PHYSICO-CHEMICAL AND SHELF-LIFE STUDIES ON REDUCED FAT LEGUME-BASED COOKIES USING SAGO FLOUR AS A FAT REPLACER

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KAJIAN SIFAT FIZIKO-KIMIA DAN JANGKA HAYAT BISKUT KURANG LEMAK BERASASKAN LEGUM DENGAN MENGGUNAKAN TEPUNG SAGU SEBAGAI PENUKAR LEMAK

ABSTRAK

Tepung sagu telah digunakan sebagai penukar lemak sebanyak 40% dan tepung gandum telah digantikan dengan 35% tepung legum (kacang kuda dan kacang hijau) dalam formulasi biskut. Kajian ini bertujuan untuk mengurangkan kandungan lemak di dalam biskut melalui penggunaan kanji sagu sebagai 'fat replacer' serta meningkatkan kualiti protein dan gentian melalui penggunaan tepung legum (kacang hijau dan kacang kuda). Kesan penggunaan 40% sagu sebagai 'fat replacer' serta penggantian dengan 35% tepung legum terhadap sifat-sifat fizikal, kimia, deria dan jangka hayat biskut telah dijalankan. Semua biskut dengan 'fat replacer' [MBF (kacang hijau dengan penukar lemak), CPF (kacang kuda dengan penukar lemak) dan CF (kawalan dengan penukar lemak)] telah menunjukkan kandungan lembapan lebih tinggi secara signifikan ($p<0.05$) berbanding biskut tanpa 'fat replacer' [MB (kacang hijau tanpa penukar lemak, CP(kacang kuda tanpa penukar lemak) dan C (kawalan tanpa penukar lemak). Namum demikian, kandungan lemak menurun secara signifikan ($p<0.05$) (30-32%) bagi biskut dengan 'fat replacer'. Kandungan protein bagi biskut yang mengandungi kacang hijau (MB dan MBF) mempunyai kandungan protein yang tinggi secara signifikan ($p<0.05$) (7.04% dan 7.17%). Kandungan abu juga berbeza secara signifikan bagi biskut dengan kacang hijau berbanding biskut lain. Bagi kandungan gentian kasar, didapati biskut kawalan (C dan CF) berbeza secara signifikan ($p<0.05$) berbanding biskut-biskut lain. Kandungan gentian dietari biskut kacang kuda (CPF dan CP) adalah lebih tinggi secara signifikan ($p<0.05$) (5.38% dan 5.03%) berbanding biskut-biskut lain. Biskut kacang kuda (CP dan CPF) didapati mempunyai tahap perencat aktiviti tripsin yang tertinggi ($p<0.05$) (3.76% dan 3.26%) tetapi sebaliknya mempunyai nilai kehadaman protein terendah (70.76% dan 70.16%) berbanding biskut-biskut lain. Keputusan analisis asid amino menunjukkan biskut-biskut yang menggunakan tepung legum mengandungi kandungan lisina yang tinggi tetapi rendah kandungan metionina dan sistina. Biskut CP didapati mempunyai diameter dan ‘spread ratio’ paling besar ($p<0.05$) berbanding biskut lain. Penambahan ‘fat replacer’ didapati mengurangkan diameter dan ‘spread ratio’ biskut secara signifikan ($p<0.05$). Analisis tekstur menunjukkan biskut dengan ‘fat replacer’ (MBF, CPF dan CF) adalah lebih keras secara signifikan tetapi kurang rangup berbanding biskut tanpa ‘fat replacer’ (MB, CP dan C). Dari segi warna, semua biskut mengandungi ‘fat replacer’ didapati mempunyai warna lebih pucat dengan nilai L yang tinggi ($p>0.05$) berbanding biskut tanpa ‘fat replacer’. Penilaian deria mendapati biskut CP adalah paling disukai berbanding biskut-biskut lain. Kajian jangka hayat pantas (ASLT) menunjukkan biskut kawalan (C dan CF) mempunyai jangka hayat paling lama (280 hari). Analisis pemindahan lembapan menunjukkan biskut dengan ‘fat replacer’ mempunyai jangka hayat lebih pendek berbanding biskut tanpa ‘fat replacer’.

ABSTRACT

Sago flour at 40% level was used as fat replacer in cookies together with wheat flour substituted at 35% with chickpea and mungbean. The purpose of using sago flour was to develop reduced fat with increased protein and fibre. The effects of adding 40% sago flour to each type of 35% chickpea and mungbean flour were evaluated for physical, chemical, sensory and shelf-life properties of cookies. All cookies with fat replacers MBF (Mungbean cookies with fat replacers), CPF (Chickpea cookies with fat replacers) and CF(control cookies with fat replacer) were shown to have significantly higher ($p<0.05$) moisture content than cookies without fat replacer MB (mungbean cookies without fat replacer), CP (chickpea cookies without fat replacer) and C (control cookies without fat replacer). However, the fat content was significantly ($p<0.05$) reduced (30-32%) for cookies with fat replacer (MBF, CPF and CF) compared to cookies without fat replacer. Protein content of cookies containing mungbean flour and mungbean flour without fat repalcer (MB and MBF) had significantly higher ($p<0.05$) amount of protein (7.04% and 7.17%). The ash content of cookies with mungbean flour (MB and MBF) were significantly higher ($p<0.05$) from the other treatments. For crude fibre content, result showed that the control cookies (C and CF) were significantly higher ($p<0.05$) from other cookies. Dietary fibre content of chickpea cookies (CPF and CP) was significantly higher ($p<0.05$) (5.38% and 5.03%) as compared to other cookies. Level of trypsin inhibitor activity for cookies containing chickpea (CP and CPF) were significantly higher ($p<0.05$) (3.76% and 3.26%) as compared to other cookies but the protein digestibility value of chickpea cookies was significantly lower ($p<0.05$) (70.76% and 70.16%). In amino acid analysis, it was observed that cookies utilizing legume flour had significantly higher level of lysine but lower in methionine and cysteine. CP cookies were observed to have the largest diameter and spread ratio ($p<0.05$) compared to other types of cookies. Addition of fat replacer was noted to decrease the diameter and spread ratio of cookies significantly ($p<0.05$). Textural analysis showed that cookies with fat replacer (MBF, CPF and CF) were significantly ($p<0.05$) harder in texture but less crispy as compared to cookies without fat replacer (MB, CP and C). In terms of colour, all cookies with fat replacer were observed to have significantly higher ($p>0.05$) L value compared with cookies without fat replacer indicating a lighter surface colour. Overall acceptability of sensory evaluation showed that CP cookie was the most acceptable among other cookies. Accelerated shelf-life studies showed that control cookies (C and CF), was found to have the longest shelf-life (280 days) as compared with the other types of cookies. Studies on moisture vapour transfer indicated that cookies with fat replacer had a lower shelf-life as compared to those without fat replacer.

CHAPTER 1 INTRODUCTION

High intakes of dietary fat are implicated for the cause of coronary heart disease. The Dietary Guidelines for Americans suggest that people choose a diet low in fat and recommend that dietary fat comprise no more than 30% of daily energy intake for healthy adults (Giese, 1996). The use of fat-modified foods was ranked as the easiest and most preferred strategy to reduce fat intake in the long term (McEwan and Sharp, 2000).

The success of fat modified food depends on the sensory acceptability of fat modified foods included in the diet and their similarity to their full-fat counterpart. Most consumers are not ready to trade taste for health; therefore, reduced-fat products need to be at least as acceptable as the full-fat ones even though they may have different taste (Roller and Jones, 1996).

As consumers have attempted to reduce their fat intakes, the demand and consumption of reduced-fat foods has increased. In the U.S, between 1995 and 1997, the number of people that have eaten a food labelled as low-fat or non-fat had increased from 73% to 75%. Fat-modified foods have become part of the national food supply. From 1990 through 1998, 15697 fat-modified foods were introduced into the market (Roller and Jones, 1996).

Baked products that are low in moisture, especially cookies are difficult to prepare when the fat is reduced (Sanchez *et al.*, 1995). Cookies are relatively high in fat, and reducing the fat component alters appearance, flavour, aroma, and texture. However, if the sweetness in the cookie is maintained, consumers will tolerate some deviations from the standard recipe in both texture and flavour (Drewnowski *et al.*, 1998). Several studies using a variety of fat replacers have produced cookies judged to be somewhat acceptable (Sanchez *et al.*, 1995; Conforti *et al.*, 1996; Armbrister and Setser, 1994; Inglett *et al.*, 1994).

Carbohydrates such as gum, starch, pectin, and cellulose have been used as commercial fat replacers. Starch and their derivatives can also be added to food products as fat replacers due to diverse binding properties (Akoh and Swanson, 1994). They provide some of the functions of fat in foods such as providing texture, mouthfeel, and opacity by binding water. Studies showed that *Litesse* (Danisco Sweeteners, Surrey, England), a polydextrose, can be substituted for 25% to 35% of fat in cookie recipes whereas *Oatrim* (Rhodia Convenience Foods. Cranbury, NJ), an oat flour enzyme hydrolysate of soluble beta-glucans and amylodextrins, can replace 50% of fat in bakery products without compromising sensory characteristics of quality (Akoh and Swanson, 1994).

Sago flour, derived from sago palm *(Metroxylon sagu*) is mainly used in the food industry as a thickening agent and stabilizer. Sago which is mostly grown in the district of the Mukah and Dalat in Sarawak contributed almost 70% of all sago production in the Malaysia. Sago has been used in traditional baked foods but it is usually added to a formulation and not as fat replacer. Sago is high in carbohydrates, especially starches. Because of this, it was theorized that sago might have the potential to replace some of the fat in cookies. Nutritionally, sago is a healthful fat replacer because they are low in fat and high in dietary fibre and minerals such as calcium and iron. They are also an inexpensive, readily available food. An added benefit is that dietary fat absorption is reduced in the presence of considerable dietary fibre.

Legumes are widely recognized as important sources of proteins. In many regions of the world, legumes are the unique supply of protein in the diet. Bressani and Elfas (1980) reported that essential amino acid pattern of legumes is almost similar to the reference or animal protein. Thus, in the developing countries where the quality proteins from animal sources are deficient, legumes can be used as protein supplement in their diets. Incorporation of legume into a familiar product such as a cookie would give the products better acceptability and distribution in the market thus supplying the required quality proteins. Moreover, legumes were also reported to have a considerable amount of resistant starch (RS) that has many beneficial physiological effects in controlling and preventing various metabolic diseases such as *diabetes mellitus*, coronary heart disease and colon cancer.

The main objectives of this study are to evaluate the effect of sago flour as a fat replacer with the incorporation of mungbean and chickpea flour to increase the protein and fibre content in cookies. Specific objectives are:

1. To determine the feasibility of using sago flour as a fat replacer ingredient in cookies by comparing the organoleptic qualities of reduced fat cookies as compared to high-fat control cookies.
2. To study the proximate, amino acid and resistant starch compositions of reduced fat cookies supplemented with chickpea and mungbean flour.
3. To study the effects of substituting sago flour with chickpea and mungbean flour on the shelf-life of cookies.
4. To study the effects of substitution of chickpea and mungbean flour on trypsin inhibitor activity and protein digestibility of cookies.

CHAPTER 2 LITERATURE REVIEW

2.1 COOKIES

2.1.1 Background

Cookies are popular and well-accepted snack food throughout the world. It is very established in industrialized countries and is rapidly expanding in developing countries. People from different age groups and backgrounds eat cookies. Cookies are available in wide variety and are nutritious and simple to produce. It can be made easily with readily available ingredients.

In most countries of the world, cookies form a very big food industry. Manley (2000) reported that the four key factors for its success are:

i. their relatively long shelf-life.
ii. their great convenience as food products.
iii. the human liking and weakness for sugar and chocolate.
iv. their relatively good value for money.

The market for cookies has been growing rapidly. The world global market for cookies reached a total of $29.3 billion in 1998 (Table 2.1). The U.S market for cookies has increased considerably from 1997 to 2001 with a forecast of $6.3 billion in 2006 (Table 2.2). The development of healthier cookies products has been on the rise in recent years.

Table 2.1 World market size of cookies and savoury biscuit. (Anon, 2003)

	Market Size (US$ Million)				
	1994	**1995**	**1996**	**1997**	**1998**
Cookies	26175.40	28553.70	29.276.2	29.256.0	29376.0
Savoury Biscuit	9789.8	10550.5	11044.2	11283.9	11336.4

The market of cookies is expected to grow further with new products innovation that emphasize on product fortification and the continued emergence of organic food. The growth of demand of cookies in the market will also benefit the manufacturer investment in new products, particularly in low calorie product such as fat and sugar free cookies.

Table 2.2 Market size of cookies and savoury biscuit in the United States (Anon, 2003)

	Market Size (US$ Million)			
	1997	**2001**	**2002***	**2006***
Cookies	5605.90	6259.70	6353.60	6365.80
Savoury biscuit	3605.60	4332.80	4384.70	4424.90

* forecasted

2.1.2 Definition of cookies

Cookies are sometimes confused with biscuit. The term cookie actually refers to hard sweet or semi-sweet type of biscuits. The term cookies is adopted in North America where biscuits can be confused with small soda raised bread or muffins. In other countries, cookies refer to wire cut products that contain large pieces of various ingredients like nut and chocolate (Manley, 2000).

Cookie has a lot of similarities with other bakery products such as bread or cakes. According to Smith (1972), cookies can be defined as a type of bread that is crispy, hard, have many varieties of flavour and made into small and thin shape. The difference between bread and cookies is in terms of the levels of fat and sugar used and the moisture content of the final product. In comparison with cakes, differences were found in terms of the dough consistency and moisture content of cookies. Cakes were baked in containers unlike cookies that were baked on any flat surface (Manley, 2000).

In biochemical terms, cookies are a semi fluid mixture, consisting of flour, sugar, shortening, water and sodium bicarbonate and that are transformed into solid form when treated by heat (Abboud and Hoseney, 1984). This semi fluid mixture, undergo the baking process where heat will promote formation and dehydration of dough, browning reaction and other physico-chemical processes. Baking will result in a porous structure with good mechanical attributes (Piazza and Masi, 1997).

Smith (1972) reported that the final products of cookies are:

i) Based on the cereal –wheat, oat, corn, etc. and not considered a cookie if more than 60% of its total weight is not based on cereal.

ii) Should have moisture content less than 5%.

2.1.3 Nutritional aspect of cookies

Cookies that have been classified as a snack food (Brown *et al.*, 1998) are not regarded by consumer as an important nutrient contributor but as a compliment for other food (Lorenz, 1983). Cookies are usually eaten for its organoleptic attributes, but not for nutritional factors. Cookies are usually high in fat and sugar but low in protein, fibre, vitamin and minerals (Hoojjat and Zabik, 1984).

Majority of cookies have high levels of fat and sugar (Drewnowski *et al.,* 1998). Typical cookies formulation has a fat content of 20-60% and sugar of 25-55% based on the weight of flour (Baltsavias *et al.*, 1999). There are many varieties of cookies in the market which utilized ingredient high in fat and sugar such as chocolate, marshmallow, caramel, jam, jellies and icing.

Cookies are regarded as unhealthy and are rejected by weight conscious consumers because of its high sugar and fat content (Zoulias *et al.*, 2000). Fat has been associated with diseases such as coronary heart diseases, high blood cholesterol, obesity and gallbladder disease. High consumption of sugar is related to diabetes and dental caries.

Cookies have the potential to be a significant contributor of essential nutrient in the human diet (Akpapunam and Darbe, 1994). This is primarily because cookies are very popular and well accepted by consumers including children (Zoulias *et al.*, 2000). Therefore cookies can be a good source of nutrient for children. Furthermore, cookies have a long shelf-life and can be produced on a large scale for wider distribution (Hoojjat and Zabik, 1984).

A successful way to improve the nutritional aspect of cookies is by preparing cookies with enriched flour (Hoojjat and Zabik, 1983). In the United States, most cookies are produced using enriched flour (Bednarcyk, 1987). Cookies using enriched flour contain a significant amount of nutrient such as protein, vitamins and minerals. These cookies are developed as a food supplement for children especially in developing countries (Manley, 2000).

The protein content and quality of cookies can also be improved by substituting cereal with legume as composite flour in cookies formulation. Cereals such as wheat are low in lysine and total protein content and are in short supply in certain countries (Tsen *et al.*, 1975; Akpapumen and Darbe, 1994). Legumes with high protein content are widely used as composite flour in the production of cookies. Among legumes that are frequently used in cookies are cowpeas, great northern bean, faba bean, navy bean, lupine bean, chickpea, field pea and soybean (Kissell and Yamazaki, 1975; Hoojjat and Zabik, 1983; Patel and Rao, 1995).

In keeping up with the present trend for lower calorie products, producers of cookies have reduced the amount of fat and sugar in the formulation. Cookie products labelled with non-fat, low fat, reduced fat and no-sugar have been widely available for consumer in recent years (Manley, 2000). It is mainly aimed at dieters who want to reduce calorie intake. The use of sugar is replaced with substances like polydextrose, acesulfame-K, cellulose and fibre in no sugar cookies product (Bullock *et al.*, 1992). Cookies utilize fat replacers such as *Litesse*, *N-Flate*, *Stellar* or *Trim Choice* in reduced fat cookie formulation (Sanchez *et al.*, 1995).

2.1.4 Ingredients

Compositions of cookie dough mainly consist of wheat flour, shortening, sweetener and emulsifying agents. Cookies consist of 75% sugar, 60% shortening, 7% eggs and 17% moisture as compared to flour weight (Armbrister and Setser, 1994). Ingredients used in cookies formulation have a great influence on the characteristic and quality of produced cookies (Ryu *et al.*, 1993).

Flour, the main ingredient in cookies contributes to texture, hardness and shape of the final cookie product. The quality and quantity of protein are the most important criteria of flour for baking cookies. The protein will determine the amount of gluten formation in cookies. A high protein content in flour will reduce spread factor in cookies (Pyler, 1988). This is because high protein flour will have a higher development of gluten network that will increase dough viscosity thus reducing cookie spread. It is found that diameters of cookies are inversely related with protein content of flour (Leon *et al.*, 1996). Therefore, soft wheat flour is usually used in the production of cookies because it has lower protein content. The protein content for soft wheat flour is usually in the range of 7.00 – 7.5% for cookies.

Other flours that are used in making cookies include maize, oat, rye, sorghum, millet, rice, barley, cassava and potato (Manley, 2000). There is a trend of utilizing legume in cookie formulation so as to improve the nutritional quality of cookies (Lorenz, 1983). Legume such as soybean is rich in protein and has been reported to be well balanced in amino acid profile.

Sweeteners are important ingredients in the production of cookies. Sweeteners in cookies not only contribute to sweetness but also add to the overall flavour and colour as a result of caramelization and Maillard reaction. Sweeteners also act as a softening agent, increasing moisture retention and volume of cookies (Pyler, 1988).

Selection of specific sweeteners is important because it gives a significant effect to the final product. The types and amount of sweetener used will affect cookie spread, appearance and crispness. The common types of sweetener used in cookies are sucrose, brown sugar, inverse syrup, molasses, nutritive sweeteners such as honey and maple syrup and non-nutritive sweetener like saccharin.

Shortening (fat) is an important component in making cookie. The types of shortening used in cookies include butter, lard, beef fat, margarine and vegetable oil (Whitley, 1971; Pyler, 1988). About 50% of shortening are used (based on flour weight) in cookie formulation so as to achieve the desired crispness of cookies (Conforti *et al.*, 1996).

Fat has numerous functions in cookies. Fat acts as a dough stabilizer when particles of fat are spread in the dough thus making it more stable. Fat also contributes to the organoleptic qualities of cookies such as flavour and aroma. The added fat will surround the gluten network formed in the dough. This will aid in the lubrication of gluten during sheeting. As a result, a softer and more extensible dough will be formed.

This will also reduce hardness of cookies by interrupting the gluten structure of the dough.

Eggs used in formulation of cookies contain lecithin that influences the texture of cookies. Lecithin in eggs acts as an emulsifier that spreads the fat phase more uniformly over the hydrophilic ingredients such as flour and sugar. This will aid in reducing the hardness of cookies by interrupting the gluten structure of the dough (Manley, 2000).

Eggs also enhance the colour, nutritive value and flavour of the desired cookies (Matz and Matz, 1978). Albumen in eggs will produce very stable foams that will support the weight of flour, sugar and other ingredients during baking. During mixing, some protein of the albumen will be denatured and will improve the mechanical attribute of other ingredients to bind together (Smith, 1972).

Leavening agents help to aerate the dough and result in a porous and lighter cookie. In cookies, the leavening process is achieved by chemical substances. A bicarbonate (leavening base) is combined with an acid phosphate that generates an acid-base reaction in the presence of heat and moisture. This reaction will yield carbon dioxide leavening gas in controlled volumes and rates (Lajoie and Thomas, 1991). The bicarbonate neutralizes the acids in the formulation and adjusts the pH to the desired crumb pH. Cookie attributes such as colour and flavour are greatly influenced by the crumb pH. Baking of cookies requires a leavening agent that can react immediately whilst releasing carbon dioxide before the structure of the dough sets. The most common leavening agent used is sodium bicarbonate (Whitley, 1971; Pyler, 1988).

2.1.5 Quality of cookies

In bakery products, such as cookies, the quality aspect is given high priority. Cookies are assessed in terms of texture (hardness and crispness), physical (spread ratio and top grain) and flavour attributes (Bajaj *et al.*, 1991). Quality of cookies is influenced by factors such as flour quality, the right baking technique, and variety and ratio of ingredient.

Texture is an important element of cookie quality. Texture of cookies is described as a combined function of the size and shape of the crumb structure, the moisture content and gradients, and the internal stresses produced during baking and cooling (Gaines *et al.*, 1992). Baking promotes dough structuring and dehydration and development of browning reaction that resulted in a finished product with porous crumb structure (Piazza and Masi, 1997). Recent development has enabled the use of instrumental techniques for measuring cookies texture that are reproducible statistically. The two attributes that are measured for cookies are hardness and crispness.

Crispness is the most important quality attribute in cookies. Crispness will determine consumer acceptability and represent the critical factor in limiting cookies shelf-life (Piazza and Masi, 1997). It is known that crispness of cookies is highly sensitive to moisture content. Crispness is related to the amount of water molecule bonded with the carbohydrate matrix that influences the relative mobility of the amorphous and crystalline component (Piazza and Masi, 1997).

Hardness can be defined as the force required to fracture a cookie. Hardness of cookies is mostly due to the protein content of flour. Gaines (1993) showed that the development of gluten during mixing of dough produce harder cookies. Usually the required hardness of cookies is just enough to maintain its shape during transportation but fractures easily when chewed in the mouth.

Spread ratio or diameter of cookies has long been used to determine the quality of flour for producing cookies (Doescher *et al.*, 1987; Gaines, 1993). Spread ratio of a cookie is the diameter divided by its thickness. Flour and sugar are the main hydrophilic components in cookies that influence cookie spread. If the flour component is hydrophobic, more water is available for the sugar component to form syrup and this will reduce the viscosity of dough during baking (Gaines *et al.*, 1992).

Hydrophilic starches have a negative relation with spread ratio of cookies. During baking, hydrophilic starch granules absorbed moisture and become swollen and gelatinised thus providing additional viscosity in cookies (Kim *et al.*, 2001). When the gelatinisation of starch increases, dough viscosity increases thus reducing cookie spread (Tsen *et al.*, 1975). Thus, starch gelatinisation increases thickness of cookies and retains more moisture (Labell, 1983). This showed that the strong affinity of flour to water influences spread ratio of cookies.

The existence of cracks that occur on the surface of cookies known as top grain has been regarded as one of the quality attributes of cookies. Cookies with good top grain have been considered as cookies with a lot of surface cracks that are produced after baking resulting from the recrystallization of sucrose on the surface of cookie. Top grain is also directly related to the diameter of cookies. A smaller diameter of cookies will produce fewer surface cracks (Gaines and Finney, 1989).

Another important quality attribute of cookies is colour. Colour of cookies greatly influences their acceptability (Zoulias *et al.*, 2000). Colour can be measured by using colour instrument or by a sensory panel. Colour of cookies is mainly due to Maillard reaction during baking.

Flavour perception is a very important factor in determining consumer acceptance of a cookie. Flavour of a cookie is mainly influenced by the fat, sugar and flavour enhancer in its formulation (Manley, 2000). In producing new cookies that are highly nutritious, the flavour of the cookies must be given priority so as to be attractive to consumers (Lorenz, 1983).

A high quality cookie has a high spread ratio, attractive appearance, pleasant flavour, brownish colour, high crispness but adequate hardness for easy chewing. The storage condition must be controlled or the organoleptic attribute of cookie will change and this will decrease its commercial value.

2.2 LEGUME

2.2.1 Background

The word legume, originated from the Latin word “legumin” which means the harvesting of the grain inside the husk of a bean. Legume is also known as “pulse” that refers to the bean’s seeds (Salunkhe and Kadam, 1989). The term legume based foods consist of germinated and ungerminated legume seeds that are used in the human diet. According to the Food and Agriculture Organization (FAO) (1977), the word legume is used for all kinds of beans.

Before the introduction of potato, most poor people in the world consumed legumes as their staple food (Salunkhe and Kadam, 1989). According to archaeologists, legume were first grown in East Asia then in the Middle East. Nowadays legumes are an important component in human nutrition, especially among the low-income groups of people in developing countries. The term legume is commonly used in India; where it is classified into three categories, namely grains, peas, and beans (Swaminathan, 1974). Legumes for consumption are prepared in many ways, such as whole legumes called grains or dehusked and split legumes, known as dhals. Red gram (pigeon pea, *Cajanus cajan*), which is native of South-east Asia, is the most widely consumed legume, especially in Southern India, where it is used mainly in the preparation of rasam, sambar and other savoury dishes.

Several reports claimed that inclusion of legumes in the daily diet has many beneficial physiological effects in controlling and preventing various metabolic diseases such as *diabetes mellitus*, coronary heart disease and colon cancer. Currently, the role of legumes as therapeutic agents in the diets of people suffering from metabolic disorders is gaining interest (Shehata, *et al.*, 1988; Simpson *et al.*, 1981). Recent opinion on healthy eating habits showed that there is an increase in the proportion of legume-based plant carbohydrates, including starch in the diet. Legumes also belong to groups of food that have the lowest blood glucose response.

Legumes are also considered as poor man's meat. They are generally good sources of slow release carbohydrates and are rich in proteins (18–25%). Soybean is unique in containing about 35–43% proteins. Legumes are the cheapest sources of supplementary proteins in Indian diets (Swaminathan, 1974). They are also good sources of minerals and vitamins. It has been reported that germinated legumes are richer in vitamin C and in some there is an increase in the riboflavin as well as niacin contents upon germination (Swaminathan, 1988). Processed legumes such as puffed Bengal gram contains proteins of fairly high biological value and is a good supplement to the diets of children.

There are many varieties of legumes such as red gram (pigeon pea, *Cajanus cajan*), black gram (*Vigna mungo L.*), broad bean (*Vicia faba L.*), Bengal gram (chickpea, *Cicer arietinum L.*), cowpea (*Vigna unguiculata L.*), field bean (*Dolichos lablab*), mungbean (*Vigna radiata*), horse gram (*Dolichos biflorus*), etc. which are commonly used, especially by the poorer section of the world population.

2.2.2 Processing of legumes

Legumes are common components of diets all over the world. They are used in a variety of food preparations either as such or in combination with cereals, because cereal proteins are generally deficient in some essential amino acids. The use of legumes assumes significance as a cheap and concentrated source of proteins, due to the high cost of proteins of animal origin and their inaccessibility by the poorer section of the population.

Legumes are generally consumed after processing into various products like milling into dhal, puffing or roasting into snack foods, grinding into flour for different food preparations or as germinated grains (Kurien, 1981). Many of the legumes contain toxic factors such as trypsin inhibitors, haemagglutinins and growth inhibitors, which are either partially or completely eliminated by different methods of processing, e.g., autoclaving. Heat processing in general, improves the nutritive value of legume proteins, by inactivating trypsin and growth inhibitors and haemagglutinins (Swaminathan, 1974).

Traditional methods of processing and cooking legumes have evolved to give acceptable, appetizing and nutritious products. Processing of legumes increases the digestibility and enhances the aroma, sensory qualities and nutritional attributes of products. Processing not only improves palatability of foods but also increases the bioavailability of nutrients.

Dehulling of legume seeds (into dhal) and splitting of cotyledons are often carried out for better product profile and acceptability. Dehulling reduces cooking time and has showed a negligible effect on the total protein content and amino acid composition. Dehulling also removes tannins that lower protein digestibility (Bressani and Elfas, 1980).

Soaking is a preliminary step common to almost all methods of preparing legumes, prior to cooking. Soaking helps in the removal of seed coat and shortens the cooking time.

The process of germination is an ancient and popular practice in many parts of the world, particularly in Asia. Germinated legumes are often added to diets to increase their acceptability and nutrient contents. Germination involves the breakdown of seed reserves owing to increased enzyme activity. Upon germination, the content of vitamins also increases considerably (Vijayaraghavan, 1981).

Heat treatment of all kinds inactivates anti nutritional enzymes and improves flavour and overall acceptability of the foods prepared. Roasting, drying, toasting and frying are some of the dry heat processing methods used for whole legume seeds, which are eaten as snack foods, e.g., fried ground nuts, roasted chickpeas, etc.

Fried dhals are quite common in India, especially in South India. Bengal gram dhal and green gram dhal are deep fat-fried with the addition of spice and salt mixture, and are used as snack items. Fried bean cakes made from fried ground legume paste are widely consumed throughout the world.

2.2.3 Legumes in cookies

Legumes that have been studied for cookie fortification include cowpea, faba bean, navy bean, chickpea and field pea (Patel and Rao, 1996). Mustafa *et al.*, (1986) reported that cookies made from 15% and 20% cowpea protein isolate were generally acceptable as compared to the control cookies. Lorenz (1983) found the overall quality of cookies to be quite satisfactory when wheat flour is substituted with up to 10% bean flour. Heagzy and Faheid (1990) reported that wheat flour substitution with 10% chickpea flour was possible without affecting baking and physical characteristic of cookies. In general, these studies indicated that physical, organoleptic and nutritional characteristic of cookies vary widely from legume to legume.

2.2.4 Resistant starch

Starches have been classified into several types based on their susceptibility to amylases and consequent digestibility profile (Table 2.3, Brown *et al.*, 1995). The fraction of starch that is not hydrolysed in the small intestine but later fermented by the colonic microflora is designated as resistant starch (RS), as it resists hydrolysis by the amylolytic enzymes elaborated by the healthy human being (Champ *et al.*, 1999).

RS which is not digested in the small intestine, (Asp, 1992; Asp and Bjorck, 1992) enters the large intestine, where it becomes an available substrate for bacterial fermentation (Cummings and Englyst, 1991). Microbial fermentation of RS produces several metabolic end products, short chain fatty acids (SCFA) such as acetic, propionic and butyric acids, carbon dioxide, hydrogen and methane (Cummings and Englyst, 1987; Macfarlene and Cummings, 1991). Some studies indicate that fermentation of RS specifically leads to an increase in butyric acid (Phillips *et al.*, 1995). These SCFA are of value to human nutrition in recent years. They have many beneficial physiological effects of value to colonic health.

Diets rich in RS may have important effects on human health with some effects similar to those reported for soluble dietary fibre (Annison and Topping, 1994). For example, RS consumption has been related to reduced postprandial glycemic and insulinemic responses, which may have beneficial implications in the management of diabetes (Granfeldt *et al.,* 1994). In vitro studies with human faeces have shown that fermentation of RS yields relatively high amounts of butyrate as compared with other non-starch polysaccharides (Cummings and Englyst, 1991).

Table 2.3 Classification of starches (Brown *et al.*, 1995)

Type of starch		Source	Digestibility in small intestines
Rapid digestible starch		Freshly cooked starchy food	Rapid
Slowly digestible starch		Most raw cereals	Slow but complete
Resistant Starch (RS)			
RS1	Physically inaccessible	Partially milled grains and seeds	Resistant
RS2	Resistant granules	Raw potato and banana	Resistant
RS3	Retrograded starch	Cooled, cooked potato, bread and corn flakes	Resistant
RS4	Chemically modified starch	Ether, ester and cross-linking of starch	Resistant

Birkett *et al.* (1996) have reported that RS has beneficial effects on putative markers of colonic health, including increased faecal bulk, lower faecal pH and increased concentration of SCFA (Cassidy *et al.*, 1994). RS has also been suggested for use in prebiotic composition to promote the growth of such beneficial microorganisms as bifidobacterium (Brown, 1996). Since RS almost entirely passes through the small intestine, it can behave as a substrate for growth of the prebiotic microorganisms.

2.2.5 Legume starch digestibility

Generally, among foods, legumes are of particular interest because they contain high level of RS. Raw legume has more than 15% amount of RS, with cooked legume between 5.0-15.0% amount of RS. This is high compared to other food such as cereals, wheat or potato. Table 2.4 shows classification of foods according to the range of RS contents (% dry matter).

Table 2.4 Classification of foods according to the range of RS contents (% dry matter) (Goni *et al.*, 1996).

Amount of resistant starch (%)	Types of food
Negligible (< 1%)	Boiled potato (hot) Boiled (rice) Pasta Breakfast cereal containing high proportion of bran Wheat flour
Low (1-2.5%)	Breakfast cereal Biscuit Bread Pasta Boiled potato (cool) Boiled rice (cool)
Intermediate (2.5-5.0%)	Breakfast cereals (Corn Flakes, Rice Crispies) Fried potatoes Extruded legume
High (5.0-15.0%)	Cooked legumes (lentils, chick peas, beans) Peas Raw rice Autoclaved and cooled starches (Wheat, potato, maize) Cooked and frozen starchy foods
Very high (>15%)	Raw potatoes Raw legumes Unripe banana Retrograded amylose

Generally, legumes contain higher level of amylose (30–40%) compared to cereals (Madhusudhan and Tharanathan, 1995). Cooked legumes are prone to retrograde more quickly, thereby lowering the process of digestion. Processed legumes contain significant amount of RS-3. The digestibility of legume starch is much lower than that of cereal starch (Madhusudhan and Tharanathan, 1995).

The higher content of amylose in legumes, which probably lead to a higher RS content, may possibly account for their low digestibility. High amylose cereal starch has been shown to be digested at a significantly lower rate (Borchers, 1961). Legumes contain more of proteins than cereals and protein-starch interaction in legumes may equally contribute to their decrease in glycemic responses (Geervani and Theophilus, 1981).

Additionally, the presence of high amounts of dietary fibre and anti nutritional factors such as phytates and amylase inhibitors may greatly influence the rate and extent of legume starch digestibility. As a consequence of poor starch digestibility, legumes promote slow and moderate post-prandial glucose and insulin responses (Jenkins *et al.*, 1982). Legume carbohydrates, known as ‘slow release carbohydrate’ because of this property, are considered beneficial in the management of diabetes and hyperlipidemia.

Legume starches contain about 30–40% of amylose and processing of legumes may lead to increase in the net RS content which may have important effects on human physiology (Edwards, 1993). Several reports claim that inclusion of legumes in the daily diet has many beneficial effects in preventing various metabolic diseases such as *diabetes mellitus*, coronary heart disease and various types of cancer (Simpson *et al.*, 1981). Current interest in the role of legumes as therapeutic agents in the diets of people suffering from metabolic disorders is growing (Thorne *et al.*, 1983). In fact, grain legumes are the major sources of RS and in turn dietary fibre (DF).

2.2.6 Mungbean

2.2.6.1 Background

Mungbean (*Vigna radiata L.*) is grown throughout Southeast Asia, Central Africa and warmer parts of China and in the United States (Salunkhe and Kadam, 1989). Mungbean is the most consumed legume in India. The annual world production of mungbean between 1981-1985 is about 14 million-15 million tones (Singkhakul and Jindal, 1990).

The reason for the mass production of mungbean is because it is a short duration crop and has a wide adaptability. Compared to other plants, mungbean is more resistant to diseases and dehydration, can be planted in arid conditions and harvested in 55-60 days (Adisarwanto *et al.*, 1992).

The high nutritional profile of mungbean contributes to its wide application and consumption through out the world. It is used in many types of food and is a cheap and good source of protein. Mungbean is also almost free from flatulence causing factors. Mungbean is easily digested and is suitable for children consumption. It is also suitable as a baby food (El-Moneim, 1999).

2.2.6.2 Classification

The scientific name for mungbean is *Vigna radiata* (L). Besides that it is also known as *Azukia radiata* (L.), *Phaseolous raditus* (L), *Phasi\eolous aureus, Rudua aurea* (Roxb.) and *Vigna aureus* (Roxb). Mungbean has several other common names such as green gram, golden gram, moong, mug and mag. Mungbean is classified under the family *Fabaceae* and genus *Vigna* (Salunkhe and Kadam, 1989).

The seed of mungbean has 3 main components, which are the seed coat, cotyledon and embryo. The coat represents 12.1%, cotyledon 85.6% while embryo 2.3%

of the total weight of the seed. The embryo has the highest protein and lipid content while starch and fibre is concentrated in the cotyledon and coat (Salunkhe and Kadam, 1989).

2.2.6.3 Composition

The proximate composition of mungbean seed is stated in Table 2.5. Mungbean is low in fat but high in fibre and protein content.

Table 2.5 Proximate composition of 100g mungbean seed (Souci *et al.*, 1994)

Main ingredients	unit	
Moisture	g	10.0
Protein	g	24.0
Fat	g	1.1
Carbohydrate	g	43.61
Total dietary fibre	g	15.75
Minerals	g	3.5

2.2.6.3.1 Minerals

Minerals such as calcium, phosphorus, iron, sodium and potassium are the most abundant minerals found in mungbean (Table 2.6). The amount of minerals varies from one variety to another. Calcium is mostly found is the seed coat. Phosphorus is concentrated in the cotyledon. Iron can be found in the embryo and cotyledon (Salunkhe and Kadam, 1989).

Table 2.6 Mineral compositions of 100g mungbean seed (Souci *et al.*, 1994)

Minerals and trace elements	unit	
Sodium	mg	5.8
Potassium	g	1.21
Magnesium	mg	207
Calcium	mg	123
Manganese	mg	1.06
Iron	mg	7.38
Copper	mg	1.05
Zinc	mg	1.84
Phosphorus	mg	371

2.2.6.3.2 Vitamin

Mungbean is also a good source of thiamine, riboflavin and niacin (Table 2.7). Other vitamins that are not present in raw seeds can be found in sprouted or germinated mungbeans.

Table 2.7 Vitamin composition of 100g mungbean seeds (Souci *et al.*, 1994)

Vitamin	unit	
Vitamin K	µg	170
Vitamin B1	µg	523
Vitamin B2	µg	237
Nicotinamide	mg	2.35
Pantothenic Acid	mg	1.71
Vitamin B6	µg	410
Folic Acid	µg	490
Vitamin C	mg	-

2.2.6.3.3 Carbohydrate

Carbohydrate composition of the whole mungbean seed is about 43.6%. Carbohydrate in mungbean consists of sugar starch and fibre. Table 2.8 shows the carbohydrate composition of mungbean. Its starch content has a 28.8% : 71.2% ratio of amylose to amylopectin (Salunkhe and Kadam, 1989).

Table 2.8 Carbohydrate composition of 100g mungbean seed (Souci *et al.*, 1994)

Carbohydrates	unit	
Glucose	mg	645
Sucrose	g	1.41
Rafinose	mg	885
Stachyose	g	1.68
Verbavose	g	2.62
Starch	g	41.55
Cellulose	g	5.0
Others		
Soluble dietary fibre	g	8.1
Non soluble dietary fibre	g	7.74

Fibre in mungbean consists of 2 main components, which are cellulose and non-cellulose polymer such as hemicellulose and pectin. Mungbean has a sugar content of about 7.2%. Legume flour has a considerably higher sugar content than wheat flour (Navikul and D'Appolonia, 1978).

2.2.6.3.4 Protein

The protein content of mungbean seed is about 24.0% but differs among cultivars. Globulin contributes to about 80% of protein reserves in mungbean seeds. Mungbeans has low concentrations of sulphur-containing amino acids and tryptophan

Mungbeans has low concentrations of sulphur-containing amino acids and tryptophan (Salunkhe and Kadam, 1989). The amino acid profile of mungbean is presented in Table 2.9. Mungbeans also contains inhibitor of trypsin but is considered low as compared to other legumes.

Table 2.9 Amino acid profiles of 100g mungbean seed (Souci *et al.*, 1994)

Amino acid	unit	
Alanine	g	1.3
Arginine	g	1.9
Aspartic Acid	g	3.38
Cystine	mg	270
Glutamic Acid	g	4.81
Glycine	g	1.24
Histidine	mg	830
Isoleusine	g	1.27
Leucine	g	2.22
Lysine	g	1.95
Methionine	mg	390
Phenylalanine	g	1.65
Proline	g	1.26
Serine	g	1.45
Threonine	g	1.02
Trytopphan	mg	380
Tyrosine	mg	800
Valine	g	1.45