UTILIZATION OF JACKFRUIT (*Artocarpus Heterophyllus Lam.*) RIND POWDER AS VALUE ADDED INGREDIENT IN BREAD

By

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%	Percentage
°	Degree
°C	Degree Celsius
a*	Red/green
b*	Yellowness
C	Carbon
Ca	Calcium
CIE	Commission International de I' Eclairage
CO_2	Carbon dioxide
e.g	Example
Fe	Iron
$FeCl_3$	Ferric chloride
FV	Final Viscosity
g	gram
h	hour
H_2SO_4	Sulphuric acid
HCl	Hydrochloric acid
I	Iodine
IDF	Insoluble dietary fiber
JFR	Jackfruit rind
JRP	Jackfruit rind powder
K	Potassium
L*	Lightness
M	Molarity
m	Meter

Mg	Magnesium
Mg	Miligram
min	Minute
mL	Mililiter
mM	Milimoar
Na	Sodium
PT	Peak temperature
PV	Pasting Viscosity
RH	Relative humidity
S	Sulphur
SB	Setback
v/v	Volume per volume
w/v	Weight per volume
w/w	Weight per weight
Zn	Zinc

PENGGUNAAN NANGKA (*Artocarpus Heterophyllus* Lam.) SERBUK KULIT SEBAGAI BAHAN TAMBAH NILAI DALAM ROTI

ABSTRAK

Objektif utama kajian ini adalah untuk membangunkan roti berserat tinggi berasaskan nangka (*Artocarpus heterophyllus* Lam.) dengan menggunakan serbuk kulit nangka dalam pembuatan roti, dan menilai ciri-ciri fizikal, berfungsi, kimia dan sifat sensori roti berserat tinggi yang dihasilkan. Kulit buah nangka telah diolah dengan beberapa langkah perendaman dan pencucian sebelum dikeringkan dan digiling. Serbuk kulit nangka (Jackfruit rind powder, JRP) yang didapati telah campurkan dengan serbuk gandum (Wheat flour, WF) dalam tiga nisbah yang berbeza (5, 10 dan 15%) untuk menghasilkan serbuk gandum (WF) yang separa digantikan dengan JRP. Kesemua sampel roti termasuk sampel roti berdasarkan WF [BC (roti kawalan)], roti berdasarkan WF digantikan dengan 5% JRP (B5JRP), roti berdasarkan WF digantikan dengan 10% JRP (B10JRP) dan roti berdasarkan WF digantikan dengan 15 % JRP (B15JRP) telah menjalani analisis proksimat dan fizikal. Pencampuran JRP telah member pengaruh yang signifikan ke atas isipadu roti dan sifat-sifat teksturnya. Meningkatkan tahap JRP yang dicampurkankan ke WF, meyebabkan peningkatan dalam kekerasan dan kegelapan sampel roti, dan penurunan dalam isipadunya berbanding dengan kawalan. Sampel roti yang dihasilkan dengan serbuk gandum yang digantikan dengan 5% JRP mempunyai skor min tertinggi untuk penerimaan keseluruhan.

UTILIZATION OF JACKFRUIT (*Artocarpus Heterophyllus* Lam.) RIND POWDER AS VALUE ADDED INGREDIENT IN BREAD

ABSTRACT

The main objectives of this study were to develop jackfruit-based high fiber bread by utilizing jackfruit rind powder in bread formulation, and to characterize physical, functional, chemical and sensory properties of produced high fibre bread. Jack fruit rind pieces were treated with a few soaking and washing steps prior to drying and milling treatments. Obtained Jackfruit rind powder (JRP) was incorporated into wheat flour (WF) in three different ratios (5, 10 and 15%) to produce partially substituted wheat flour (WF) with JRP. All bread samples including bread sample based on WF [BC (as control)], bread based on WF substituted with 5% JRP (B5JRP), bread based on WF substituted with 10% JRP (B10JRP) and bread based on WF substituted with 15% JRP (B15JRP) were undergone proximate and physical analysis. The incorporation of JRP caused significant influence on bread volume and texture attributes. Increasing the level of JRP incorporated into WF, caused an increase in hardness and darkness of bread samples, and decrease in their volume compared to the control. Bread samples substituted with 5% JRP had the highest mean scores of overall acceptance.

CHAPTER ONE

INTRODUCTION

1.1 Background

Jackfruit (*Artocarpus heterophyllus* Lam.) belongs to the family Moraceae, and can be considered as the largest fruit among the edible fruits. Jackfruit has multiple fruit (syncarp) with a green to yellow brown rind. The rind composed of hexagonal, conical carpal apices (Elevitch *et al.,* 2006). It consists of essential nutrients such as carbohydrate, proteins, fiber, fat, vitamins and minerals. According to a report by Azad (2000), Potassium (191-407 mg/100 g fresh weight), Phosphorus (38-41 mg /100 g fresh weight) and Magnesium (27mg /100 g fresh weight) are the most abundant elements in the ripe fruit respectively.

Jackfruit tree is native in South East Asia and popular in several tropical and sub-tropical countries (Haq, 2006). Five states in Malaysia namely Terengganu, Kedah, Perak, Johor and Pahang constitute about 77% of the area under jackfruit (Aman, 1984). It is one of the most important local products in Malaysia which has multiple uses in industry and food applications. Food products from jackfruit are varied e.g. fresh jackfruit meat, jackfruit dried slice, jackfruit puree, and jackfruit essence (Aman, 1984). Jackfruit rind powder is produced from jackfruit residue, a by-product of the jackfruit processing industry (Asquiri *et al.,* 2008).

Recently, utilization of by-products with high nutrient values to develop value added food products have been receiving special attention. “Functional Foods” is an interesting research area in processed food industry. Several professional and international health organizations have defined functional foods that include conventional whole foods, enhanced or enriched foods and foods that provide beneficial physiological or health (IFIC, 1998; ILSI, 1999). High fiber bread is one of the known products categorized in 'Functional food,' which is health beneficial. According to reports by Guillon and Champ (2000), and Galisteo (2008), high dietary fibre intake has been proved to be beneficial for human health with reducing effect on colonic cancer. White bread has been more popular because of its organoleptic properties (Ingram and Shapter, 2006), however, there are increasing demands toward consumption high fibre breads due to their health prompting properties. Moreover, utilizing some bread enhancer such as calcium propionate and proper processing can significantly improve the texture of high-fiber breads (Stanley and Linda, 2006).

Thus, utilization of jackfruit rind as functional food instead of animal feed seems an interesting beneficial research which merits a study. Bakery products using Jackfruit rind powder as a source of dietary fiber can provide value added income, employment, opportunities and health benefits (Haq, 2002). Moreover the utilization of Jackfruit rind powder (JRP) is an environment friendly technology since it could solve the waste disposal problem of residues. High-Fiber Jackfruit rind powder as food supplement/additive in breads and cookies can be used as fiber food to help preventing constipation. It can be used as well as fiber food for patients with diabetes and moderately raised cholesterol levels. Moreover, since a vast amount of jackfruit residue is produced annually in Malaysia, utilization of this waste product in the production of value-added breads would benefit the country economically.

According to our knowledge no existing research has been conducted on JRP as functional food.

The aim of this research is to utilize Jackfruit rind powder as dietary fiber ingredients in bakery industry and to produce value added jackfruit-based bakery products such as breads and cookies to enhance the quality and special characteristics of existing bakery products in the market.

1.2 Objectives

The primary objective of this research is to develop high fiber bread with potential health benefits and functional properties by incorporation of Jackfruit rind powder (JRP) as dietary fiber source. Other specific objectives are:

1. To determine the physic-chemical and functional properties of JRP.

2. To evaluate the effect of added JRP in breads in term of the chemical, physical and sensory attributes.

This project is also aimed at optimal utilization of underutilized local Jackfruit by-products in the processed food industry.

CHAPTER TWO

LITERATURE REVIEW

2.1 Taxonomy and Origin of Jackfruit

Jackfruit (*Artocarpus heterophyllus Lam.*) belongs to the family Moraceae that is a fairly large sized tree and bears the largest fruit among the edible fruits. Jackfruit tree is native in South East Asia and popular in several tropical and sub-tropical countries. Jackfruit tree grows well under humid and warm climates of hill slopes. It is largely propagated by seed and being a highly heterozygous and cross-pollinated crop, which resulted in immense variation in the population for yield, size, shape and quality of fruit and period of maturity (Haq, 2002).

The genus *Artocarpus,* which is a member of the family Moraceae is part of the tribe called *Urticales*. This family includes species which are economically important. *Broussonetia* species are cultivated in the Asian tropics for paper pulp and the bast of *Artocarpus elasticus* and other *Artocarpus* spp. are locally used as fibre for rope and paper (Haq, 2002). However, the other members of Moraceae such as species of fig of the genus *Ficus* produce important fruits for humans in tropical regions. *Maehura* species produce sour fruits which are orange-like in North America and *Morus* species produce mulberry fruits in Europe and Asia (Haq, 2006).

Jackfruit is thought to be originated in the Western Ghats region of India. Some others have proposed that jackfruit originated in Malaysia (Elevitch and Manner, 2006; Haq, 2006). This uncertainty about the origin is due to insufficient taxonomic research carried out. Molecular research recently has provided important pointers to formation sequence of gene pools of jackfruit. However since this research has been conducted in Japan, Thailand and the USA only, a limited number of reports were available for analyses (Sidhu, 2001).

Several *Artocarpus* species provide edible and economically valuable fruits (Wester, 1921). Jackfruit *A. integer* (Thunb.) Merr., is eaten fresh and is truly domesticated and important in Malaysia and Indonesia. There are two other species which are minor domesticates: *A. odoratissimus* Blanco from Borneo and selected wild forms from Indonesia and Malaysia and *A. rigidus Blume* from the Malesian archipelago (covering Malaysia, Indonesia and extending to Papua New Guinea). A range of wild species of *Artocarpus* fruits are gathered for fresh consumption such as *A. lakoocha Roxb,* which are mainly confined to peninsular India and Nepal.

Jack fruit tree is monoecious and both male and female inflorescences are found on the same tree (Bose, 1985; Morton, 1987). After successful pollination, it takes three to seven months for completion of the process of fruit development. The fruit consists mainly of three regions, the fruit axis, the persistent perianth and the true fruit. The axis, the core of the fruit is inedible and is rich in latex due to the presence of laticiferous cells and holds the fruits together (Prakash et al., 2009).

Jackfruit is considered as a research worthy species because of its huge potential use in nutrition and because of its potential ability to increase local incomes specially when grown in agroforestry and homegarden systems. It is sometimes of high value locally (Rehm and Espig, 1991) and valuable when introduced to other parts of the world where it can be fairly cultivated in suitable climates (Morton, 1965).

2.2 Jackfruit: Artocarpus heterophyllus Lam.

The synonyms of the species of jackfruit (botanical or scientific name: Artocarpus heterophyllus Lam.) are: *A. philippinensis* Lam., *A. maxima* Blanco, *Soccus arboreus major* Rumph., *Polyphema jaca* Lour., *A. brasiliensis* Gomez (Soepadmo, 1992). Nevertheless, since various synonyms given to this species there is some confusion in relation to taxonomic nomenclature. One of the synonymes which is often used is *A. integrifolius* Auct. Nevertheless, it actually belongs to *A. integer* (Thunb.) Merr.

2.2.1 General morphology

It is described as an evergreen medium-sized to large tree with 10-20 m tall, (sometimes even reaching 30 m), with a dense crown and a long taproot. The crown is conical when the trees are young or grown under shaded conditions and reaches a diameter of 3.5-6.7 m at five years; becoming rounded and somewhat irregular when older.

The bark is described as somehow scaly and greyish brown or dark grey. Branches spread from low down the trunk while inserted at angles ranging from 30-90º. Twigs are cylindrical and mainly smooth but sometimes with short, white hairs, which become smooth later.

2.3 Fruits

Jackfruit provides a large yellowish syncarp (30-100 cm long and 25-50 cm in diameter), with a round-cylindrical which hangs on a stout stalk. The surface of the fruit is covered with numerous protruding pyramidal sections. The shape and colour of pericarp is yellow-white or yellow and waxy-firm (Corner, 1938). The fruit axis is rigid and slightly fleshy. The perianth's lower part becomes edible and fleshy; while the middle and the upper parts form the rind of the fruit (Plates 2.1, 2. 2 and 2.3). The perianth is the most important and bulk of the fruit (Prakash et al., 2009) which is made up of three different regions: the lower fleshy edible region, commonly called as the bulb; the middle fused region, that forms the rind of the syncarp and the upper free and horny non-edible region which is known as the spikes (Prakash et al., 2009). The ripe fruit (flesh) contain well flavoured yellow sweet bulbs and seeds.

(a)

(b)

(c)

Plate 2.1: (a) Mature jackfruit grown on the tree (b) the large fruit after picking, (c) Packed jackfruit bulbs (Source: own)

2.4 Seeds

The seed is firm and waxy, oval and oblong in shape. Each seed approximately is 2-4 x 1-2 cm in size and 2.5-14 g in weight (Gunasena *et al.,* 1996). In general, each fruit syncarp includes 100-500 seeds. The inner part of the seed coat is brown and thin.

The testa is thin and leathery and is rather thick, tough, parchment-like and crinkly when dry. The inner seed coat is a thin, brownish membrane.

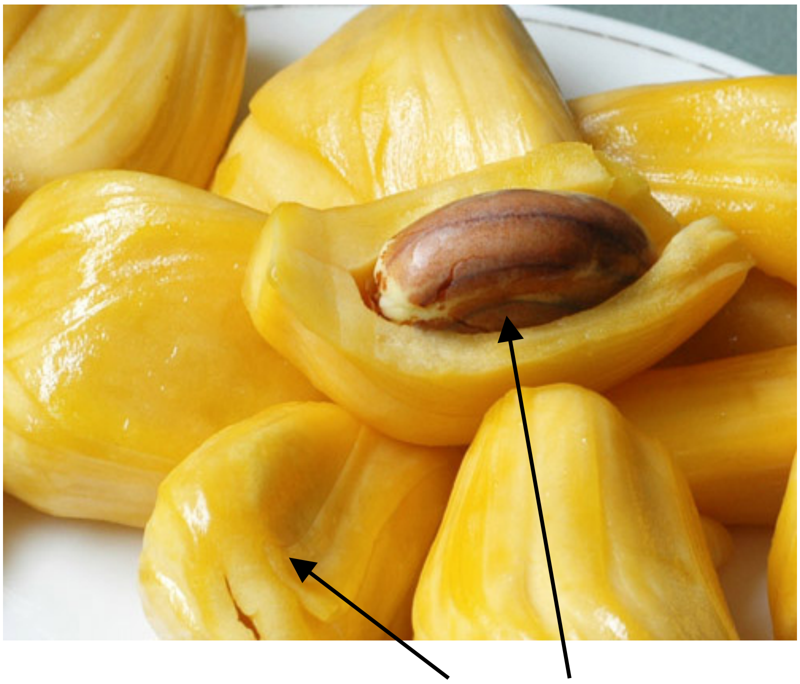

Plate 2.2: Jackfruit bulb and seed (Source: own)

2.5 Nutritional Value

Jackfruit consists of essential nutrients such as carbohydrate, proteins, fiber, fat, vitamins and minerals (Table 2.1). According to a report by Azad (2000), Potassium (191-407 mg/100 g fresh weight), Phosphorus (38-41 mg /100 g fresh weight) and Magnesium (27mg /100 g fresh weight) are the most abundant elements in the ripe fruit, respectively.

The concentration of carbohydrates and proteins vary depending on the variety of the jackfruit even thought they are from the same region. The protein and carbohydrate concentration of different varieties of jackfruit seed from Kanyakumari district of India Recently were evaluated (Chrips, et al., 2008). Variation in the levels of fats, minerals and vitamins has also been reported and is represented in Table 2.1. Furthermore, jackfruit quantitatively contains more protein, calcium, iron and thiamine compared to other tropical fruits *e.g.* banana, mango, pineapple and papaya, and are a good source for these essential nutrients (Bhatia et al. 1955; Kumar et al., 1988; Haq, 2006).

Table 2.1 Composition (100 g) of Jackfruit (fresh weight basis).

Composition of ripe fruit	
Water (g)	72.0-94.0
Protein (g)	1.2-1.9
Fat (g)	0.1-0.4
Carbohydrate (g)	16.0-25.4
Fibre (g)	1.0-1.5
Total sugars (g)	20.6-21.2
Total minerals (g)	0.8-0.9
Calcium (mg)	20.0-37.0
Magnesium (mg)	27.0-30.0
Phosphorus (mg)	38.0-41.0
Potassium (mg)	191-407
Sodium (mg)	2.0-41.0
Iron (mg)	0.5-1.1
Vitamin A (IU)	175-540
Thiamine (mg)	0.03-0.09
Riboflavin (mg)	0.05-0.4
Vitamin C (mg)	7.0-10.0
Energy (Kj)	88-410

Source: Narasimham (1990); Soepadmo (1992); Gunasena *et al,* (1996); Azad (2000).

2.6 Jackfruit Rind

Jackruit rind (Plate 2.3), which includes perianths of unfertilised fruits, has been genereally processed to produce syrups and jellies due to its good basis of pectin. Rinds along with other waste parts of the fruits are utilized as a nourishing feed for livestock (Sudiyani *et al.,* 2002). To optimize the digestibility, supplemental nitrogen has to be provided. Thus, molasses-urea cake is fed along with the jackfruit waste for cattle for a better digestibility (Haq, 2006). The rind thickness enlarges from about 0.4 cm to 1-2 cm (Haq, 2006) at maturity. Similarly the pithy core or receptacle increases from about 1.9 cm to 7.5 cm in width. Nevertheless, it only composes about 16% of the total fruit width. As fruit matures, the latex amount in the core increases, however, it is reduced as the fruit ripens (Moncur, 1985).

Plate 2.3: Jackfruit rind (Source: own)

2.7 Vernacular Names

In English, jackfruit is commonly called *"jak"* or *"jack,"* with adaptations of the Portuguese *"jaca"* (Popenoe, 1974). It can be derived from the Malaysian name, *"tsjaka"* or *"chakka"* or from the word "Chakka" of Malayalam which is a regional Indian language (Pradeepkumar et al., 2008). Jackfruit tree produces the largest tree-borne fruits in the world and a mature tree can yield anywhere between ten to two hundred fruits (Reddy et al., 2004; Haq, 2006).

At times these fruits which contain numerous hard cone-like points may be as heavy as 45 kg in weight, and up to 36 in. in length and 20 in. in diameter (Prakash et al., 2009). Due to these characteristics in the ancient Indian language of Sanskrit jackfruit is referred to as Atibruhatphala (Ati=very, bruhat=big, phala= fruit) and Kantaphala (Kanta=thorny, phala=fruit) (Samaddar, 1985; Haq, 2006; Prakash et al., 2009).

Further common names in specific languages are listed below.

English: Jackfruit, jak, jack, jaca-tree,

French: Jacque or jacquier, jack

Spanish: Jaca, jacquero

Dutch: Nangka, jacca

German; Jacabaum, Jackbaum

Portuguese: Jaqueira, Jaca, Jaca da Baia.

2.8 Domestication

Jackfruit is thought to be originated in the Western Ghats region of India. Some others have proposed that jackfruit originated in Malaysia (Zielenski, 1955; Ruehle, 1967; Barrau, 1976). It is not known in the wild form. The uncertainty about the origin is because of inadequate data collected, however some researchers have contributed for it essentially to be clarified (Haq, 2006).

Jackfruit trees appear to have a great variability and it is due to its natural cross pollination and protandry. Nevertheless, a wide range of cultivars have been identified which can be classified in two groups (Haq, 2006):

a) Cultivars with soft-fleshed fruits, with a taste of acidic to sweet and with a strong aroma.

b) Cultivars with firm-fleshed fruits, which basically are sweet to slightly acidic and less aromatic.

2.9 Origin and Distribution of the Fruit

The exact region of jackfruit has been a debate issue in the literature. Some authors reported that Malaysia might be the centre of origin (Ruehle, 1967), while Martin *et al*., (1987) believed that jackfruit is indigenous to tropical Asia. However, most authors agree in their report that jackfruit has been originated in the rain forest of the Western Ghats of India (Soepadmo, 1992; Elevitch et al, 2006; Haq, 2006; Azad et al., 2007).

Nowadays, Jackfruit is widely grown in many Asian countries especially Bangladesh, Myanmar, Nepal, Sri Lanka, Thailand, Malaysia, Indonesia, India and the Philippines. It is also grown in Southern China and in the Indo-Chinese region in Laos, Cambodia and Vietnam (Manjunath, 1948; Morton, 1987; Narasimham, 1990; Gunasena *et al.,* 1996).

From Asia it spread to tropical Africa especially the eastern part namely Zanzibar, Kenya, Uganda and Madagascar. It is also grown in Mauritius. From the mid-seventeenth century to the late nineteenth century, the species spread further to tropical and subtropical America (Brazil, Surinam, the Caribbean and USA) and Australia (Haq, 2006).

According to a report by Morton (1987) in 1782, plants captured from a French ship bound for Martinique were taken to Jamaica where the tree is now common.

In Australia it is mostly grown in the tropical regions of north Queensland and near the Northern Territory around Darwin where these fruits are available for most of the year.

Jackfruit trees which were grown in Florida in the 1880s might have been introduced from Sri Lanka. Many seedlings were planted and they survived in South Florida. Jackfruit was introduced into northern Brazil in the mid-nineteenth century. It is more popular there and in Surinam, and after that elsewhere in the New World.

The cultivation was spread in neighbouring countries to South and South East Asia and to Southern China.

Plate 2.4 Cutting a large fruit, Rayong, Thailand
(Source: C. Elevitch, 2006)

2.10 Cultivation Cost

Since jackfruit is not regarded as a major fruit by most national research programmes, collecting data for actual production areas, total production and production cost is complicated. However, from the available sources it can be known that production from Indonesia, Malaysia and Thailand exceeds 7.5 million tonnes (Haq, 2006).

Based on reports, jackfruit can be considered even more profitable than mango or other major fruits, due to its regular fruiting and high market price (Haq, 2006).

Fruiting season and the time of maturity are the most important factors which affect supply and marketing of jackfruit. They vary depending on the climatic conditions and ecosystems. The jackfruit season is divided into: early, peak and off-peak based on its accessibility in the market (Soepadmo, 1992; Crane *et al.,* 2003).

2.11 Jackfruit rind powder

Jackfruit rind powder (JRP) can be produced from jackfruit residue, a by-product of the jackfruit processing industry. Upgrading the use of jackfruit residue from animal feed to functional food will be of great benefit to the country. Bakery products using Jackfruit rind powder (JRP) as a source of dietary fiber can provide value added income, employment, opportunities and health benefits for the population. Moreover the utilization of Jackfruit rind powder (JRP) is an environment friendly technology since it could solve the waste disposal problem of residues.

Jackfruit rind powder (JRP) is sub-classified according to its fat content, protein content (low protein), fiber content (high fiber) and minerals. It has the potential to be identified as a promising ingredient in the formulation of functional food products due to its high dietary fiber content. It consists of 60% dietary fiber (56% insoluble and 4% soluble).

2.12 Minerals

Minerals are defined as inorganic compounds that yield no energy but play a key role in proper function and regulation of metabolisms in human body (Eruvbetine, 2003). Every form of living matter requires these inorganic elements or minerals for their normal life processes (Ozcan, 2003).

Minerals as inorganic nutrients usually are required in small amounts from less than 1 to 2500 mg per day, depending on their type. As with vitamins and other essential food nutrients, mineral requirements vary with animal species. For instance, humans and other vertebrates need large amounts of calcium for construction and maintenance of bone and normal function of nerves and muscles. Phosphorus is an important constituent of adenosine triphosphate (ATP) and nucleic acid. It is also essential for acid-base balance, bone and also tooths formation. On the other hand, red blood cells cannot function properly without iron in haemoglobin, the oxygen-carrying pigment of red blood cells. Iron is also an important component of the cytochromes bearing an important function in cellular respiration (Soetan et al., 2010).

Magnesium, copper, selenium, zinc, iron, manganese and molybdenum are important co-factors which can be found in the structure of certain enzymes. They are indispensable in many biochemical pathways. Vertebrates need iodine to make thyroid hormones.

Sodium, potassium and chlorine have an important role in the maintenance of osmotic balance between cells and the interstitial fluid. Magnesium is a critical component of chlorophyll in plants.

It is important to note that the interactions between nutrition and diseases, nutrition and drug metabolism have been proved and reported. Excessive intake of minerals may upset homeostatic balance and lead to toxic side effects. For instance, excess sodium intake is associated with high blood pressure. Similarly, excess iron may cause severe liver damage. Also, severe shortages or self-prescribed minerals can change the delicate balance in body functions which enhances health. The knowledge of the biochemistry of the mineral elements is crucial since individuals who suffer from a chronic illness or taking medications need to be enlightened.

Information on mineral element content of foods, diets and water is required to evaluate the dietary intake and adequacy of minerals, (Simsek and Aykut, 2007). There is no sufficient information on the trace element content of water and lots of plant foods consumed in some less developed countries.

Some factors such as soil acidity and season affect mineral uptake by plants. Plants use these minerals as structural components in carbohydrates and proteins; organic molecules in metabolism e.g. magnesium in chlorophyll and phosphorus in ATP; enzyme activators like potassium, and for maintaining osmotic balance. Calcium is highly important in the maintenance of firmness of fruits (Olaiya, 2006). However, its requirement in fruits depends on cell wall stability and membrane integrity (Belakbir et al., 1998). Mineral elements play important roles in health and disease states of humans and domestic animals.

It is important to regularly obtain up-to-date information on the minerals content of water and the commonly consumed plant foods utilized for human and animal foods and feeds respectively.

2.13 Dietary Fiber

Dietary Fiber (DF) is defined as non-digestible carbohydrate and lignin from the edible parts of plant which is resistant to digestion, hydrolysis and absorption in small intestine of human digestive tract (Prosky, 1999; Mugford, 1991). However, recently the definition has been expanded to include oligosaccharides, such as inulin, and resistant starches. The beneficial effects of dietary fibre for human health have been widely reported (Schneeman, 1998; Champ and Guillon, 2000).

The special characteristics of DF has been believed to play a major role in the prevention and treatment of various gastrointestinal disorders (hernia, duodenal ulcer, gall stones, appendicitis, constipation, hemorrhoids, colon carcinoma), obesity, atherosclerosis, coronary heart diseases, colorectal cancer and diabetes (De Escalada Pla *et al.*, 2007). It has been known as an alternative way to add dietary fiber into food and to enhance the lack of dietary fiber in daily diet. Dietary fibers promote beneficial physiological effects including laxation which results from increasing the dietary fiber component of one's diet instead of other food components. This physiological effect is mostly taken for granted but it imparts positive feelings to the individual consuming the dietary fiber along with other benefits of improved laxation. Not all dietary fibers impart all of the positive physiological effects, but they are expected to impart at least one of the positive impacts. When a signal or other parameter is attenuated, it is adjusted so it is neither too high, nor too low. Research over the past several decades has proven that a positive adjustment in levels of serum cholesterol, a biomarker related to the risk of coronary disease is produced by consumption of high fiber foods and dietary fibers. Also, a significant decrease in the peak level of serum glucose after eating is caused by an increased consumption of dietary fiber and high fiber foods in place of other foods in a particular meal, which in general is beneficial to health, especially in susceptible individuals. A lot of evidences indicate these positive attributes for increased dietary fiber consumption. Dietary fiber has been defined on the basis of the properties which have been characterized as part of the extensive worldwide research studies during the past 30 years (Jones et al., 2006). These research studies have correlated the positive health impacts of dietary fiber with its increased consumption. As a result of this definition plant components are accepted as being included in the defined dietary fiber that imparts the positive health effects. A category of dietary fiber namely analogous dietary fiber is defined as those materials, not necessarily intrinsic to a part of a plant as consumed, but that exhibit the digestion and fermentation properties of fiber. This category of materials, in addition to the requisite digestion and fermentation properties, must also exhibit a positive potential health benefit that has been attributed to dietary fiber. This inclusion clearly states that certain food ingredients, whether they are plant extracts, concentrates, modified carbohydrates, or designed produced compounds, should be recognized as dietary fiber considering their nutritional properties and labelling requirements as part of a food. Importance and relevance of dietary and analogous fiber and their functional properties, is clear as stated (AACC, 2001).

Not only fiber has nutritional applications, but also can be used for technological purposes e.g. as bulking agent or as fat substitute in foods (Guillon and Champ, 2000). It is highly recommended by the World Health Organization (WHO, 2003) to consume foods containing more than 25 g of total dietary fiber per each day. This has enhances efforts to add dietary fibre into food products.

Regarding therapeutic potential of dietary fibre, more fibre incorporated food products are being developed. Addition of dietary fibre to a wide range of products will contribute to the development of value-added foods or functional foods that nowadays are in high demand. In addition to the physiological benefits provided by high fibre foods, studies have shown that fibre components may give texture, gelling, thickening, emulsifying and stabilizing characteristics to certain foods (Dreher, 1987; Sharma, 1981).

According to WHO, dietary fiber is the only dietary ingredient with a convincing inhibitory impact against obesity.

A range of variety of plan food sources, such as fruits, vegetables, legumes and cereals in raw or processed form are rich in dietary fiber. Different types of plant species contain different composition of dietary fibers (soluble and insoluble). For instance, cellulose can be generously found in vegetables and cereals, while hemicelluloses can be found in whole grain cereals and bran. Lignin is reported to be found mostly in fruits with edible seeds such as berries and also in root vegetables such as carrot.

The amount of different dietary fiber constituent varies depending on the growing stages of the plant. Other than maturity, ripening and the portion of the plant consumed and storage condition of plants can be effective on the composition of dietary fiber (Elleuch et al., 2011).

In general, dietary fiber can be classified in two groups: soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). The sum of soluble and insoluble is called total dietary fiber (TDF). Soluble dietary fiber mostly consists of non-cellulosic polysaccharides available in fruits, legumes, barley, peas and oats. On the other hand, majority of IDF contain cell wall components such as cellulose, hemicelluloses and lignin, and can be found in wheat, vegetables and many grain products.

2.13.1 Soluble dietary fiber (SDF)

SDF plays a key role in absorptive and digestive processes since it is an indigestible fiber. It is also effective in controlling the blood glucose levels and slowing down the glucose absorption process in diabetic patients. Some examples of SDF are pectin, inulin, β-glucan and gum (Elleuch et al., 2011). There are reports which indicated that by consuming food sources rich in SDF, blood cholesterol decreased in patients with high blood cholesterol levels (Dhingra et al., 2004).

(a) Pectin

Pectins are a family of complex polysaccharides containing 1,4-linked α-D-galactosyluronic acid residues. They are present in most primary cell walls and in the non-woody parts of terrestrial plants. They are also known as rhamnogalacturonans because of presence of rhamnose which is a 6-deoxy-hexose sugar. In pectin, the galacturonic acids can be partly presented as the free carboxylic acid which can be ionized and bind with minerals.

Pectin contents of dietary fibers are estimated based on the galacturonic acid, however there is not a specified method to evaluate it accurately since some hemicellulosic compounds also contain uronic acid (Dhingra et al., 2012).

Pectin is stable at ordinary conditions; nevertheless, it becomes unstable in excess heat. It is soluble in pure hot water, and can form gels once cooled. It is partially soluble in cold water and insoluble in alcohol and organic solvents. When pectin is mixed with alcohol or organic solvent and mixed with water it is soluble, whereas di- and tri- salts are weakly soluble or insoluble. Gelling formation is a very important property of pectin which caused its wide utilization in food industries. Products such