinggi secara signifikan ($p \leq 0.05$) dikesan dalam kraker UPF pada semua peratus penambahan, manakala bagi kraker PPF, kandungan fenolik yang tinggi secara signifikan ($p \leq 0.05$) ditunjukkan pada 15 % dan 20 % penambahan. Kandungan magnesium dan kalium meningkat secara signifikan ($p \leq 0.05$) dalam kraker PPF pada penambahan 15 %, manakala bagi kraker UPF, pada penambahan 10 %. Kandungan kalsium berbeza secara signifikan ($p \leq 0.05$) bagi kraker yang ditambah 20 % UPF. Penilaian sensori menunjukkan kraker 5 % PPF dan 5 % UPF mendapat penerimaan tertinggi dari segi warna, rasa dan tekstur. Kestabilan penyimpanan bagi kraker 5 % PPF dan 5 % UPF telah dikaji untuk selama 180 hari dengan persampelan dilakukan setiap 30 hari untuk penentuan aktiviti air, kandungan lembapan, ketengikan (kepekatan TBA-malondialdehid), penilaian sensori dan kiraan mikrob (jumlah kiraan yis dan kulat, jumlah kiraan plat). Secara keseluruhan, kedua-dua kraker 5 % PPF dan 5 % UPF menunjukkan kemerosotan dalam kualiti sepanjang tempoh penyimpanan, walaupun masih selamat dimakan pada persampelan terakhir.

UTILIZATION OF PEELED AND UNPEELED PUMPKIN FLOUR AS A VALUE ADDED INGREDIENT IN CRACKERS

ABSTRACT

The aim of this study is to develop a value-added food from peeled pumpkin pulp flour (PPF) and unpeeled pumpkin pulp flour (UPF) in crackers at substitution levels of 5 %, 10 %, 15 % and 20 % of wheat flour weight. Physico-chemical properties of PPF and UPF were determined with wheat flour as control. The physico-chemical, textural, sensory and storage stability were also investigated for all types of crackers, using 100 % wheat flour crackers as control. PPF and UPF were significantly higher ($p \leq 0.05$) in water holding capacity (WHC) and oil holding capacity (OHC). Significantly high ($p \leq 0.05$) ash and crude fibre content together with significantly low ($p \leq 0.05$) moisture content and water activity were also observed for PPF and UPF. It was revealed that total dietary fibre (TDF), soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) contents were significantly higher ($p \leq 0.05$) in PP F and UPF. Resistant starch (RS), scavenging activity, β-carotene and phenolics content were found to be significantly high ($p \leq 0.05$) in PPF and UPF. Mineral content of PPF and UPF were significantly higher ($p \leq 0.05$) in calcium and magnesium. Despite significantly low ($p \leq 0.05$) in apparent amylose content, PPF and UPF exhibited good pasting profile with significantly low ($p \leq 0.05$) pasting temperature, breakdown viscosity and set back value. Significantly high ($p \leq 0.05$) final viscosity was also achieved in PPF and UPF. Incorporation of PPF and UPF into crackers at different levels significantly

($p\leq0.05$) affected colour parameters. Crude fibre content increased significantly ($p\leq0.05$) in PPF crackers at all levels of incorporation but for UPF crackers the increase was only for 15 % and 20 %. TDF and IDF contents were significantly higher ($p\leq0.05$) in 15 % and 20 % PPF crackers. Similar results was recorded by UPF crackers at all levels of incorporation, along with significantly high ($p\leq0.05$) SDF. RS, β-carotene and scavenging activity were significantly high ($p\leq0.05$) in PPF and UPF crackers. Significantly high ($p\leq0.05$) phenolic content was observed for UPF crackers at all levels of incorporation. PPF crackers showed similar results at 15 % and 20 %. Magnesium and potassium content significantly increased ($p\leq0.05$) in PPF crackers at 15 % and UPF crackers at 10 % incorporation. Calcium content was significantly higher ($p\geq0.05$) for 20 % UPF crackers. Sensory evaluation results showed that 5 % PPF and UPF were the most acceptable in terms of colour, taste and texture. Storage stability of 5 % PPF crackers and 5 % UPF crackers were investigated for 180 days with sampling on every 30 days for water activity, moisture content, rancidity (TBA-malondialdehyde concentration), sensory evaluation and microbial count (yeast and mold count, total plate count). On the whole, both crackers showed deterioration in quality over the storage period, although the crackers were still safe for consumption on the last sampling.

CHAPTER 1

INTRODUCTION

1.1 Background of research

Bakery industry went through an evolution since the past century (Mondal & Datta, 2008). Novel baking techniques and introduction of innovative ingredients have greatly contributed towards the developments in bakery industry. Bakery products are widely being used as source to incorporate nutritious ingredients (Sudha *et al.,* 2007). Continuous research have been carried out to produce nutritionally superior bakery products with better quality and low in cost (Mondal & Datta, 2008), and there has been a growing trend of consuming value added bakery products. Consumers place a high demand on food which claims to exert some health benefits on regular consumption (Aparicio-Saguilán *et al.,* 2007). Such food products are known as functional food. Functional food are food that exhibit beneficial physiological function in body, such as improving well being and reducing risk of diseases, in addition to providing dietary nutrients (de Roos, 2004). Functional food usually has reduced content of an ingredient that increases the risk of a disease, or enriched with a 'protective' ingredient that reduces the risk of a disease (de Roos, 2004). Fibre enriched products are often considered as functional food (Filipovic *et al.,* 2007). According to Vitali *et al.,* (2009), cereal based food are often developed as functional food. Nutritive value and functionality of biscuits, are popular as a convenient food due to its low cost, wide variety of taste, long shelf life (Vitali *et al.,* 2009) could be improved by addition of wholegrain other than wheat and other types of dietary fibre. Increased consumption of dietary fibre reduces the risk of many chronic diseases. Dietary fibre protects against cardiovascular diseases, controls serum lipid and glucose levels, regulates gastrointestinal and bowel functions and helps to maintain a healthy body weight (American Dietetic Association, 2008). High fibre diet is less dense in energy and more satiating. Fruits, vegetables, cereals, and legumes are food with high fibre content. However, the importance of incorporating sufficient amount of dietary fibre in daily diet has often being overlooked, mainly due to the fast moving lifestyle nowadays. Consumers are instead turning to fibre supplements as an easier way to fulfill the recommended intake or as an additional fibre source. Consumption of more vegetables and fruits reduces the risk of cancer, diabetes, heart diseases and age related functional decline (Temple, 2000). Fruits and vegetables received much attention due to the antioxidant, antimutagenic and anticarcinogenic activities of their biologically active substances, such as phenolics and carotenoids (Dillard & German, 2000). Besides the roles of dietary fibre, diet rich in plant food is also associated with lower risk of diseases due to the antioxidant and other bio-active substance free radical damages (Buttriss, 2003a). Antioxidants have the ability to scavenge the free radicals which have deleterious effects on DNA, lipids and proteins of membrane cells. There are numerous compounds in plant food which possess antioxidant properties, of which Vitamin C and Vitamin E are the most commonly known. Other plant origin substances which can act as antioxidants include phenolic compounds. Phenolic compounds (phenols and polyphenols) have at least one aromatic ring with one or more hydroxyl group attached to it. Phenolic compounds are responsible for the colour, aroma and flavour of vegetables and fruits. Flavonoids and phytoestrogens, which are among the important phenolic compounds are reported to possess anti-carcinogenic and weak oestrogenic activity, respectively (Buttriss, 2003b). Carotenoids are responsible for the attractive colour of some fruits and vegetables, namely tomatoes, mangoes, pumpkins, papayas and capsicums. More than 600 different carotenoids have been identified, and β-carotene is the most predominant in human diet. β-carotene possess provitamin A activity, in addition to its antioxidative property.

Pumpkin has drawn the attention of many researchers mainly due to its attractive colour and fibrous internal structure. Deep coloured vegetables and fruits are reported to be good sources of phenolics, such as flavonoids and carotenoids (Sass-Kiss *et al.,,* 2005). A total of 3274 metric tonnes and 3250 metric tonnes (estimation) of pumpkin were produced in Malaysia in the year 2007 and 2008 respectively (Anon, 2009) for local consumption. Pumpkin is often cooked as a vegetable dish or used in desserts. It is very common to see the sweet tasting yellowish flesh of pumpkin ending up in coconut gravy as 'masak lemak labu' or in a spicy, sweet sauce as 'pumpkin chutney' on the lunch plate of most Malaysians. Desserts such as 'pengat labu' and pumpkin pies are irresistible to many. In western culture, the pumpkins are often carved and made into 'jack-o-lanterns' which are used as an important decorative item during Halloween. Pumpkin has been reported to contain high fibre and β-carotene that can promote good health on regular consumption. Pumpkin seeds oil is high in unsaturated fatty acids particularly oleic and linoleic acids (El-Adawy & Taha, 2001; Nyam *et al.,* 2009). The flesh, besides being eaten as it is, has been turned into flour or incorporation into various food products to increase the nutritive value and sensory acceptance.

A number of studies have been reported on the utilization of different fibre sources in food (Bilgiçli *et al.,* 2007), especially bakery products. Mendonça *et al.,* (2000) reported the utilization of corn bran in expanded snacks, Bilgiçli *et al.,* (2007) utilized apple fibre, lemon fibre, wheat fibre and wheat bran in cookies, Filipovic *et al.,*(2007) worked on bread added with sugar-beet fibre while Ajila *et al.,* (2008) studied the performance of mango peel powder in soft dough biscuits. There has been a report by de Escalada Pla *et al.,* (2007) on the compositional and functional properties of fibre products obtained from pumpkin, suggesting that pumpkin is also a good source of dietary fibre. Addition of dietary fibre contributes to the development of value-added food and functional food which are high in demand (Abdul-Hamid & Luan, 2000).

Studies have been revolving around the effects of processing, drying processes and chemical properties of pumpkins. For the effects of processing, Azizah *et al.*, (2009) studied the impact of boiling and stir frying on the phenolic, carotenoid and radical scavenging activity of *Cucurbita moschata* while Emadi *et al.*, (2007) studied the abrasive peeling of pumpkin. A number of researchers have carried out experiments on the drying processes of pumpkin. This include Garcia *et al.*, (2007) who studied the kinetics of osmotic dehydration and air-drying of *Cucurbita moschata* pumpkins, Kowalska *et al.*, (2008) who investigated the effect of blanching and freezing on the osmotic dehydration of pumpkin and Mayor *et al.*, (2008) who studied the microstructural changes in the parenchymatic pumpkin tissue during osmotic dehydration. Chemical properties of pumpkin, especially fluted pumpkin have been reported by Singh *et al.,* (2007) who studied the morphological, thermal and rheological characteristics of starch isolated from *Cucurbita pepo* pumpkins, Akwaowo *et al.,* (2000) who worked on the mineral and antinutrients content of fluted pumpkin, Hamed *et al.,* (2008) who studied the nutritional and physicochemical properties of fluted pumpkin seed and Essien *et al.*, (1992) who investigated the chemical properties of pod and pulp of fluted pumpkin. On the other hand, Wu *et al.*, (2008) compared the antioxidant activity and endogenous hormone levels of bush and vine type *Cucurbita moschata*, Gliemmo *et al.,* (2009) investigated the colour stability of *Cucurbita moschata* puree during storage, Caili *et al.,* (2007) studied the properties of protein-bound polysaccharides of pumpkin fruit while Jun *et al.,* (2006) elucidated the characteristics of pectic polysaccharides of pumpkin peel.

. There were studies reported on the utilization of pumpkin powder in breads. Ptitchkina *et al.,* (1998) studied on the enhancement of loaf volume and acceptability of bread added with pumpkin powder while See *et al.,* (2007) investigated the physico-chemical and sensory properties of bread incorporated with pumpkin. Lee *et al.,* (2002) studied the enhancement of β-carotene content of noodles with addition of pumpkin powder. However, very limited literature is available on the utilization of pumpkin in other bakery products, especially crackers.

1.2 Objectives

Rationale of conducting this research is the increasing interest in fibre and antioxidant rich food and the growing market for functional food and nutraceuticals. Besides that, development of fibre and antioxidant added convenient food, particularly crackers, would be an advantage for the fast-paced lifestyle as it could compensate for deficiency in the diet through regular consumption. It was stated in the Federal Agricultural Marketing Authority (FAMA) statistical report that although Malaysia produced 21, 520 metric ton of pumpkin in year 2012, the per capita utilization was only at 0.29kg/person/year. This reflects the underutilization of the pumpkin among Malaysian. Thus, this research would be beneficial in term of promoting pumpkin to be utilized as an alternative source of fibre and antioxidant in bakery products, especially crackers. Upon completion of this research, new information on the nutritive value of the pumpkin could also be expected. The research is aimed at evaluating the potential of pumpkin (peeled and unpeeled) as a value-added ingredient in crackers with specific objectives as followings:

i) to elucidate the physicochemical and functional properties of peeled and unpeeled pumpkin

ii) to incorporate peeled and unpeeled pumpkin flour as an ingredient in crackers

iii) to evaluate the effect of peeled and unpeeled pumpkin in terms of the physicochemical and sensory attributes of crackers

CHAPTER 2

LITERATURE REVIEW

2.1. Pumpkin

2.1.1 Botanical characteristics

"All the pumpkin tribes are among the marvels of the vegetable world in respect to their many unusual and extravagant characters" (Bailey, 1929). This statement depicts the attention already received by pumpkin, long before its nutritional and health benefits were revealed with adequate scientific proof. Pumpkin belongs to family Cucurbitaceae, which is widely distributed in tropical countries of both hemispheres (Herklots, 1972). Cucurbitaceae family covers a vast variety of plants including melon, watermelon, cucumber, squashes and pumpkin (Mayor *et al.,* 2008). Botanically pumpkin is defined as fruit, although it is commonly considered as vegetable (Azizah *et al.*, 2009). Pumpkin, from the genus Cucurbita is green in colour when unripe, and turns yellow on ripening (Caili *et al.,* 2007). Pumpkin could be found in three main species, which are *Cucurbita moshcata, Cucurbita pepo* and *Cucurbita maxima*. There are various cultivars of Cucurbita, and majority of them are large and trailing plants (Wu *et al.,* 2008). Fruits of *Cucurbita pepo* have hard, angular stem with coarse-grained flesh. *Cucurbita moshcata* fruits have moderately hard and smooth angled stem and fine or coarse grained flesh with gelatinous fibres. Stem of *Cucurbita maxima* fruit is usually soft and round with fine-grained flesh. Pumpkin has been reported to be best grown on light textured acidic soil under warm climate. It takes around three to four months from seedling for the pumpkin fruit to mature, and fruits harvested at full maturity have a long shelf-life and can be transported easily. Careful handling to avoid bruises to the fruits will ensure an extended storage of the pumpkins. The differences in physical appearance of *Cucurbita moschata*, *Cucurbita maxima* and *Cucurbita pepo* is shown by Figure 2.1.1.a, Figure 2.1.1.b and Figure 2.1.1.c respectively

2.1.2 Pumpkin as food

Generally, pumpkin can be eaten when it is immature or ripe but cooking is essential prior to consumption. Pumpkin can be boiled, baked, steamed (Desai & Musmade, 1998), dried, pickled or canned (Mayor *et al.,* 2008). *Cucurbita pepo* which is also known as Kamo-kamo pumpkin among the New Zealand Maoris can be boiled, baked or fried for consumption (Singh *et al.,* 2007). Mashed flesh of cooked pumpkin has been used as filling for pumpkin pie which is a favourite dessert in the United States (Desai & Musmade, 1998), In Argentina, *Cucurbita moschata* is more preferred due to its taste quality (de Escalada Pla *et al.,* 2007). Apart from being consumed as it is, pumpkin can also be processed into syrup, jam, jelly and puree (Gliemmo *et al.,* 2009) in order to prolong the shelf-life and to diversify its utilization in the food industry.

Figure 2.1.1.a ***Cucurbita moschata*** **(Adapted from Anon, 2013a)**

Figure 2.1.1.b ***Cucurbita maxima*** **(Adapted from Anon, 2013b)**

Figure 2.1.1.c ***Cucurbita pepo*** **(Adapted from Anon, 2013c)**

2.1.3 Nutritional compositions of pumpkin

Pumpkin has been receiving an increasing attention due to its nutritional value, polysaccharides content of the fruit and the oil content of the seeds (Murkovic *et al.,* 2004). It was reported by Emadi *et al.,* (2007), that people in Asia and Pacific countries place a high demand on pumpkins. According to Kowalska *et al.,* (2008), pumpkin is considered as a low calorie food as 100 g of its flesh gives only 17 kcal energy. Jun *et al.,* (2006) reported that pumpkin is a good source of carotene, pectin, mineral salts, vitamins and other bioactive substances, such as phenolic compounds and terpenoids (Crozier, 2003).

Proximate compositions of pumpkin as reported by Lingle, (1993), See *et al.,* (2007) and McCance & Widdowson, (2000) are summarized in Table 2.1.3. Generally, the variations observed in the compositions are due to differences in cultivar, soil and agricultural practices, methods of handling, storage conditions and method of analysis.

Table 2.1.3 Proximate compositions of pumpkin

Constituent	g/100g edible portion		
	A	**B**	**C**
Moisture	91.60	92.24	95.0
Protein	1.00	0.98	0.70
Fat	1.00	0.15	0.20
Fibre	1.10	0.56	1.00
Total carbohydrate	6.50	5.31	

Table 2.1.3 - Continued

Constituent	A	B	C
Minerals	0.80	0.76	mg/100g edible portion
			• Sodium Trace • Potassium 130 • Calcium 29 • Magnesium 10 • Iron 0.4 • Copper 0.02 • Zinc 0.2

* A : Adapted from Lingle (1993)

B : Adapted from See *et al*., (2007)

C : Adapted from McCance & Widdowson, (2000)

2.1.4 Health benefits of pumpkin

Besides being a part of normal diet, pumpkin has been reported to confer some therapeutic effects (Kowalska *et al.*, 2008). Pumpkin was used in folk medicine to treat urinary complaints, kidney stones and as anti-rheumatic-agent (Guzmán-Maldonado & Paredes-López, 1998). Some health benefits have been linked to regular consumption of pumpkin. Ptitchkina *et al.*, (1998) reported that pumpkin powder contains 40 % cellulose, 4.3 % hemi cellulose and 4.3 % lignin, which are the main components of insoluble dietary fiber. Consumption of high fiber diet has been reported to protect against health disorders such as diabetes mellitus, cardiovascular diseases, constipation, hemorrhoids, and colon cancer (Mendeloff, 1987; Anderson *et al.*, 1994).

Fibre also has a buffering effect on the pH of stomach as it binds to the excess acids produced by the digestive system, aid in fecal bulking and intestinal emptying (Vergara-Valencia *et al.*, 2006). Protein-bound polysaccharides from the pumpkin pulp were reported to help in regulating the serum insulin levels, reduce blood glucose levels and improve glucose tolerance (Li *et al.*, 2005). McCance & Widdowson, (2000) stated that 100 g of raw pumpkin flesh contains 450μg carotene while Lingle, (1993) reported the presence of 2.67 mg β-carotene in 100 g edible portion of pumpkin. β-carotene has been reported to prevent certain types of cancer and cardiovascular diseases (Gliemmo *et al.*, 2009), mainly due to its antioxidant properties. The mechanism by which β-carotene protects against cancer was reported to be its capability to scavenge free radicals in the body (Ziegler, 1989). β-carotene is also the precursor for Vitamin A, which is important for healthy skin and vision.

2.2. Biscuits, crackers, and cookies

2.2.1 Overview

'Biscuits' is the original British word used to include small baked products (usually of flat shape) based on wheat with various inclusions of fat, sugar and other ingredients; it therefore includes crackers and the more luxurious product called cookies (Manley, 2001). They typically have a moisture content of less than 4% and have a long shelf life (Manley, 1998a). According to Smith (1972), a biscuit should has more than 60% of its total weight based on a cereal content (wheat, oat, maize, barley, soy, rye, etc), contain less than 5% moisture and considered a biscuit if so-called by custom, habit or tradition. The word cookie is not much used in the United Kingdom by either bakers or customers, whereas in North America, any type of biscuit, except crackers, might be referred to as cookie (Smith, 1972). Generally, cookies are formulated with high levels of sugar and vegetable shortening, or butter, and low levels of water. According to Cauvain & Young (2000a), English term 'biscuits' refers to low-moisture, hard eating and sweetened thin product with long shelf life. The term biscuit in US on the other hand, describes sweetened product with intermediate moisture, which is known as scone in United Kingdom.

2.2.2 Crackers

The art of making cookies and crackers is that of turning simple ingredients into wonderful things. Savoury crackers represent the practical and may have been the first convenience food. Many cultures and cuisines developed their own special crackers; Italian biscotti, Jewish ‘mandlebrot’, German ‘Zwieback’ and English ‘rusk’ are some examples. The word cracker appears to have originated in North America sometimes back in 18th century. Food historians generally agree that the light, crispy crackers we know today appeared in the 19th century, which coincides with the discovery of chemical leaveners, such as baking powder and soda. Crackers started out as thin, crisp, non-sweet, bite-size flatbreads. After World War II, the crackers industry expanded along with the rest of the snack food field (Smith, 2004). ‘Crackers’ is a name first used in North America from mid 18th century for a plain, unsweetened, dry, hard bread product; thus corresponding to part of the domain covered by the wider English term ‘biscuit’. When crackers are broken into pieces, they make a cracking noise, which accounts for the name (Davidson, 1999). Neo *et al.*, (2007) defined crackers as unsweetened, salty, thin and crisp biscuits. Crackers, together with cookies and breakfast food are important as energy providers in human nutrition (Rada-Mendoza *et al.,* 2004). Cream crackers are a typical British product. The first cream crackers were produced back in 1880, by W. & R. Jacob Ltd of Ireland. (Smith, 1972) and are now available in many countries. Crackers contain little or no sugar and moderate level of fat (Hoseney, 1986; Manley, 1983).

Crackers are made from low moisture dough that generally contain low amount of sugar and high levels of fat (Atwell, 2001) which is fermented to give a dry, flaky structure (Manley, 2001). However, the original characteristic of crackers, which is the large square shape with a soft flaky structure, has been lost, and nowadays it is common to have products known as crackers with none of the characteristics.

There are 3 major types of crackers; saltine, chemically leavened and savoury. Saltine which is also known as soda crackers or premium crackers are widely consumed in United States of America. It is square in shape but smaller than cream crackers and was produced by the sponge-dough method. Saltine production requires about 24 hours, much of it for fermentation. Soda bicarbonate is used to give higher pH to this cracker (Manley, 2001). Chemically leavened crackers are generally called ‘snack crackers’ and have a final pH of about 6.5 as compared to 7.0 to 7.1 for saltines. It requires a single stage mixing and a relatively short rest time (2 – 4 hours). Flavoured or savoury crackers are produced by adding appropriate flavoring agent directly to the dough before or to surface of crackers after baking (Smith, 2004). Flavours of crackers arise from fermentation process whereby the longer the process, the better is the taste. Crackers have holes in them to help keep the product even in texture, flat in shape and crisp to taste. The process by which the holes are made is called ‘docking’. Holes are spaced evenly to facilitate the evenness of the crackers. The holes facilitate steam release from the crackers and prevent big blisters on the crackers

(Manley, 1998b). High temperature, short time bake, puffs the thin dough sheets into crackers by vaporizing internal water.

2.2.3 Crackers in Malaysia

Malaysians have identified crackers as an unsweetened, salty, thin and crisp biscuit. This is close to the definition of crackers by the English, in terms of the technical aspect. The first commercial production of crackers started in year 1885 by William Beale Jacob under the brand Jacob's. Since then, crackers had gained tremendous popularity among people of all around the world, especially in England and countries affected by the British colonialism, including Malaysia. However, in Malaysia crackers are often referred to as 'keropok', a local fish/prawn/vegetable snack. 'Keropok' is a dried, crisp food generally popular in South East Asian cuisine (Taewee, 2011). It is made from starch or flour, seasonings and a protein ingredient such as fish or prawn. The dough obtained upon mixing of the ingredients is first cooked (boiled or steamed) and then dried (sun dried or hot air oven dried). Finally they are deep fried prior to serving.

2.2.4 Ingredients

2.2.4.a Flour

Flour is produced from finely ground meal of wheat or other grains (Bloom, 2007), but wheat flour is the principal ingredient in bakery products. The major wheat species for commercial flour milling is *Triticum aestivum L.* (Matz, 1989). Wheat sown in spring produces 'hard wheat' kernels which are milled into ‘strong flour’ with protein content ranging from 10.5 % to 14.5 %. On the other hand, wheat sown in autumn/ winter produces ‘soft wheat’ kernels which are milled into ‘medium/weak flour’ with protein content ranging from 8.5 % to 10.5 % (Manley, 1998a). Strong flour is preferred for products that need lengthy fermentation and extensive kneading, such as bread and crackers, while soft flour is more desired for biscuit production (Manley, 1998a). All purpose flour is a blend of hard and soft wheat that contains medium protein content. It is the most widely used flour for bakery products (Bloom, 2007). The characteristic of wheat flour which enables it to form the basis of bakery industry that has existed for thousands of years is that, it can be made into cohesive and elastic dough when mixed with water under suitable conditions. The influence of wheat flour on baked products depends on its composition, especially protein, starch and fibre content and also on the physicochemical properties such as particle size and protein quality (Cauvain & Young, 2000a). Wheat flour can be used either as white wheat flour or whole meal flour. Since flour may be present to the extent of 80% or more of the finished product, its qualities are the principal controlling factors in machining quality of the dough. It is also an important texture determinant (Matz & Matz, 1978).

On a 14 % moisture basis, wheat flour usually contains 7 % to 15 % of protein. Gluten is the functional component in flour protein (Atwell, 2001). Gluten is made up of gliadin and glutenin subunits, which present at 33 % and 16 % of the flour protein, respectively (Atwell, 2001). Hydrated gliadin is viscous and can be stretched into a thin strand due to its extensibility properties, but hydarated glutenin is very elastic, so much so that it returns to its original shape when stretched. The combined effect of gliadin and glutenin gives gluten the viscoelastic properties, which is a major concern in dough mixing and formation. Starch makes up 63 % to 72 % of wheat flour, with 25 % amylose and 75 % amylopectin. Amylose exist as a linear molecule, with α-1,4 linkages holding the glucose units together, while amylopectin has α-1,6 linkages holding the glucose units in a highly branched manner, in addition to α-1,4 linkages that bond the glucose units as a linear chain. Functionality of starch depends on its behaviour upon contact with water. Starch gelatinization, pasting properties and retrogradation are some of the starch functionality that has significant effect on food systems. The primary function of wheat flour in baking is that it provides structure. Gluten is the key player of this role. Texture of baked products is highly determined by the starch in the flour. Starch molecules expand when coming into contact with water to form a network that holds the other ingredients. Flour contains natural sugars that caramelize during baking. Therefore, flour is also responsible for the colour and flavour of bakery products.

Formation of paste and pasty liquids is the basis of desserts, sauces and gravy recipes (Fox & Cameron, 1995). Changes in viscosity of batter and dough have a great effect on volume and texture of bakery products (Atwell, 2001). A typical pasting curve of wheat flour is shown by Figure 2.2.4a

Initial rise in viscosity, as shown in region A-B is caused by the starch gelatinization. The starch granules swell and begin to exude their component into water and viscosity increases as the temperature rises at a constant rate from 50^{o} C to 95^{o}c. This phenomenon is also known as gelatinization (Thomas & Atwell, 1999). Starch is said to be 'cooked' or 'pasted' at this point. Pasting temperature indicates the minimum temperature to cook the sample (Shimelis *et al.*, 2006) and onset of viscosity increase.

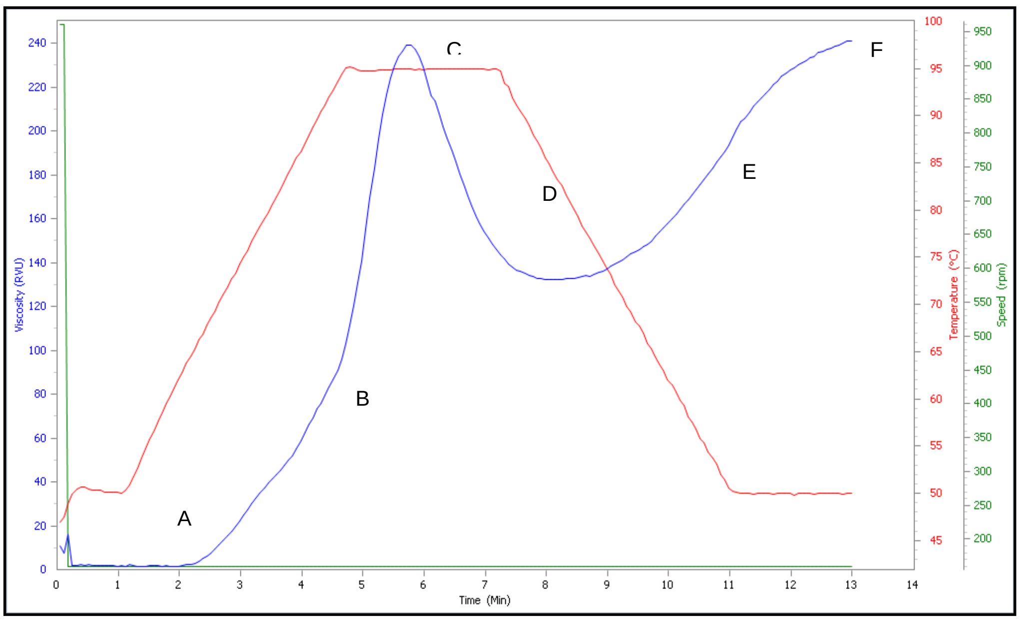

Figure 2.2.4a Typical pasting curve of wheat flour (Thomas & Atwell, 1999)

At region B-C, viscosity rises to peak viscosity and then begins to decrease. At this point, the temperature is held constant at 95^{o}C. At peak viscocity (point C), all the starch granules are swollen and fully pasted, and the paste viscosity is maximum (Thomas & Atwell, 1999). Following peak viscosity, shear alignment of exuded starch components occurs, causing a viscosity drop. This is known as the breakdown phase (region C-D). Dengate (1984)defined breakdown as the disintegration of paste stability, in which the swollen starch granules are disrupted and the amylose leach out into solution (Whistler & BeMiller, 1997). High value of breakdown reflects low stability of the starch paste. After point D, temperature decreases at a constant rate, during which the reassociation of starch components occurs. Hydrogen bonding between adjacent molecules is re-established and a gel is formed (Fox & Cameron, 1995) with an increase in viscosity. This is known as setback phase, which is shown by region D-E. Setback viscosity represents retrogradation of the starch gel formed. It indicates the tendency of the starch gel to undergo syneresis upon cooling (Singh *et al.*, 2004). The resulting gel could be a firm gel or a viscoelastic paste, depending on the amylose content of the starch. Higher amylose content will produce a firmer gel (Thomas & Atwell, 1999). Beyond point E, viscosity increases. This is due to the rearrangement and aggregation of exuded amylose molecules (Miles *et al.*, 1985). Ability of starch-based material to form a viscous paste or gel after cooking and cooling is defined as final viscosity (point F).

2.2.4.b Fat

Fats, saturated or unsaturated have been used in bakery products to improve palatability and mouth-feel. Fat can act as lubricants and contributes to plasticity of dough (Maache-Rezzoug *et al.*, 1998). The formation of gluten is controlled by adding fat to flour, thus less elastic dough can be produced. Roles of fats in different bakery products have been summarized in Table 2.2.4.b

Table 2.2.4.b Roles of fat in different bakery products

Types of bakery product	Functions of fat
Breads	Contributes to crumb softness and improves oven spring
Cakes	Enhance air incorporation during mixing, produce finer, softer crumb
Biscuits and cookies	Contributes to biscuit aeration and sensory properties
Pastries	Reduces moisture migration in composite pastry products and improves sensory acceptance
Laminated products	Improves sensory properties

(Adapted from : Cauvain & Young, 2000a)

All purpose shortening are the most commonly used in cookies and crackers. Shortening is a compounded plastic fat refined from pure vegetable oils or mixed with animal and/or marine animal oils (Smith, 1972). It is usually made of hydrogenated vegetable oils. Shortening is available as whitish solid which is tasteless and stays at same consistency at different temperatures (Bloom, 2007).

According to Igoe & Hui (2001), shortening is any animal or vegetable oil or fat that 'shortens' or retards the development of gluten strands in bakery goods for the purpose of producing tender and crisp texture. It is usually solid fats instead of oils used in baked goods to impart tenderness and soft crumb. Where bland flavours or label claims of 'vegetable origin' are important, hydrogenated fats prepared from soybean or cottonseed oil are the shortenings of choice (Matz, 1989).

2.2.4.c Yeast

Yeast is an important ingredient in fermented dough. Yeast is a microscopic organism that produces carbon dioxide through fermentation. Yeast converts sugar, usually glucose into ethyl alcohol and carbon dioxide (Mehas & Rodgers, 2002*). Saccharomyces cerevisae,* or bakers' yeast is a fungus of the type which does not form mycelia (Matz, & Matz, 1978). Sucrose and maltose can be broken down to simple sugars (hexoses) by enzymes present in yeast cell, but starch and dextrins cannot be attacked by *Saccharomyces cerevisae*. Enzymes present in flour are responsible for the production of sugars (dextrose or maltose) from the starches present in dough. Although chemical leaveners predominate in cookie formulations, large quantities of yeast are used in cracker making. The advantage of yeast leavening is that it can contribute a characteristic taste and aroma (Matz & Matz, 1978). Yeast, as received by the baker, is both in the compressed or the dried state; the former contains 70% moisture, and the latter contains approximately 92% solids. Active dry yeast is manufactured from a different strain than compressed yeast and it has a slightly longer lag period respective to maltose fermentation. It can tolerate drying, high sugar concentration, and some inhibitors such as propionates better than the compressed yeast strains. Active dry yeast has greater storage stability, helps maintain uniformity in dough, ease of measuring, greater storage convenience, and better dispersibility (Matz, & Matz, 1978). Yeast action on glucose yields alcohols which is driven off during baking and carbon dioxide gas which helps the dough to rise in volume and inflate (Williams & Pullen, 1998). This is an essential step in bread making and other fermented products. Carbon dioxide contributes to changes in texture and eating quality.

2.2.4.d Salt

Salt is a natural, edible white crystalline mineral (Bloom, 2007). Salt (sodium chloride) improves the flavour of most recipes by acting as a flavour enhancer (Manley, 2001). The usual cracker dough or batter can take 1.5% of salt without the occurrence of an unpleasant saline taste in the finished product (Matz & Matz, 1978). Salt is commonly added to bakery formulas at levels of from 1.0-2.5% of the flour weight, with more additions probably being near the lower than the higher side of the range. Sodium chloride affects both the fermentation rate of yeast and the rheology of the dough. Salt inhibits or 'controls' fermentation. This effect is not due solely to the increased osmotic pressure which results from the addition of salt to a dough formula, but is partly a specific manifestation of the action of the sodium and chloride ions on the semi permeable membranes of yeast