FILM BEHAVIOUR OF NATURAL RUBBER LATEX TREATED WITH BANANA SKIN

GOH TOK MUN

A thesis submitted in partially fulfillment of the requirements for the award of degree of Bachelor of Applied Science (Honours) in Industrial Chemistry

Faculty of Industrial Sciences and Technology
UNIVERSITI MALAYSIA PAHANG

2012

ABSTRACT

Natural rubber latex (NRL) is the milky fluid obtained from the *Hevea Brasiliensis* tree. Proteins the naturally occurring components of NRL have been related to hypersensitivity. Therefore, study on protein in NRL films is crucial. It created one of the biggest markets for improved in the glove industry. Bio-based polymer such as soy bean and milk has been investigated as a component in plastic. However, it is costly. As starch-based materials proved to be good biodegradable sources, banana skins are chosen. Large quantities of waste generated from banana peels will cause serious problems if disposed indiscriminately. It can be new sources pushes to brand new trial in polymer industry for banana skin on the study of film behavior. In the present study, banana skin powder is introduced in NRL due to its good sources of nutrients where Maillard reaction believed in cross link with the protein in NRL thus reduces protein contributed by banana skin. Other than that, banana skin is introduced to increasing the mechanical properties. Five samples conducted in this research by varying the banana skin loading, which are 0%, 5%, 10%, 15% and 20%. Lowry method is been used to measures total protein content. Result showed that protein content in NRL film increase with the banana skin loading. The highest protein content found to be latex film treated with 15% of banana skin loading. Based on the ASTM recommends their standards for medical gloves that all examination and surgical gloves should contains less than 200 $\mu g/dm^2$, latex film treated with banana skin need undergoes proper leaching during the process of production to reduce the extractable protein (EP) content. For mechanical properties, dumbbell shaped samples are cut from the mould sheets according to ASTM D412. Tensile strength increased up to 10% filler loading. Further increase in filler loading after 10% resulted in a reduction of tensile properties. While for tensile modulus, M100, M300 and M500 increased with the filler loading. The results obtained in this research intended help boosts development in the production of glove industry in future. As in conclusion, study on film behavior of NRL treated with banana skin leads to green environment.

ABSTRAK

Lateks getah asli (GA) merupakan cecair susu yang diperolehi dari pokok getah '*Hevea Brasiliensis*'. Protin sejenis komponen yang sedia ada pada GA telah dikaitkan dengan hipersensitiviti. Oleh sebab itu, kajian terhadap kandungan protin dalam filem lateks GA adalah penting. Ia bertindak sebagai pemacu dalam pasaran bagi pembaharui produk industri sarung tangan. Sebelum ini, kajian telah dijalankan terhadap polimer bersifat Bio seperti kacang soya dan susu. Namun, kajian-kajian tersebut memerlukan kos yang tinggi. Apabila bahan berasaskan kanji didapati baik dalam terurai, kulit pisang terpilih dalam penggunaan komposit plastik mesra alam dengan lateks GA. Jumlah besar sampah yang dihasilkan oleh kulit pisang didapati akan menyebabkan masalah serius jika dibuang secara berterusan, oleh demikian ia boleh digunakan sebagai sumber baru pada filem lateks GA yang mendorong ke arah pembangunan dalam industri polimer. Dalam kajian ini, serbuk kulit pisang diperkenalkan dalam lateks GA kerana ia kaya dengan sumber nutrisi di mana Maillard dipercayai akan bertindak balas menyambung silang dengan protin dalam lateks GA maka mengurangkan protin dari kulit pisang. Selain daripada itu, kulit pisang diperkenalkan adalah untuk meningkatkan sifat-sifat fizikal dalam lateks GA. Lima sampel disediakan dengan pembezaan dari segi jumlah serbuk kulit pisang, iaitu 0%, 5%, 10%, 15%, dan 20%. Kaedah Lowry digunakan untuk menilai jumlah protin. Hasil keputusan menunjukkan kandungan protin bertambah dengan serbuk kulit pisang dalam filem lateks GA. Kandungan protin yang tertinggi adalah lateks GA yang mempunyai 15% kulit pisang. Berdasarkan ASTM, sarung tangan perubatan seperti sarung tangan untuk pemeriksaan dan sarung tangan pembedahan harus mengandungi kandungan protin yang kurang daripada 200 $\mu g/dm^2$, lateks GA yang mengandungi kulit pisang perlu melalui larut lesap sewaktu proses pengeluaran untuk mengurangkan protin terlarut. Bagi menguji sifat-sifat fizikal selepas penambahan kulit pisang, sampel dipotong dengan mengikut ASTM D412. Kekuatan tensil didapati meningkat. Namun dengan penambahan 15% dan 20% kulit pisang didapati mengurangkan kekuatan tensil. Manakala ujian untuk M100, M300 dan M500 menunjukkan peningkatan terhadap penambahan kulit pisang dalam filem. Keputusan yang diperolehi dalam kajian ini bertujuan meningkatkan pembangunan dalam pengeluaran sarung tangan industri pada masa depan. Secara kesimpulan, kajian terhadap sifat-sifat dalam filem lateks GA yang berisi dengan kulit pisang menyumbang persekitaran yang baik.

TABLE OF CONTENTS

	Page
SUPERVISOR'S DECLARATION	ii
DECLARATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT	v
ABSTRAK	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF ABBREVIATIONS	xiv
LIST OF APPENDICES	xvi

CHAPTER 1 INTRODUCTION

1.1	Background of the Study	1
1.2	Problem Statement	3
1.3	Research Objective	5
1.4	Scope of Study	5
1.5	Significant of Study	5

CHAPTER 2 LITERATURE REVIEW

2.1	Introduction	6
2.2	Banana	6
	2.2.1 Edible Banana	7
2.3	Banana Skin	8
	2.3.1 Composition of Banana Skin	8
2.4	Banana Fiber and Its Application	9
2.5	Natural Rubber Industry	10
2.6	Natural Rubber	12

2.7 Properties of Natural Rubber 13

2.7.1 Mechanical Properties of Natural Rubber 14
2.7.2 Mechanical Properties of Natural Rubber Latex in Industry 15

2.8 Total Solid Content of Natural Rubber Latex 16

2.9 Protein 16

2.9.1 Protein Denaturation 20
2.9.2 Protein in Natural Rubber Latex 25

2.10 Latex Allergy 28

2.11 Maillard Reaction-Protein Crosslinking 29

2.12 Protein Reduction in NRL Gloves 30

2.12.1 Water Leaching of Gloves 30
2.12.2 Post Washing and Chlorination of Gloves 31

2.13 Protein Determination Methods 32

2.13.1 Kjeldahl Method 32
2.13.2 Bradford Method 33
2.13.3 Biuret Method 33
2.13.4 Lowry Method 33
2.13.5 Ultraviolet method 34
2.13.6 ELISA 35
2.13.7 RAST 35
2.13.8 SPT 36

CHAPTER 3 METHODOLOGY

3.1 Introduction 37

3.2 Materials and Equipment 37

3.3 Sample Preparation 39

3.3.1 Preparation of Dried Banana Skin Powder 40
3.3.2 Dried Banana Skin Powder Compounding Process 40
3.3.3 Latex Compounding and Vulcanization Process 41

3.4 Natural Rubber Latex Film Testing 42

3.4.1 FT-IR Analysis of Protein 42
3.4.2 Protein Content Measurement 42
3.4.3 Tensile Properties on Films 47

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Introduction 49

4.2 FT-IR Analysis 49

4.3 Extractable Protein Content 51

4.4 Tensile Properties 56

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Protein Content in NRL Films Filled with Banana Skin 59

5.1.1 Water Leaching 59

5.1.2 Centrifugation of NRL 60

5.1.3 Evaluation of NRL Allergenicity 60

5.2 Mechanical Properties 61

REFERENCES 62

APPENDIX A-G 68-74

LIST OF TABLES

Table No.		Page
1.1	Contents in the milky white fluid, latex	2
2.1	Top 10 banana producing nations	7
2.2	Minerals composition of banana peel in concentration mg/g	8
2.3	Proximate composition and anti - nutritional content of banana peel	9
2.4	Destinations of natural rubber exports in percentage	10
2.5	Malaysian NR statistics from 1998-2010	11
2.6	Malaysia's Export of Selected Rubber Products, 2005 – 2009	13
2.7	Properties for neoprene, natural rubber latex and polyisoprene	15
2.8	Physical test for latex rubber finger cots according to ASTM D412	15
2.9	Allergens found in latex	26
2.10	Symptoms of Type I allergy and Type IV allergy	29
3.1	Material for vulcanization process	37
3.2	Solvent used for latex testing	38
3.3	Material for protein test	38
3.4	Equipment used for experiment	39
3.5	Parameter for natural rubber latex on dried banana skin powder compounding process	40
3.6	Latex film formulation based on part per hundred of rubber	41
3.7	Reagent for analysis	43
3.8	Formulation for standard calibration curve	44
3.9	Length (mm) for dimension	48
4.1	Absorbance of albumin in different concentrations	53

4.2	Extractable protein concentration in latex films treated with different banana skin loading	55
4.3	Extractable protein in latex films treated with different banana skin loading	56
4.4	Mechanical testing of films	57

LIST OF FIGURES

Figure No.		Page
1.1	Incidence of suspected NRL-induced contact urticaria cases in BGW-insured HCWs and a subset of HCWs employed in acute-care hospitals	2
2.1	Stress strain curves of banana fibers	10
2.2	Cis-1,4-polyisoprene- natural rubber structure	12
2.3	Sample ASTM D412 test report on tensile strength at rupture	14
2.4	Primary structure of a protein	17
2.5	Secondary structure: The most common are the alpha helix and the beta conformation	18
2.6	Tertiary structure of the antigen-binding portion of an antibody molecule	19
2.7	Denaturation of protein	20
2.8	Denaturation by alcohol	22
2.9	Denaturation by acid or base	23
2.10	Denaturation by reducing agents	24
2.11	Resonance structures of the peptide bond that links individual amino acids to form a protein polymer	25
2.12	Schematic of the formation of Maillard cross-linker induced soy protein gels	30
2.13	Skin testing on arm	36
3.1	PP centrifuge tube (15 ml)	45
3.2	Microcentrifuge tube (1.5 ml)	45
3.3	Vortex mixer	45
3.4	UV Visible Spectrophotometer	46
3.5	Dumbbell shaped for tensile testing	48

3.6	Dumbbell cutter	48
4.1	FT-IR spectrum for NRL films filled treated with different banana skin loading	50
4.2	Calibration curve for albumin standards	53
4.3	Effect of filler loading on tensile strength and elongation at break of natural rubber latex films	58
4.4	Effect of filler loading on modulus at 100%, modulus at 300%, and modulus at 500% of natural rubber latex films	58

LIST OF ABBREVIATIONS

AIDS	Acquired immune deficiency syndrome
ASTM	American Society for Testing and Materials
DNA	Deoxyribonucleic acid
DOC	Sodium deoxycholate
DRC	Dry rubber content
ELISA	Enzyme-linked immunosorbent assay
EP	Extractable protein
FDA	Food and Drug Administration
FT-IR	Fourier Transform Infra-Red spectroscopy
HCW	Health care workers
KOH	Potassium hydroxide
LEAP	L1 element amplification protocol
MBT	Mercaptobenzothiazoles
MIDA	Malaysian Industrial Development Association
NR	Natural rubber
NRL	Natural rubber latex
PBS	Phosphate buffered saline
PP	Polypropylene
PTA	Phosphotungstic acid
RAST	Radioallergosorbent test
RNA	Ribonucleic acid
SB	Spina bifida
SEM	Scanning Electron Microscope

SPT	Skin Prick Test
TCA	Trichloroacetic acid
TDF	Total dietary fibre
TSC	Total solid content
UV	Ultraviolet
ZDEC	Zinc diethyldithiocarbamate

LIST OF APPENDICES

Appendix		Page
A	FT-IR Spectrum for 0% banana skin loading	68
B	FT-IR Spectrum for 5% banana skin loading	69
C	FT-IR Spectrum for 10% banana skin loading	70
D	FT-IR Spectrum for 15% banana skin loading	71
E	FT-IR Spectrum for 20% banana skin loading	72
F	Formula for extractable protein content	73
G	Characteristic infrared bands of peptide linkage	74

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Natural rubber latex (NRL) is extracted from *Hevea brasiliensis* tree and is used to produce different kinds of rubber goods like gloves, condoms, balloons and some part of medical and dental equipments (Rogero et al., 2003). It is an emulsion of rubber polymer in an aqueous dispersion. Rubber latex from field collection contains many natural substances including proteins and 34 % polyisoprene rubber polymer as in Table 1.1. Proteins are a naturally occurring component of NRL. These proteins, which can be present on the surface of NRL gloves, have been related to hypersensitivity reactions in some humans who come into contact with them (Perrella and Gaspari, 2002). Figure 1.1 shows two distinct populations are particularly affected by latex allergy, health care workers (HCW) and children with spina bifida (SB) (Meade et al., 2002). The three basic reactions caused by latex are irritant dermatitis, allergic contact dermatitis and immediate allergic reactions. Therefore, reduction of protein levels in manufactured natural rubber latex products is important for preventing sensitization and adverse allergic reactions to latex.

Generally, natural rubber latex is produced by over 2,000 plant species. The term natural rubber or caoutchouc refers to a coagulated or precipitated product obtained from latex of rubber plants *Hevea brasiliensis*, which forms non-linked but partially vulcanizable polymer chains which have molecular masses of about 10^6 Da with elastic properties (Rose and Steinbuchel, 2005). Besides that, natural rubber has high elasticity and a polymer molecular structure which consists of a long chain made up of tens of thousands of monomer strung together.

Table 1.1: Contents in the milky white fluid, latex

Contents	Percentage (%)
Rubber cis - 1, 4 - polyisoprene	34 %
Proteins	2 - 3 %
Sterol glycosides	0.1 - 0.5 %
Resins	1.5 - 3.5 %
Ash	0.5 - 1.0 %
Sugars	1.0 - 2.0 %
Water	55 - 65 %

Source: Cacioli (1997)

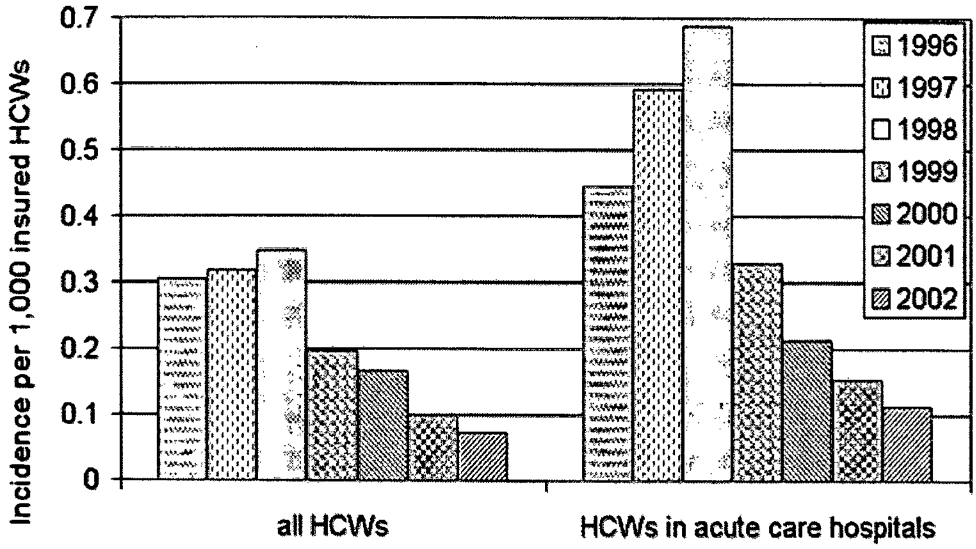

Figure 1.1: Incidence of suspected NRL-induced contact urticaria cases in BGW insured HCWs and a subset of HCWs employed in acute-care hospitals

Source: Allmers et al. (2004)

Banana constitutes the principal food resources in the world. These cultures occupy the Fourth world rank of the most significant foodstuffs after rice, corn and milk. In the present study, banana skin powder is introduced as filler in NRL due to its good sources of nutrients. The peel is known for its anti fungal and antibiotic properties. A study on the chemical composition of fruit peels of the banana claimed that its peel was rich in total dietary fibre (TDF) (40–50 %). The protein content in peel of the banana was 8–11 %. Leucine, valine, phenylalanine and threonine were essential amino acids in significant quantities while lysine was the limiting amino acid. The content of lipid varied from 2.2 % to 10.9 %, it was rich in polyunsaturated fatty acids, particularly linoleic acid and a-linolenic acid. Potassium was the most significant mineral element (Happi Emaga et al., 2007). The results indicate that if the peels are properly exploited and process, they could be a high-quality and cheap source of carbohydrates and minerals. No doubt, in terms for the latex aspects specification, banana peels able contribute maximum manganese and copper content as filler in NRL films.

As starch-based materials have been proven to be good biodegradable sources, banana skins are chosen to be used in developing biodegradable plastic composite with natural rubber latex. Natural rubber latex is used because it is a renewable resource which can be biodegraded and it contains natural stabilizers such as proteins and lipids that could help compatibilization with starch (Rouilly et al., 2004). The development of the processing industries of bananas (chips, flours, pulps dried and jam, spirits distilled from wine or beer) is growing. Significant quantities of banana peels equivalent to 40 % of the total weight of fresh banana. Large quantities of waste generated from banana peels will cause real environmental problem, thus it is essential to find applications for these peels (Zhang et al., 2005). One of its applications is to be new sources pushes to brand new trial in polymer industry for banana skin on study protein content in NRL films.

1.2 PROBLEM STATEMENT

Natural rubber latex (NRL) is used for a variety of applications including exam gloves, surgical gloves, catheters, tubing and condoms. Due to concerns about AIDS and other blood and fluid borne diseases, the rubber glove market in recent years has experienced high growth. The natural rubber latex products industry is presently in the midst of a paradigm shift because of endogenous proteins in inexpensive NRL cause allergic reactions (Annals of Emergency Medicine, 2002). Because of the complex nature of latex extracts, accurate protein measurement is a challenge (Beezhold et al., 2002). In order to avoid this problem, exam gloves are being developed from much more expensive synthetic polymers.

On the other hand, studies showed that from the viewpoint of renewable materials and environmental reasons, soy protein has been investigated in NRL films. The attempt to use protein in rubber latex can be traced back to 1930's. A few patents had claimed the use of protein in rubber composites. Lehmann and co-workers had demonstrated the use of casein, a milk protein, in natural rubber latex to achieve approximately four times increase in the modulus but these bio-based polymers such as soy bean and milk are costly. Chemical composition in banana skin is able contribute in increasing mechanical properties for natural rubber latex. As such, it is able to decrease cost for products that use natural rubber latex as a raw material. The price for natural rubber latex is kept on fluctuating. As natural source is depleting it is expect that price of natural rubber will be kept on increasing. Due to these factors, there is a need for improved and new products in the glove industry. New sources need be sought after as to avoid the over dependency on a single source. Study on protein content and the mechanical properties in NRL films filled with banana skin will leads to explore a new, cheaper and economical shift towards green environment.

Recent studies have shown that allergy to NRL is significantly associated with hypersensitivity to foods or fruits, including avocado, chestnut, papaya, kiwi and banana (Chen et al., 1998). Chestnut allergy has been considered in the context of the latex-fruit syndrome. Cross-reactive allergens with latex and other fruits, such as avocado and banana are closely linked to the syndrome. Class I chitinases with a hevein-like domain from chestnut, avocado and banana as well as latex hevein (Hev b 6.02) have been identified as the main allergens responsible for these cross-reactions (Sa´nchez-Monge et al., 2006). There is some information on how reducing the amount of protein antigens in NRL. Therefore this research is to provide study on protein content in NRL films filled with banana skin. It can be a low cost and effective brand new trial in polymer industry for banana skin used as filler in NRL films.

1.3 RESEARCH OBJECTIVE

By referring to the problem statement above, this research is done to:

i. To introduced banana skin as filler in NRL films
ii. To study protein content in NRL films treated with banana skin
iii. To study new bio-based organic filler as an alternative in increasing mechanical properties of natural rubber latex

1.4 SCOPE OF STUDY

In this research, few samples conducted by varying the amount of banana skin based on parts per hundred rubbers. Comparison would be done among the samples that have been predefined its composition and study would carry on based on its effect to water soluble protein content. Lowry method standardized assay by ASTM used in determining protein concentrations, it was the method of choice for accurate protein determination. While for the physical test of tensile strength, the mechanical test carried according to ASTM D412.

1.5 SIGNIFICANT OF STUDY

Nowadays people are really helped with some gadgets that they have. All of those things really prove that technology give good effect in our daily life. It same as in this research is to provide a new technology in reusable of banana skin as a waste transforms polymer industry towards a green environment. Increase in the demand as a result of industrial development and population growth have drives variety new sources in production of NRL films be practiced. This research consider a low cost, new sought of over depend on a single source and intended help boosts development in the production of NRL industry in future.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter briefly explain about all the components and elements as for its definition and others related issues which could explain this research in a more detailed manner. It is divided into four main elements: composition of banana skin, natural rubber industry, protein in NR and protein determination methods. The interconnections of these elements are showed in this chapter. It includes the comments and facts that other researchers as well as their research reports obtained from journals. From this chapter will gain a clearer understanding of the problem statement, also the objective and the significant as the rationale of this study.

2.2 BANANA

Banana is the common name for the herbaceous plants of the genus Musa and is cultivated mainly for its fruit (Tock et al., 2010). There are 25–80 species in the genus Musa, depending on the taxonomist. Musa is important not only for fruit production, but also has provided man with clothing, tools and shelter prior to recorded history. In 2001, total planted area of banana in Malaysia reached 33,704.2 ha (Khalil et al., 2006). For 2009, the top 10 banana producing nations are showed in below Table 2.1.

Table 2.1: Top 10 banana producing nations (in million metric tons)

India*	26.2
Philippines	9.0
China	8.2
Ecuador	7.6
Brazil	7.2
Indonesia	6.3
Mexico*	2.2
Costa Rica	2.1
Colombia	2.0
Thailand	1.5
World Total	**95.6**

* Countries use 2008 FAO data

Source: Food and Agriculture Organization of the United Nation data (2009)

2.2.1 Edible Banana

A number of distinct groups of edible bananas have been developed from species of Musa. By far the largest and now the most widely distributed group are derived from Musa acuminata and Musa balbisiana either alone or in various hybrid combinations. The next but much smaller group is derived from members of section Callimusa, previously classified as Australimusa and is restricted in importance to Polynesia.

From the time of Linnaeus until the 1940's, different types of edible bananas and plantains were given Linnaean binomial names. Edible bananas have an extremely complicated origin involving hybridization, mutation and finally selection by humans. Haploid contribution of Musa acuminata and Musa balbisiana are designated as A and B, respectively. Basically, all edible banana cultivars can be classified into six groups which are AA, BB, AAA, AAB, ABB and ABBB. They are respectively diploid, triploid and tetraploid. However, most of them are triploid. 'Nangka' belonging to AAB group type in Musa, is a cooking variety banana that widely distributed in Malaysia.

2.3 BANANA SKIN

Banana fruit peel is an organic waste that is highly rich in carbohydrate content and other basic nutrients that could support microbial growth. A major problem experienced by agro-based industries in developing countries is the management of wastes. The disposal of agricultural wastes on land and into waterbodies are common and has been of serious ecological hazards (Smith et al., 1987). Inefficient and improper methods of disposal of solid waste result in scenic blights, create serious hazards to public health, including pollution of air and water resources, accident hazards and increase in rodent and insect vectors of disease, create public nuisances, otherwise interfere with community life and development (Tchobanoglous et al., 1993). Table 2.2 and 2.3 shows the composition of banana skin.

2.3.1 Composition of Banana Skin

Table 2.2: Minerals composition of banana peel in concentration mg/g

Minerals composition	Concentration (mg/g)
Potassium	78.10 + 6.58
Calcium	19.20 + 0.00
Sodium	24.30 + 0.12
Iron	0.61 + 0.22
Manganese	76.20 + 0.00
Bromine	0.04 + 0.00
Rubidium	0.21 + 0.05
Strontium	0.03 + 0.01
Zirconium	0.02 + 0.00
Niobium	0.02 + 0.00

Source: Anhwange et al. (2009)

Table 2.3: Proximate composition and anti - nutritional content of banana peel

Proximate composition and anti - nutritional content	**Percentage (%)**
Moisture	6.70 + 02.22
Ash	8.50 + 1.52
Organic matter	91.50 + 0.05
Protein	0.90 + 0.25
Crude Lipid	1.70 + 0.10
Carbohydrate	59.00 + 1.36
Crude Fibre	31.70 + 0.25
Proximate composition and anti - nutritional content	**Concentration (mg/g)**
Hydrogen cyanide	1.33 + 0.10
Oxalate	0.51 + 0.14
Phytate	0.28 + 0.06
Saponins	24.00 + 0.27

Source: Anhwange et al. (2009)

2.4 BANANA FIBER AND ITS APPLICATION

Banana fibers obtained from the stem of banana plant (*Musa sapientum*) have been characterized for their diameter variability and their mechanical properties, with a stress on fracture morphology (Mukhopadhyay et al., 2008). Figure 2.1 shows the stress strain curves of banana fibers. It is a natural bast fiber, which has its own physical and chemical characteristics and many other properties that make it a fine quality fiber. Generally banana fiber consists of cellulose, hemicellulose and lignin. The banana fiber is highly strong fiber, smaller elongation and light weight with an average fineness of 2400 N m. It has somewhat shiny appearance depending upon the extraction and spinning process.

Banana fiber primarily used for making items like ropes, mats and some other composite materials. With the increasing environmental awareness and growing importance of eco-friendly fabrics, banana fiber has been recognized for its good qualities. Now its application is in the fields such as apparel garments and home furnishings. Rugs made from banana silk yarn fibers are also very popular (Banana fiber, 2011).

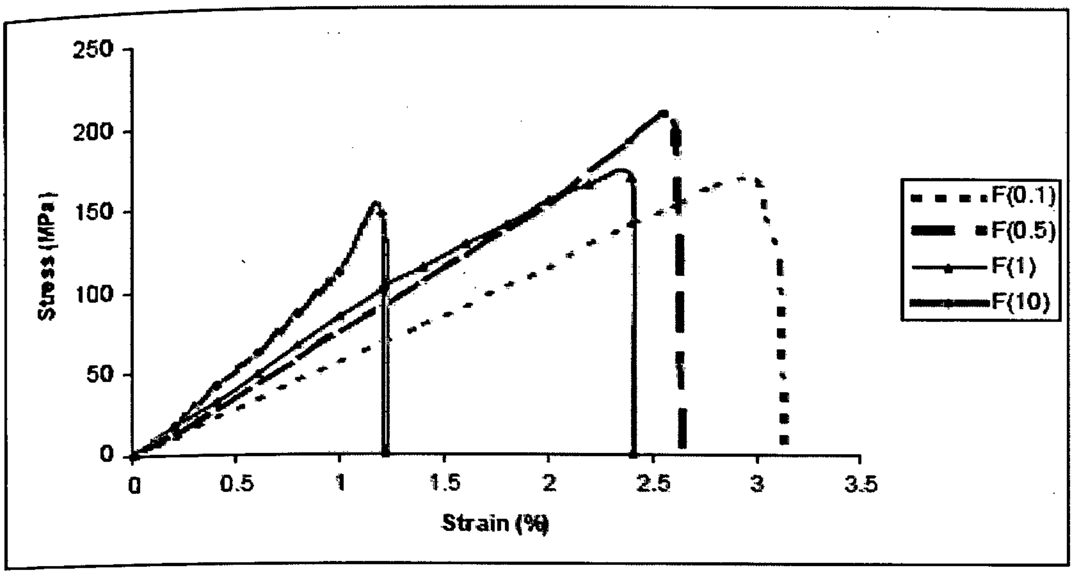

Figure 2.1: Stress strain curves of banana fibers

Source: Mukhopadhyay et al. (2008)

2.5 NATURAL RUBBER INDUSTRY

Malaysia is the fifth largest consumer of NR in the world after China. It is also the world's largest producer of latex gloves, catheters and latex thread. Table 2.4 shows the destinations of natural rubber exports from Malaysia.

Table 2.4: Destinations of natural rubber exports in percentage

Destinations of NR exports	Export percentage (%)
China	38.7
Germany	12.1
Islamic Republic of Iran	6.1
Republic of Korea	5.2
United States of America	4.0
Netherlands	3.4
Brazil	2.8
France	2.8
Portugal	2.3

Source: Department of Statistics, Malaysia (2010)

It is significant to note that the bulk of the earnings were attributed to particular gloves (The Malaysian Natural Rubber Industry, 2008). In Malaysia, market has been shift away from powdered gloves to powder-free. Also it has seen synthetic gloves become increasingly important. The statistics of Malaysian NR from 1998-2010 are show as follows in Table 2.5.

Table 2.5: Malaysian NR statistics from 1998-2010

Year	Production			Imports		
	Dry	Latex	Total	Dry	Latex	Total
1998	699,299	186,398	885,697	248,803	315,319	564,122
1999	600,064	168,808	768,872	252,278	296,099	548,377
2000	774,248	153,360	927,608	164,241	383,993	548,234
2001	761,594	120,473	882,067	250,317	225,358	475,675
2002	775,334	114,498	889,832	235,090	221,776	456,866
2003	854,619	131,028	985,647	166,036	270,516	436,552
2004	960,841	207,894	1,168,735	140,168	285,459	425,627
2005	935,529	190,494	1,126,023	169,137	292,720	461,857
2006	1,073,698	209,934	1,283,632	204,786	307,407	512,193
2007	1,023,190	176,363	1,199,553	261,535	343,585	605,120
2008	918,656	153,709	1,072,365	199,758	322,995	522,753
2009	746,106	110,913	857,019	399,357	339,382	738,739

Year	Exports			Consumption		
	Dry	Latex	Total	Dry	Latex	Total
1998	900,883	88,027	988,910	65,579	267,731	333,310
1999	872,179	111,502	983,682	77,622	266,825	344,447
2000	886,185	91,793	977,978	85,357	278,358	363,715
2001	740,553	80,301	820,854	76,763	324,125	400,888
2002	809,313	77,706	887,019	77,415	330,469	407,884
2003	869,302	77,173	946,475	73,890	347,891	421,781
2004	1,035,700	73,430	1,109,130	90,739	312,030	402,769
2005	1,072,035	55,912	1,127,947	80,884	305,588	386,472
2006	1,075,868	58,483	1,134,351	74,555	308,769	383,324
2007	962,457	55,595	1,018,052	82,642	367,604	450,246
2008	872,222	44,377	916,599	80,592	388,302	468,894
2009	664,602	38,449	703,051	66,053	402,616	468,669
2010*	212,439	14,441	226,880	20,371	102,539	122,910

Note: * Jan-Mar

Source: Department of Statistics, Malaysia (2010)