A Study on Insect Repellency Effects of Bamboo 100%, Soybean 100%, Organic Cotton 100% and Cotton 100% Knitted Fabrics

M.Sc. Thesis

in

Textile Engineering

University of Gaziantep

Supervisor
Prof. Dr. Mehmet TOPALBEKİROĞLU

Co-Supervisor
Assoc. Prof. Dr. Cem GÜNEŞOĞLU

By
Mehmet DİGİLLİ
September 2015

T.C.
GAZIANTEP UNIVERSITY
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES
TEXTILE ENGINEERING DEPARTMENT

Name of the Thesis: A Study on Insect Repellency Effects of Bamboo 100%, Soybean 100%, Organic Cotton 100% and Cotton 100% Knitted Fabrics

Name of the Student: Mehmet DİGİLLİ
Exam Date: 03.09.2015

Approval of the Graduate School of Natural and Applied Sciences

Prof. Dr. Metin BEDİR
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Mehmet TOPALBEKİROĞLU
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Cem GÜNEŞOĞLU
Co-Supervisor

Prof. Dr. Mehmet TOPALBEKİROĞLU
Supervisor

Examining Committee Members:	Signature
Prof. Dr. Mehmet TOPALBEKİROĞLU	....
Assoc. Prof. Dr Mevlüt TAŞCAN	....
Assist. Prof. Dr. Halil İbrahim ÇELİK	....

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Mehmet DIGILLI

ABSTRACT

A STUDY ON INSECT REPELLENCY EFFECTS OF BAMBOO 100%, SOYBEAN 100%, ORGANIC COTTON 100% AND COTTON 100% KNITTED FABRICS

DİGİLLİ, Mehmet

M.Sc. in Textile Engineering

Supervisor: Prof. Dr. Mehmet TOPALBEKİROĞLU

Co-Supervisor: Assoc. Prof. Dr. Cem GÜNEŞOĞLU

September 2015, 52 pages

Insect-borne diseases affect millions of people's life around the world every year. Insect repellent textiles are one of the important tools to prevent insect-borne diseases.

In this study, insect repellency finish provided by permethrin-based insect repellent chemical (Konservan P10) on single jersey knitted fabrics each made of different fibers cotton 100%, organic cotton 100%, bamboo 100%, and soybean 100% respectively. The fabrics were subjected to insect repellency test based on visual observation and the results were evaluated. Insect repellency values of the fabrics were also investigated with application of chemical in different concentration. The best insect repellency effect was obtained from organic cotton among the fabrics. Furthermore, it was clarified that insect repellent fabrics obtained by application of Konservan P10 do not provide antibacterial effect.

Key Words: Insect repellency, permethrin, visual observation, insect, knitted fabric

ÖZET

100% BAMBU, 100% SOYA, 100% ORGANİK PAMUK VE 100% PAMUK ÖRME KUMAŞLARIN BÖCEK İTİCİLİK ETKİLERİ ÜZERİNE BİR ÇALIŞMA

DİGİLLİ, Mehmet

Yüksek Lisans Tezi, Tekstil Mühendisliği Bölümü

Tez Yöneticisi: Prof. Dr. Mehmet TOPALBEKİROĞLU

Eş Tez Yöneticisi: Doç. Dr. Cem GÜNEŞOĞLU

Eylül 2015, 52 sayfa

Böcek yoluyla taşınan hastalıklar her yıl milyonlarca insanın hayatını etkilemektedir. Böcek itici tekstiller, böcek yoluyla taşınan hastalıkları önlemek için önemli bir araçtır.

Bu çalışmada, böcek itici bitim işlemi sırasıyla %100 pamuk, %100 organik pamuk, %100 bambu ve %100 soya süprem kumaşlara permetrin-bazlı böcek itici kimyasal (Konservan P10) ile sağlanmıştır. Kumaşlar görsel gözleme dayalı böcek iticilik testine tabi tutulmuştur ve sonuçlar değerlendirilmiştir. Kumaşların böcek iticilik değerleri kimyasalın farklı konsantrasyonlardaki aplikasyonu ile de değerlendirilmiştir. Kumaşlar arasındaki en iyi böcek iticilik etkisi organik pamuktan elde edilmiştir. Ayrıca, Konservan P10 aplikasyonu ile elde edilen böcek itici kumaşların antibakteriyel etki sağlamadığı açığa kavuşturulmuştur.

Anahtar Kelimeler: Böcek iticilik, permetrin görsel gözlem, böcek, örme kumaş

ACKNOWLEDGEMENTS

I would like to express deepest gratitude to my supervisor Prof. Dr. Mehmet TOPALBEKİROĞLU for his continuous encouragement during the investigation and fulfillment of this study.

I wish to express my sincere thanks to Assoc. Prof. Dr. Cem GÜNEŞOĞLU for his invaluable advices, guidance and continuous support.

I am grateful to Murat Bekmez and Thor Specialities (UK) Limited for providing me insect repellent chemical. Also, I would like to thank Research Assistant Dr. Mehmet Yaran for his helps to obtain the insects.

Finally, I take this opportunity to express gratitude to all members of Textile Engineering Department for their help and support. Also a special thanks to my wife for her unceasing encouragement, support and patience.

TABLE OF CONTENTS

LIST OF FIGURES

page

LIST OF TABLES

page

CHAPTER 1

INTRODUCTION

1.1 Introduction

Today's era is the one of modernization of the textile industry or the world of textile. Every sector of textile and every field related to textiles is developing with the advancements taking place. Smart textiles or functional textiles are one such field. Protective textiles are among one such smart application of smart technology in textiles. Protective textiles refer to those textile products which have a functionality of giving protection from something in some or the other sense. These can be mosquito repelling or may be insect repelling and also may be anti-bacterial and anti-fungal. These may also be heat and cold resistant or with any other property [1].

1.2 Cotton

Cotton today is the most used textile fiber in the world. World textile fiber consumption in 1998 was approximately 45 million tons. Of this total, cotton represented approximately 20 million tons [2].

1.2.1 Characteristics of Cotton

Cotton, as a natural cellulosic fiber, has a lot of characteristics, such as;

- Comfortable soft hand
- Good absorbency
- Color retention
- Prints well
- Machine-washable
- Dry-cleanable
- Good strength
- Drapes well
- Easy to handle and sew

1.2.2 End-Uses of Cotton

• **Apparel:** Wide range of wearing apparel: blouses, shirts, dresses, children' wear, active wear, separates, swimwear, suits, jackets, skirts, pants, sweaters, hosiery, and neckwear.

• **Home Fashion:** Curtains, draperies, bedspreads, comforters, throws sheets, towels, table cloths, table mats, and napkins [3].

1.2.3 Chemical Structure of Cotton

Cotton is a linear, cellulose polymer. The repeating unit in the cotton has two glucose units, called cellobiose. Cotton consists of about 5000 cellobiose units. Its degree of polymerization is thus 5000. Hence it is a very long, linear polymer, about 5000 nm in length and about 0.8 nm thick.

The most important chemical groups on the cotton polymer are the hydroxyl groups or -OH groups which are also present as methylol groups or –CH2OH. Due to the presence of hydroxyl group, polar nature of polymer gives rise to hydrogen bonds between the OH-groups of adjacent cotton polymers. Chemical formula of the cellulose polymer is shown in Figure 1.1

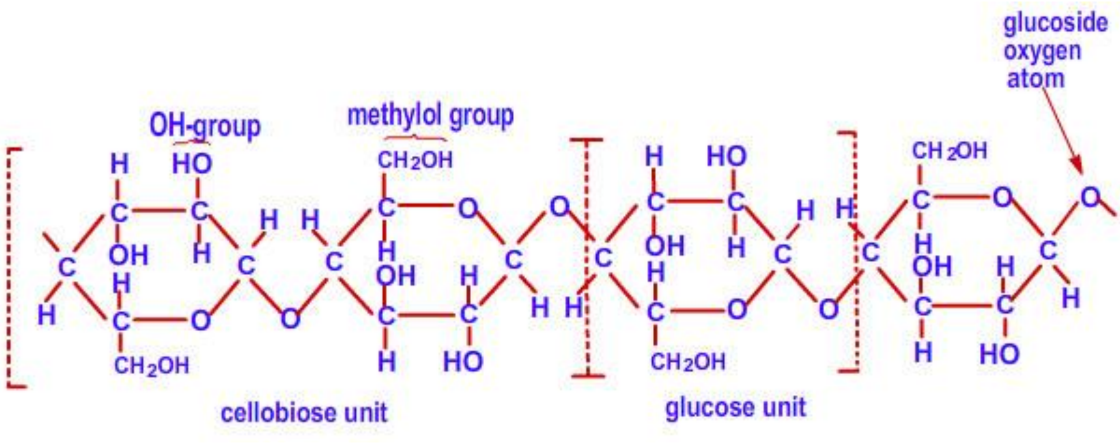


Figure 1. 1 Chemical formula of the cellulose polymer [4]

Polymer system of cotton is crystalline in nature. It consists of about 65 to 70 per cent crystalline and about 35-30 per cent amorphous regions. Polymer system of cotton shows well-ordered and oriented crystalline regions. The maximum distance across which hydrogen bonds can form between polymers is 0.5nm in crystalline regions. Hydrogen bonds are the dominant forces of attraction present in the polymer system of cotton. Van der Waals forces which are also present have little relevance.

The polymer system of cotton can be imagined as a roll of wire netting. The crystalline regions are therefore the well-ordered lines and rows of hexagonal holes of the wire netting. The amorphous regions are a disarrangement of these orderly lines [4].

1.3 Organic Cotton

Cotton grown without the use of any synthetic chemicals i.e., plant growth regulators, defoliants and fertilizers is considered 'organic' cotton [5].

1.3.1 Characteristics of Organic Cotton

Studies have shown that organic cotton fibers have better physical properties, than conventional cottons in terms of length, bundle strength, length uniformity and maturity. Breaking elongation is also higher for organic cotton by as much as 20% ash and wax content in organic cotton are lower and absorbency better as compared to conventional cotton. Organic cottons shows better durability and color retention. The presence of heavy metals like cobalt, iron copper, lead and calcium is reported to be lower in organic cotton [6].

1.3.2 End-Uses of Organic Cotton

In general, end-use is the same as ‘non-organic’ cotton. Textile products popularly available in organic cotton include: baby and children’s wear, women’s wear, intimate wear/underwear, bathroom and bedroom products (sheets, towels, nightwear). Organic cotton can also be found in health and personal hygiene products (facial care, feminine hygiene products, and baby diapers) [7].

1.4 Bamboo

Bamboo fiber is a regenerated cellulosic fiber produced from bamboo. Starchy pulp is produced from bamboo stems and leaves through a process of alkaline hydrolysis and multi-phase bleaching. Further chemical processes produce bamboo fiber [8].

1.4.1 Characteristics of Bamboo

- Softer than cotton, with a texture similar to a blend of cashmere and silk.
- Because the cross-section of the fiber is filled with various micro-gaps and micro-holes, it has much better moisture absorption and ventilation. Moisture absorbency is twice than that of cotton with extraordinary soil release.

- Natural antibacterial elements (bio-agent “bamboo kun”) in bamboo fiber keep bacteria away from bamboo fabrics.
- Garment of bamboo fiber can absorb and evaporate human sweat in a split of second just like breathing. Such a garment makes people feel extremely cool, comfortable and never sticking to skin even in hot summer.
- 100% bamboo yarns show a great elasticity i.e. nearly 20%. Even in 100% bamboo woven fabrics a remarkable elasticity can be obtained wherein the use of elastomeric fibres like elastanes may be eliminated.
- Bamboo fabrics need less dyestuff than cotton, modal or viscose. It seems that the absorption of dyestuffs is remarkably better. Bamboo absorbs the dyestuffs faster and shows the colors better.
- Anti-ultraviolet nature of bamboo fibre has made it suitable for summer clothing, especially for the protection of pregnant ladies and children from the effect of ultraviolet radiation.
- Product of bamboo fibre is eco-friendly and bio-degradable [8].

1.4.2 End-Uses of Bamboo

- Intimate apparels include sweaters, bath-suits, underwear, tight t-shirt, socks.
- Due to its anti-bacterial nature, non-woven fabric has wide prospects in the field of hygiene materials such as sanitary napkin, masks, mattress, food-packing, bags.
- Sanitary materials: bandage, mask, surgical clothes, nurses wears and so on. It has incomparably wide foreground on application in sanitary material such as sanitary towel, gauze mask, absorbent pads, and food packing.
- Decorating items: curtain, television cover, wall-paper and sofa slipcover.
- Bathroom products: towel and bath robe [8].

1.4.3 Chemical Structure of Bamboo

Chemical structure of bamboo fiber is shown in Figure 1.2

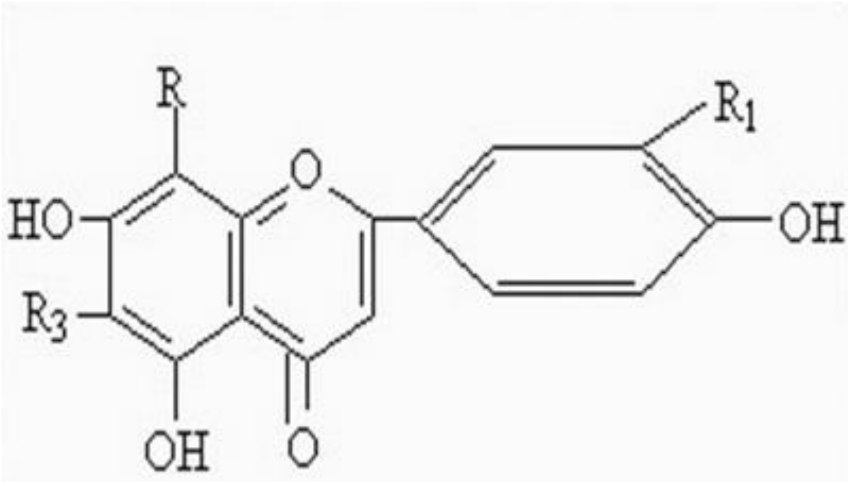


Figure 1. 2 Chemical structure of bamboo fiber [9]

1.5 Soybean Protein Fiber

Soybean fiber is a man-made regenerated protein fiber from soybean protein blended with Polyvinyl Alcohol [10]. Soybean Protein Fiber or SPF is the only renewable botanic protein fiber we can touch today. SPF is a unique Active fiber**.** Its moisture absorption, ventilation, draping and warmth cover the superior performances of natural fibers and synthetic ones [11].

1.5.1 Characteristics of Soybean Protein Fiber

Fabrics from soybean protein fiber shows the following characteristics

Cashmere Feel: The fabric made of soybean Protein fiber is soft, smooth, light. It has cashmere feel but smoother than cashmere; it is as comfortable to skin and human’s second skin

Dry and Comfortable: the moisture absorption or bean fiber is similar to that of cotton fiber, but its ventilation is superior to of cotton.

Luxurious appearance: Soybean protein fiber fabric has joyful silky luster with perfect drape and elegant, fabrics of yarn in high count has fine and clear texture and classical shirting.

Good color fastness: the original color of soybean protein fiber is ivory like tussah color. It can be dyed by acid dyes and active dyes; especially the color is quite fresh and lustrous with the later dyes while quite stable in the sunshine and perspiration. Its anti-ultraviolet is superior to cotton fiber, much more superior to viscose and silk.

Function of Health: Soybean Protein Fiber possesses many amino acids necessary to human's body, so this sole botanic protein fiber has the function of health than no other fiber processes. Meeting people's skin, the amino acid in soybean protein can activate the collagen protein in the skin, resist tickling and evaporate the skin. Bacteria resistant elements are integrated in the fiber's molecule chain, which makes the fabrics keep the property of resisting coli bacillus, staphylococcus aureus and candida albicans permanently, this avoids shortcoming of not permanent effect when the antibacterial function is added to the yarn when finishing [11].

1.5.2 End-Uses of Soybean Protein Fiber

Woven and knitted fabrics made of soybean protein fibers can be used for apparel (personal underwear, T-shirts, pullovers, sweaters, evening dresses, children's clothing and sportswear) and home textiles (towels, bed linen, blankets, bathrobes, pyjamas) [12].

Low tensile strength of soybean protein fibers in wet state limited their commercial application. Fibers were used predominantly in blends with wool, cotton or synthetic fibers in woven and knitted fabrics for apparel and in upholstery, also in cars, despite of lower abrasion resistance than wool [13].

1.5.3 Chemical Structure of Soybean Protein Fiber

Like many other plant proteins, soybean proteins are mainly storage proteins that provide amino acids during seed germination and protein synthesis. The monomer of the storage protein has the same amino acid residues as many other proteins and is linked by amide bonds into polypeptide chains as shown in Figure 1.3 [14].

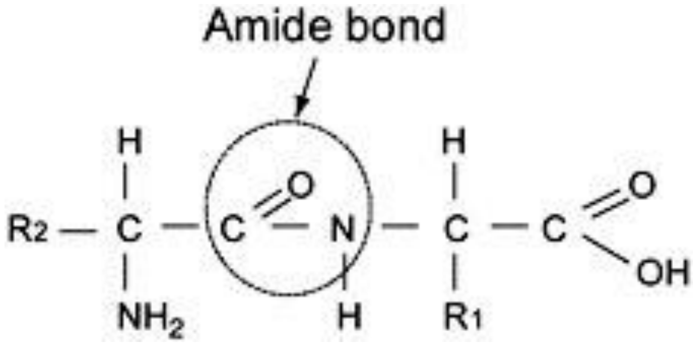


Figure 1. 3 Structure of amide bond linking amino acid

1.6 Aim of the Thesis

Insect repellency is an important feature to be applied on the cloths especially for the outer wears. It is obvious that insect repellent cloths will take an important place in daily life when we consider high rate of insect-borne diseases.

The best of our knowledge is that insect repellent textiles have not been evaluated with respect to different fiber characteristics. In this study we aimed to determine which fiber (cotton, organic cotton, bamboo, soybean) will show the highest insect repellent performance after treatment. Hence, this study will help us to find out whether insect repellency is directly related with fiber type or not.

In this study fabric samples were treated with insect repellent chemical (Konservan P10) with two different concentration which are 10g/L and 30g/L respectively. Fabrics were tested to find out insect repellency values under different concentrations. Insect repellency test were carried out with a special plexiglass experimental setup and test results shed a light on the subject to determine the right chemical concentration value to obtain satisfactory insect repellent fabrics. Furthermore, the tests results gave an idea to suggest a suitable fabric type among the samples to be used for manufacturing insect repellent clothes.

It was also aimed to clarify that whether insect repellent chemicals would give anti-bacterial effects or not. Fabrics which were treated with 30g/L insect repellent chemical (Konservan P10) were subjected to antibacterial tests to illuminate the issue.

1.7 Previous Works

Although some studies are found about mosquito repellent fabrics and their manufacturing methods, studies on insect repellent textiles are mainly focused on manufacturing of insect repellent fabrics with different insecticide chemical at finishing process. These studies are generally restricted with commercial applications and patents. Furthermore, the best of our knowledge is that insect repellency values of different kinds of samples (cotton, organic cotton, bamboo, soybean silk fiber) have not been compared. This study can be acceptable to be the first in this field and will shed a light for the future studies. Some studies on insect and mosquito repellent fabrics are summarized as follows:

Tanveer [1] examined mosquito repellent textiles and their applications under class of protective textiles. He stresses the importance of mosquito repellent textile to be used for protection against insect-borne diseases such as malaria. In the study Tanyeer also explained mechanism of insect repellent action with respect to tactile and olfactory senses. He mentions four particular methods to conduct insect repellency test namely field test, indoor test, cone test and cage test.

Kranthia [15] determined Insecticide resistance of five major cotton pests (Helicoverpa armigera, Pectinophora gossypiella Earias vittella, Spodoptera litura and Bemisia tabaci) to widely used insecticide groups (pyrethroids-cypermethrin; organophosphates-chlorpyriphos; cyclodienes-endosulfan) in main cotton growing regions of India. They compared the resistance of these five strains against commonly used insecticides. According to the results obtained from the survey they determined the suitable insecticides to be used in main cotton growing regions of India.

Chio and Yang [16] studied developments of natural insect repellents. They calculated average number of mosquitoes landing on extracts of neem oil (a well-known insect repellent), djulis leaf (an indigenous plant from Taiwan), djulis seed and sea lily with different concentrations at a certain time interval. They compared the results by probit analysis and proved that djulis is a better insect repellent than that of neem oil.

Specos [17] studied on testing of microencapsulated citronella oil treated cotton fabrics and ethanolic solution of citronella sprayed cotton fabrics to compare their mosquito repellency efficiencies according to cage test method. Based on the test description, human arms covered with citronella treated samples and untreated samples separately then inserted to the test chamber together with bare arm as control. Test chamber was contained approximately 200 Aedes aegypti mosquitoes which had not been fed for three to five days. Numbers of mosquitos landing on the covered arms were calculated after one minute of exposure and the results were evaluated by statistical analysis. The study showed that fabrics treated with microencapsulated citronella presents higher and longer lasting protection from insects in comparison to fabrics sprayed with an ethanol solution of the essential oil ensuring repellency effect more than 90% for three weeks.

Hebeish [18] studied to prepare an insect repellent cotton fabric with Limonene which is an important natural insecticide. Limonene was applied to the weave cotton fabric samples and samples modified via grafting with monochlorotriazinyl-b-cyclodextrin (MCT-b-CD) with different doses 250mg/m2, 500mg/m2, 750mg/m2, 1000mg/m2 and 1500mg/m2 respectively. Fabrics were conducted insect repellency test and repellency, knockdown and mortality rates observed after different time intervals were corrected using the Abbott's formula (Abott, 1925). Blank or untreated (control) samples were also tested in parallel to the treated samples for control purposes. Relation between insecticide doses-treated fabrics and toxic activity were expressed by graphs. In the study it was showed that impregnated fabrics display lower initial knockdown activities against mosquitoes the results are nearly equal to those of blank samples. Surface coating method provides high repellent action about 100%. MCT-b-CD finished cotton fabrics treated with limonene are higher than those of the blank sample. It was also proved that repellency increased by increasing exposure time. He also proved that the treated fabrics with three mentioned methods can be washed and stored while keeping their insecticidal property.

1.8 Structure of the Thesis

This thesis starts with the introduction chapter that includes general information about the fiber types which were used for the experimental study and the chapter includes the aims to be achieved. Related literature studies were reviewed in this chapter as well.

In Chapter 2, general information was given about insect repellency and test methods of insect repellency were described.

Chapter 3 is about experimental studies. Sample properties and application of insect repellent chemical were explained in this chapter.

Chapter 4 contains insect repellency and antimicrobial test results with their graphical representations. Comparison of the insect repellent performance of the samples with different chemical concentration was also covered in this chapter.

Chapter 5 includes the conclusions and recommendation for future studies.

CHAPTER 2
INSECT REPELLENCY

2.1 Introduction

An insect repellent is a substance applied to skin, clothing, or other surfaces which discourages insects (and arthropods in general) from landing or climbing on that surface [19].

Insect-repellent textiles are considered by public health agencies worldwide to be an increasingly important component in the fight to reduce the incidence of insect-borne infectious diseases such as malaria, West Nile virus, encephalitis, dengue fever, Lyme disease and numerous others. Insect-borne diseases afflict hundreds of millions of people each year and represent a significant portion of overall infectious diseases, which globally rank second among all causes of death. Vaccines and therapeutic drugs have yet to be developed to treat many of these diseases, so preventive measures must be taken to control these insects and avoid contact with them [20].

Every year, millions of people around the world are affected by insect-borne diseases. The impact of these preventable diseases on families, communities and the economies of developing countries are tremendous. Insect repellent fabrics will be an important tool in the battle against insect-borne diseases and improve the health of people worldwide.

2.2 Common Insect Repellents

Common insect repellents can be given as below.

- Deet (n,n-diethyl-meta-toluamide)
- Permethrin
- Icaridin
- Nepetalactone

- Citronella oil
- Neem oil
- Bog myrtle
- Dimethyl carbate

In this study Konservan P10, whose constitution is water miscible synthetic pyrethroid, 10% Permethrin, was used as an insect repellent chemical. Hence, we preferred to deal with Permethrin in detail rather than other insect repellents.

2.3 Permethrin

Permethrin is a man-made insecticide, structurally similar to a naturally-occurring chemical called pyrethrum. Pyrethrum was initially derived from the crushed dried flowers of the daisy Chrysanthemum, whose insecticidal properties have been recognized since the 18th century. The permethrin which is currently sold to consumers is a synthesized product that was developed in the 1970's [21].

Permethrin is used:

as an insecticide

- in agriculture, to protect crops
- in agriculture, to kill livestock parasites
- for industrial/domestic insect control

as an insect repellent or insect screen

- in timber treatment

as a personal protective measure (cloth impregnant, used primarily for US military uniforms and mosquito nets)

in pet flea preventative collars or treatment.

2.3.1 Features of Permethrin

Physical and chemical features of phermetrin is shown in Table 2.1

Table 2. 1 Physical and Chemical Features of Phermetrin

Molecular Formula	$C_{21}H_{20}Cl_2O_3$
Molecular Mass	391.29 g mol^{-1}
Appearance	Colorless crystals
Density	1.19 g/cm^3, solid
Melting Point	34 °C, 307 K, 93 °F
Boiling Point	200 °C, 473 K, 392 °F
Solubility in water	5.5 x 10^{-3} ppm

2.3.2 Molecular Structure

Molecular structure of permethrin is indicated in Figure 2.1

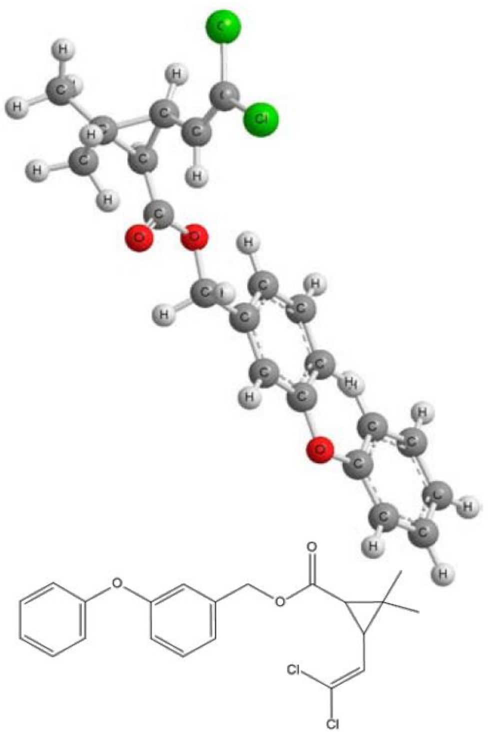


Figure 2. 1 Molecular structure of permethrin [22]

2.3.3 How Does Permethrin Work?

Permethrin works as a contact insecticide, damaging the nervous system of insects which come in contact with it, leading to either their death or “knockdown”.

Permethrin is effective against multiple species of crawling and flying insects, including mosquitoes, ticks, fleas, bedbugs, chiggers, and flies. Ticks crawling across permethrin-treated pant legs or socks are likely to drop off before they are able to attach and feed [21].

2.3.4 Is Permethrin Safe?

Permethrin should be applied to clothing or other fabrics. It is not intended for direct application to the skin. Once Permethrin has dried on the clothing it bind very strongly to the fibers and absorption through the skin is negligible.

Any permethrin that may get on the skin inadvertently is poorly absorbed (less than 2% of applied dose). It is rapidly inactivated by skin and liver esterases, its metabolites are then excreted by the kidneys. Occupational exposure to high doses of permethrin has been associated with symptoms of itching, burning and numbness. Studies have shown permethrin not to be a human teratogen, mutagen, or carcinogen.

Permethrin is also environmentally safe as it is degraded by sunlight, its half-life is less than 30 days in soil and the chemical is readily metabolized by soil microorganisms [21].

2.4 Test Methods

2.4.1 Field Test

Field studies are the ultimate verification of the performance of the product. The most realistic conditions deliver the most meaningful results. Figure 2.2 shows field test method.

Figure 2. 2 Testing repellent-treated textiles in the field near Regensburg [1].

2.4.2 Indoor Test

In the indoor test, the test rooms are air conditioned, and the number, age, and species of the mosquitoes used can be controlled. This test is a good alternative to field test and more realistic than cage tests, but possible at any time and at less expense. Figure 2.3 shows indoor test of and insecticide-treated textile.

Figure 2. 3 Indoor test of an insecticide-treated textile

2.4.3 Cone Test

In the cone test, mosquitoes (usually malaria mosquitoes, Anopheles gambiae) are introduced into a standardized cone for a defined time span, then removed and transferred to small cages to determine the knock-down and knock-dead rates [1]. Figure 2.4 shows cone test of an insecticide-treated textile.

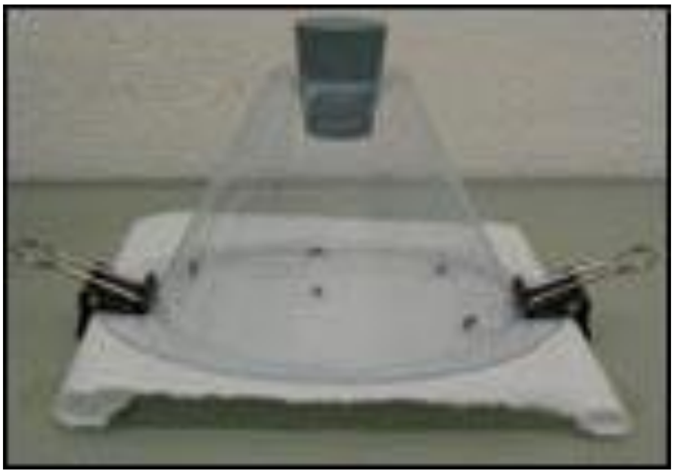


Figure 2. 4 Cone test of an insecticide-treated textile

2.4.4 Cage Test

Cage tests are the quick and cost-effective way determines the mosquito-repelling qualities of treated textiles. They are ideal for product development. The tests follow the acknowledged protocol for cage tests of repellents. For such a test, volunteers cover a defined area of their forearms with the textiles and then present it to hungry mosquitoes in cage [1]. Volunteer arms without mosquito repellent treatment and with mosquito repellent treatments are indicated in Figure 2.5 and Figure 2.6 respectively.

Figure 2. 5 Cage Test without mosquito repellent treatment

Figure 2. 6 Cage Test with mosquito repellent treatment

CHAPTER 3
MATERIALS AND METHODS

3.1 Introduction

Because of global warming the distribution of mosquitoes has expanded from tropical regions to northern latitudes, and that leads to a spread in sources of viral infection from mosquitoes [1]. Spreading viral infections from the various types of mosquitoes and insects brings lots of diseases. Hence, insect repellent textiles gain importance to be used as a protective method against insect-borne diseases.

3.2 Materials

In this study four different yarns were selected with different raw materials and the same yarn count. Cotton, organic cotton and bamboo yarns obtained from Selcuk Iplik San. Tic. A.S (Gaziantep) and Soya yarn were obtained from Hayteks Ekolojik Tekstil San. Tic. Ltd. Şti. (Ankara).The yarns were knitted with the circular sock machinery in the laboratory of textile engineering department to obtain fabric samples. General features of the samples were indicated in Table 3.1

Table 3. 1 General features of the samples

Fabric Type	Yarn number	Pattern type	Weight (g)/Sqm	Thickness	Wales/Course (per cm)
Cotton	30/1 Ne	Single jersey	108,62	0,68mm	14/12
Organic Cotton	30/1 Ne	Single jersey	120,45	0,72mm	14/12
Bamboo	30/1 Ne	Single jersey	132,78	0,59mm	20/12
Soya	32/1 Ne	Single jersey	107,10	0,54mm	16/15

Chemicals:

NaOH were used in the pretreatment process to increase hydrophility of the samples. Konservan P10 which was obtained from Thor Specialities (UK) Limited was used as insect repellent chemical. Water miscible synthetic pyrethroid, permethrin-based this chemical is suitable to apply either by exhaust or padding methods.

Insects:

Insects were collected from field (university campus area) thanks to field work, together with staff of University of Gaziantep, Biology Department. Two types of insects were used in this study. They are Capnodis and Larinus and both are belongs to order of Coloeptera.

Capnodis is generally known as pistachio worm. This insect is quite harmful to pistachio trees. Figure 3.1 indicates the picture of Capnodis.

Figure 3. 1 Capnodis

Larinus are feed on flower heads, destroying the developing seeds of the weeds. Figure 3.2 illustrates the picture of Larinus.

Figure 3. 2 Larinus

Scientific classification of insects used in this study is shown in Table 3.2

Table 3. 2 Scientific classification of Capnodis and Larinus

	Capnodis	**Larinus**
Kingdom:	Animalia	Animalia
Phylum:	Arthropoda	Arthropoda
Class:	Insecta	Insecta
Order:	Coloeptera	Coloeptera
Family:	Buprestiade	Curculionidae
Genus:	Capnodis	Larinus

Machineries and Equipments:

SDL ATLAS brand sock knitting machinery was used to manufacture samples from the yarns (Figure 3.3)

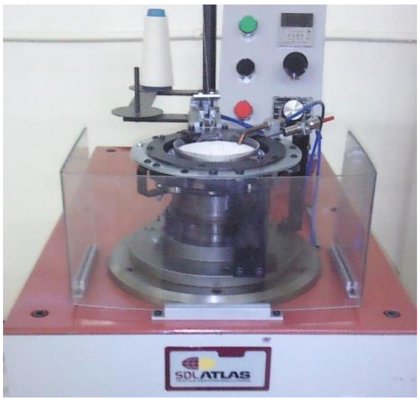


Figure 3. 3 Sock knitting machinery

Loupe indicated in Figure 3.4 was used to calculate the wales and course per cm

Figure 3. 4 Loupe

All chemical process was carried out in chemical laboratory of textile engineering department. In this regard, prowhite brand machinery shown in Figure 3.5 was used for padding and to squeeze the samples with desired pressure.

Figure 3. 5 Padding mangle

Prowhite brand dryer shown in Figure 3.6 was used to dry samples after padding process of each sample

Figure 3. 6 Dryer

Circular cutting apparatus shown in Figure 3.7 is used to take a precise cutting ($100cm^2$) from each sample to calculate gram per square meter values of each sample.

Figure 3. 7 Sample cutter

Schmidth brand digital thickness tester shown in Figure 3.8 was used to determine the thickness of the samples.

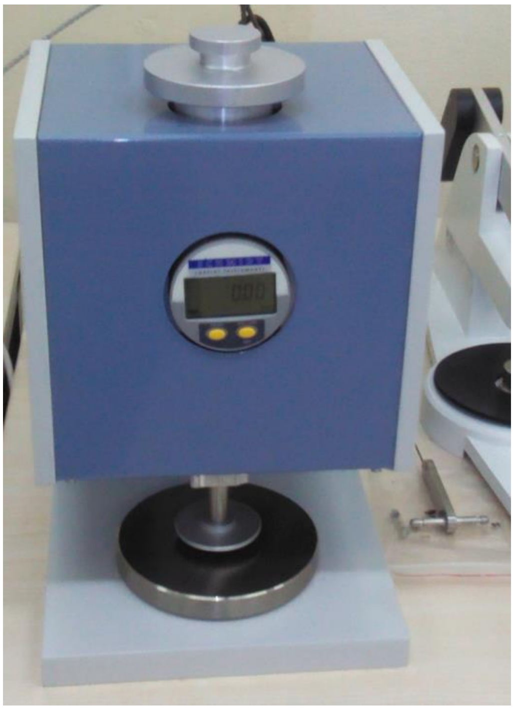


Figure 3. 8 Schmidt digital thickness tester

Axis brand digital weighing scale shown in Figure 3.9 was used to calculate g/sqm values and to determine amount of solution which was prepared for the finishing processes.

Figure 3. 9 Weighing scale

Thermal brand heater shown in Figure 3.10 was used to heat the solutions which was prepared in the beakers

Figure 3. 10 Heater

Special plexiglass experimental setup shown in Figure 3.11 was used to conduct the insect repellency test. The apparatus consist of one removable separator to divide the cage into two sections. One section to place treated sample and the other one to place untreated control samples to determine the insect repellency values of the treated samples.

External dimensions of the plexiglass test apparatus is 25x50x30h cm

Figure 3. 11 Plexiglass testing apparatus

3.3 Method

Yarns were knitted with sock knitting machinery with a speed of 50rev/min. The knitting process was lasted to obtain each circular sample with a length of 50cm. After that fabrics were exposed to pre-treatment process according to the following procedure to increase hydrophilic character of each sample.

Pre-treatment process:

Each sample was treated with NaOH solution separately according to recipe indicated in Table 3.3

Table 3. 3 Increasing hyrophility

Chemical	Temperature	Liquor Ratio	Duration	PH
NaOH	95^oC	1:10	1 hour	10,5

After treatment with NaOH, the samples were neutralized with pure water (PH:4,5) during 20minutes. Then the samples were dried completely at natural environment.

Application of Insect Repellent Chemical (Konservan P10)

Two pieces with a length of 23cm was cut from each sample and samples were classified in two groups as Group-1 and Group 2. KonservanP10 was applied to each group with different concentrations as indicated in Table 3.4

Table 3. 4 Classifications of samples

	Knitted Fabric	Length	Width	Concentration of Konservan P10	Application Method	PH	Liquor Pick up
GROUP 1	Cotton	23cm	9,5cm	10g/L	Padding Mange	6	65%
	Organic Cotton						
	Bamboo						
	Soybean						
GROUP 2	Cotton	23cm	9,5cm	30g/L	Padding Mangle	6	65%
	Organic Cotton						
	Bamboo						
	Soybean						

Each sample was squeezed 2 times at 3 bar pressure by padding machine with a speed of 2m/min.

Drying Process:

Samples were dried with Prowhite brand dryer at 140^{o}C during 5 minutes.

Insect Repellency Test:

Experiment was carried out with 17 numbers of insects. 10 insects were placed on sample which was treated with Konservan P10 and 7 insects were placed on untreated fabric of the same sample. On the other hand, cotton treated with 10g/L or 30g/L Konservan P10 tested with cotton without insect repellent chemical, similarly bamboo treated with 10g/L or 30g/L Konservan P10 tested with bamboo without insect repellent chemical and so on.

After placing the samples and insects properly, separators were removed and stopwatch was started. Movements of the insects were observed during 30 minutes and replacement status of the insects was recorded every 10 minutes. This experiment and observation procedure was repeated for all the samples separately.

Furthermore, since there is no an international standard for this test, researchers decide whether results are successful or not considering numerical evaluation after observation. Therefore; considering the numerical majority, we accepted the test is successful if 70% or more insects leaved away from the treated samples.

During test of each sample; it was taken into consideration to use all the insects alive. In order to achieve this, insects which was get harmed or died during test were replaced with alive ones from the insect container. Test environment is shown in Figure 3.12

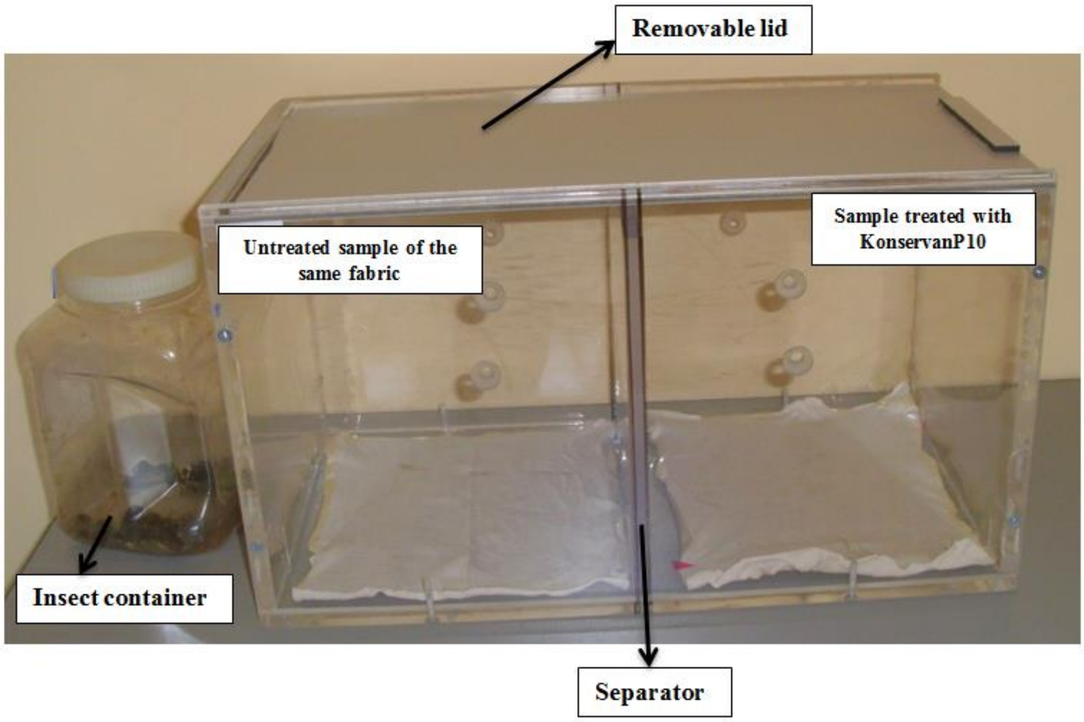


Figure 3. 12 Test environment

Antimicrobial Test:

Insect repellent samples (applied 30g/L Konservan P10 chemical concentration) were exposed to antimicrobial test according to ASTM E2149-01 test method. In the test antibacterial activity values against *E. coli* (ATCC 35218) and the results were recorded.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Introduction

Insect repellent values of the treated fabrics were determined by comparison with untreated (control) samples. Repellency values of all samples and applications of chemical concentrations were compared and evaluated. The insect repellency percent of each sample were indicated by a graphical representation and 70% repellency value was considered as successful and acceptable result. Relationship between insect repellency features and antimicrobial effects were clarified by exposing the insect repellent samples to the antimicrobial test. The results were evaluated.

4.2 Insect Repellency Test with 10g/L Concentration (Konservan P10)

4.2.1 Treated Cotton 100% (10g/L) Versus Untreated Cotton 100%

Figure 4.1 Shows the movements of the insects between treated cotton fabric sample (10g/L Konservan P10) and untreated fabric (control sample) within 30 minutes. It was observed that number of the insects on the treated samples was decreased from 10 to 6 within first 10 minutes. The legs of the insects were sticking between the loops of the knitted fabrics and this was making difficult for insects to take a step on the surface of the fabric. Hence, the insect movements were quite slow from the treated sample to the control samples.

From 10 to 20 minutes 2 insects leaved the treated sampled slowly while others moving to the edges of the fabrics.

From 20 to 30 minutes the movements were slowed considerably and stagnancy was noticed among the insects.

Sample	Cotton 100%
Konservan P10	10g/L

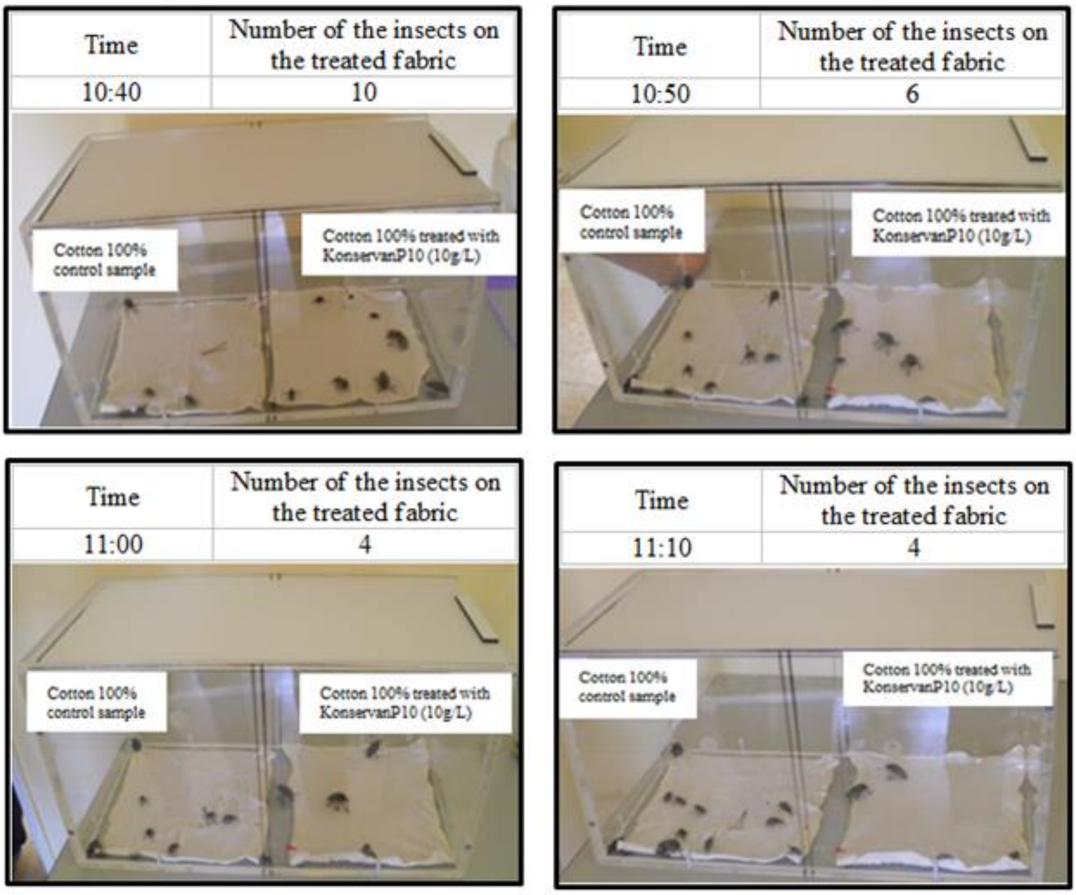


Figure 4. 1 Movements of the insects between treated cotton (10g/L) and control sample within 30 minutes

Under the light of this experiment an insect repellency graph can be drawn as in Figure 4.2 According to graph in Figure 4.2, It can be said that insect repellency efficiency of the cotton sample with 10g/L Konservan P10 concentration is not satisfactory.

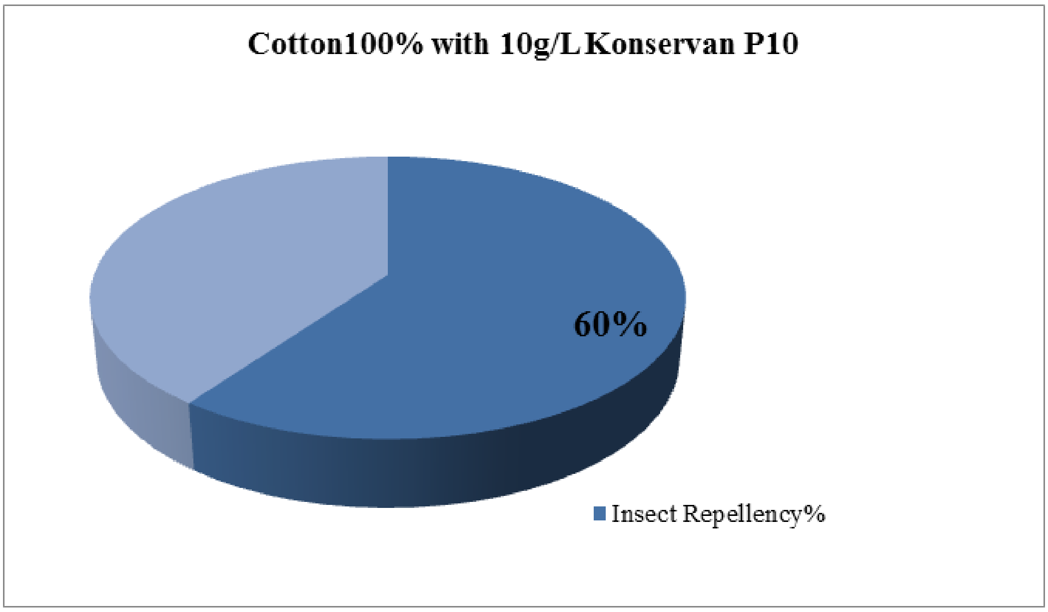


Figure 4. 2 Insect repellency percent of cotton with 10g/L Konservan P10

4.2.2 Treated Organic Cotton 100% (10g/L) Versus Untreated Organic Cotton 100%

Figure 4.3 Indicates the movements of the insects between treated organic cotton fabric sample (10g/L Konservan P10) and untreated fabric (control sample) within 30 minutes. It was observed that number of the insects on the treated sample was decreased from 10 to 5 within first 10 minutes. It was also noticed that movements of the insects were faster than that of treated cotton100%.

From 10 to 20 minutes number of the insects remained the same on the treated sample. It can be said that there was almost no movements on the fabric.

From 20 to 30 minutes a small movement started on the treated fabric and 2 of the insects passed slowly on the control sample.

Sample	Organic Cotton100%
Konservan P10	10g/L

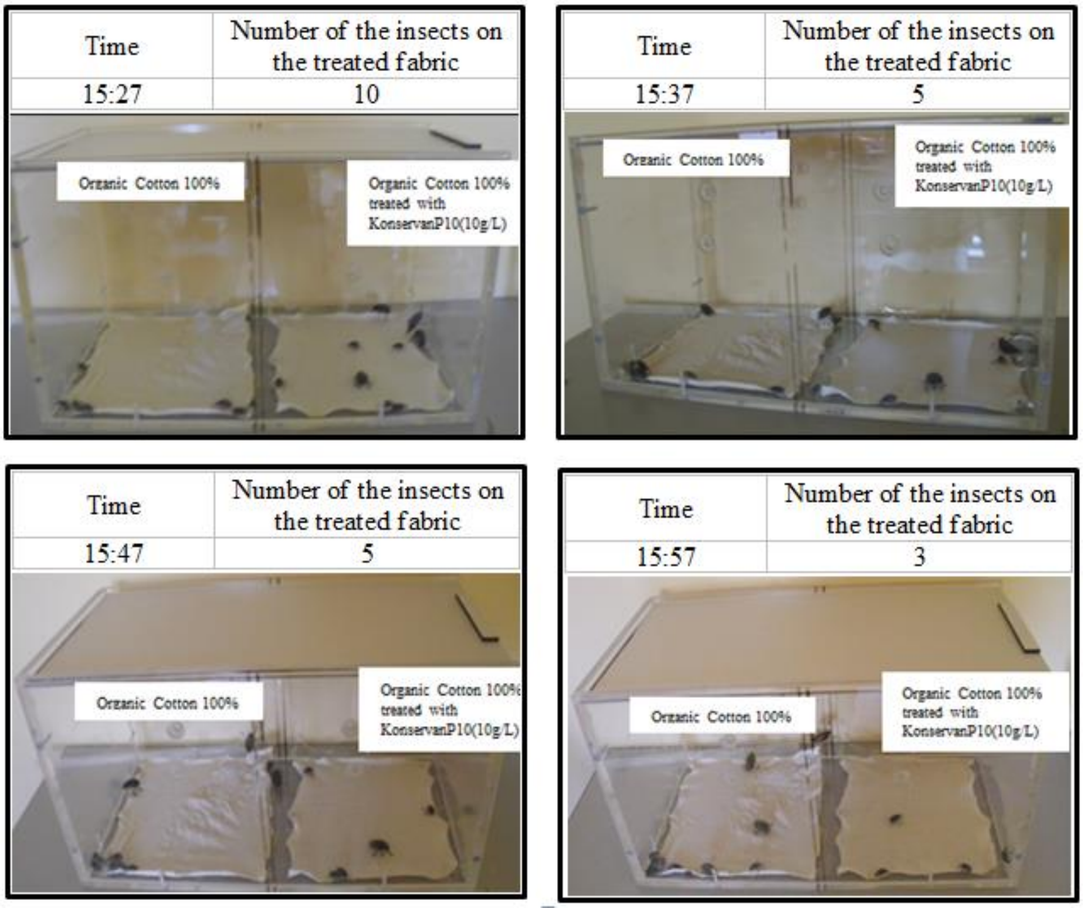


Figure 4. 3 Movements of the insects between treated organic cotton (10g/L) and control sample within 30 minutes

According to the data obtained from this experiment an insect repellency graph can be drawn as in Figure 4.4 According to graph in Figure 4.4, It can be said that organic cotton sample treated with 10g/L KonservanP10 passed the test. However, it has to be pointed out that the value is on the critical acceptance point.

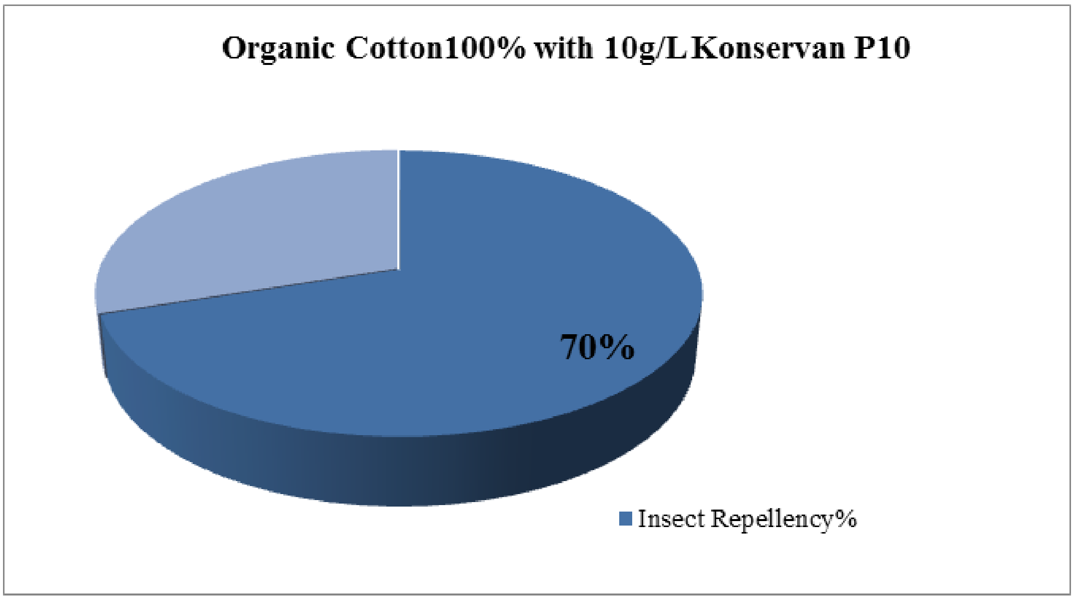


Figure 4. 4.Insect repellency percent of organic cotton with 10g/L Konservan P10

4.2.3 Treated Bamboo 100% (10g/L) Versus Untreated Bamboo 100%

Figure 4.5 Indicates the movements of the insects between treated bamboo fabric sample (10g/L Konservan P10) and untreated fabric (control sample) within 30 minutes. It was observed that number of the insects on the treated sample was decreased from 10 to 7 within first 10 minutes. It was observed that passing speed of the insects was quite slow.

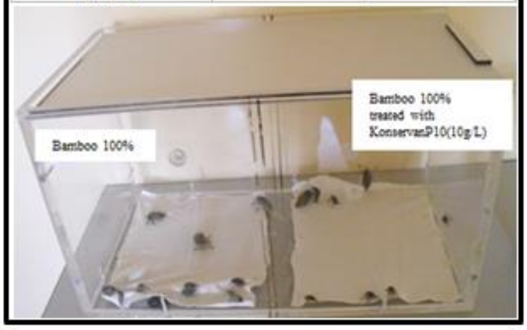
Number of insects remained on the treated sample were seen as 4 between 10 to 20 minutes. Small movements of the insects were seen on the fabric.

Within the last 10 minutes of this experiment there was no movement on the treated fabric at all. The stagnancy was last till the end of the time.

Sample	Bamboo 100%
Konservan P10	10g/L

Time	Number of the insects on the treated fabric
16:58	10

Time	Number of the insects on the treated fabric
17:08	7



Time	Number of the insects on the treated fabric
17:18	4

Time	Number of the insects on the treated fabric
17:28	4

Figure 4. 5 Movements of the insects between treated bamboo (10g/L) and control sample within 30 minutes

In accordance with the data obtained from this is experiment an insect repellency graph can be drawn as in Figure 4.6 According to this graph, it can be said that bamboo sample treated with 10g/L KonservanP10 failed the insect repellency test with a percent of repellency value 60%

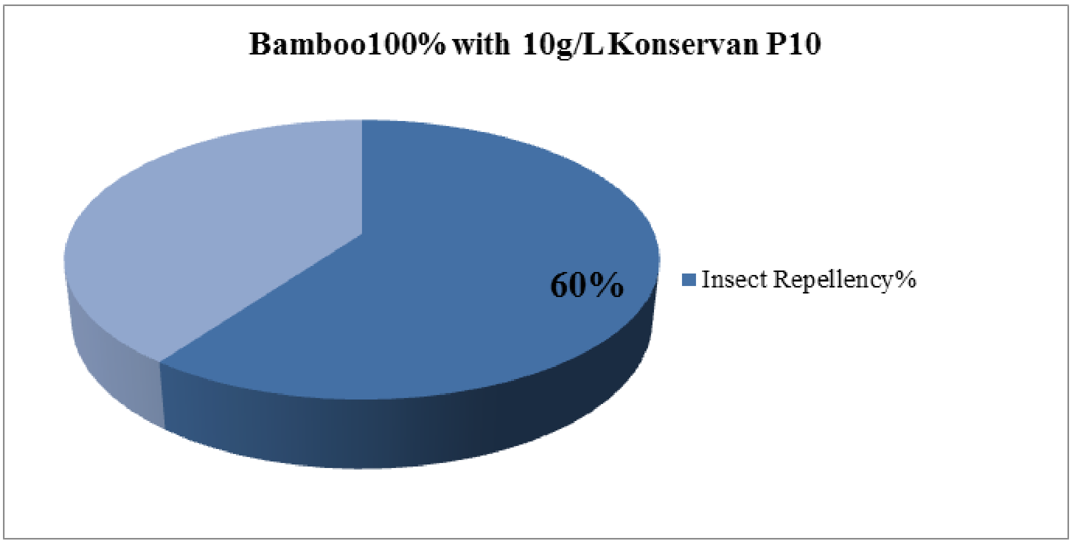


Figure 4. 6 Insect repellency percent of bamboo with 10g/L Konservan P10

4.2.4 Treated Soybean 100% (10g/L) Versus Untreated Soybean 100%

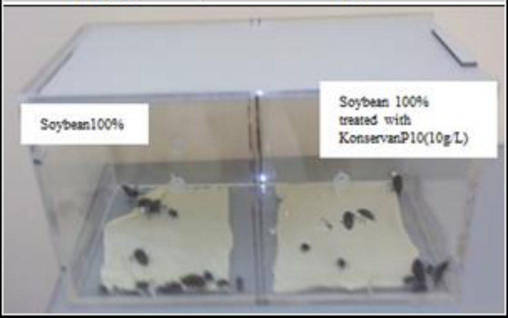
Figure 4.7 Indicates the movements of the insects between treated soybean fabric sample (10g/L Konservan P10) and untreated fabric (control sample) within 30 minutes. It was observed that number of insects on the treated sample was decreased from 10 to 8 within first 10 minutes. The insect movements were rather slow.

Only 1 insect passed to the control sample between 10 to 20 minutes. The number of insects was 7 on the treated sample within second ten minutes.

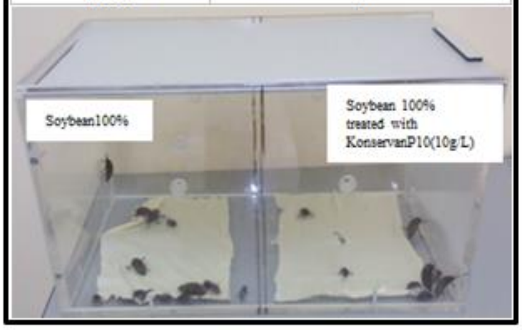
Within last 10 minutes of this experiment, 2 insects left from the treated sample. The number of the insects was 5 when the experiment time finished.

Sample	Soybean 100%
Konservan P10	10g/L

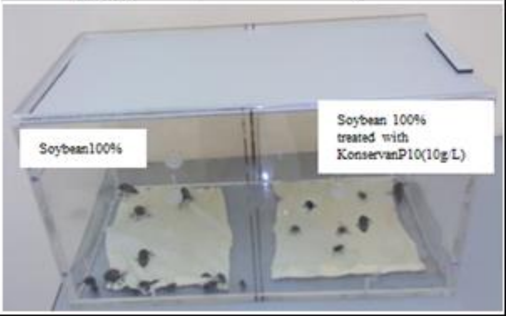
Time	Number of the insects on the treated fabric
18:20	10



Time	Number of the insects on the treated fabric
18:30	8



Time	Number of the insects on the treated fabric
18:40	7



Time	Number of the insects on the treated fabric
18:50	5

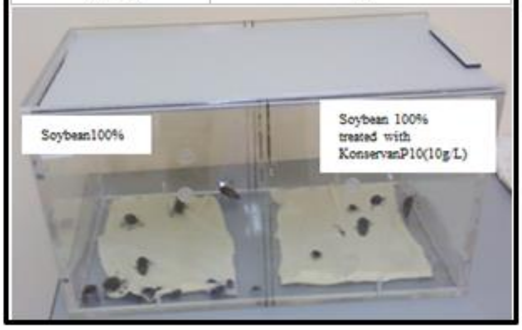


Figure 4. 7 Movements of the insects between treated soybean (10g/L) and control sample within 30 minutes

According to the data obtained from this experiment an insect repellency graph can be drawn as in Figure 4.8. In accordance with this graph, it is obvious that soybean sample treated with 10g/L KonservanP10 did not provide a satisfactory result and failed the insect repellency test.

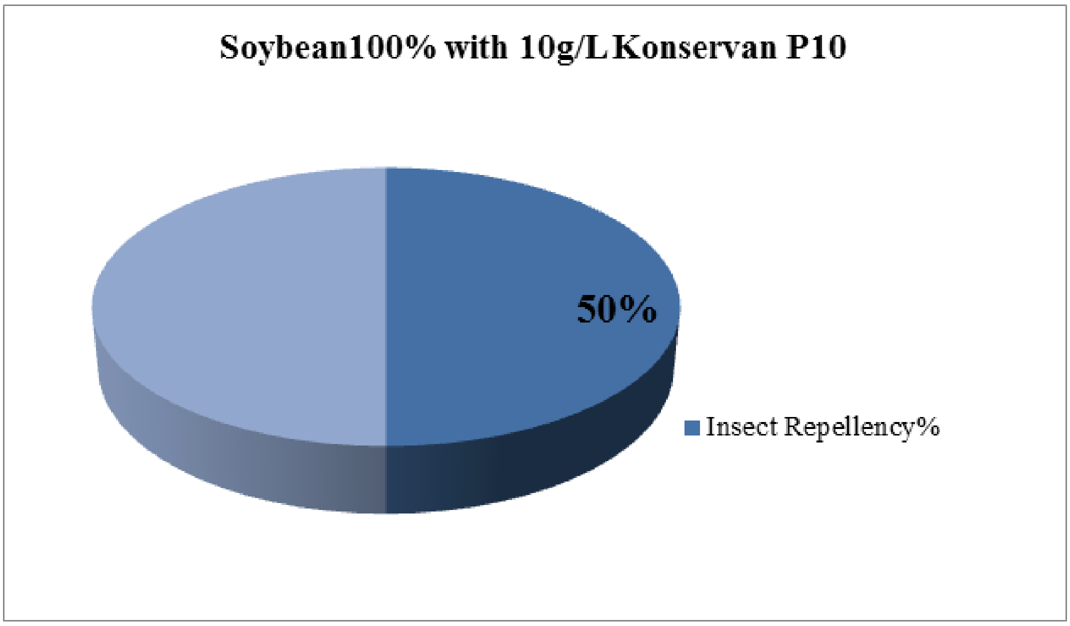


Figure 4. 8 Insect repellency percent of soybean with 10g/L Konservan P10

4.3 Insect Repellency Test with 30g/L Concentration (Konservan P10)

4.3.1 Treated Cotton 100% (30g/L) Versus Untreated Cotton 100%

Figure 4.9 Indicates the movements of the insects between treated cotton fabric sample (30g/L Konservan P10) and untreated cotton fabric (control sample) within 30 minutes. It was observed that the number of insects on the treated sample was decreased rapidly and 4 insects left within first 10 minutes.

The insect movements from treated sample to control sample were continued between 10 and 20 minutes of the experiment. The number of insect on the treated sample was only 1 at the end of the second 10 minutes.

From 20 to 30 minutes the last insect also changed its place and moved to the control sample. At the end of the last 10 minutes there was no insect on the treated cotton sample.

Sample	Cotton 100%
Konservan P10	30g/L

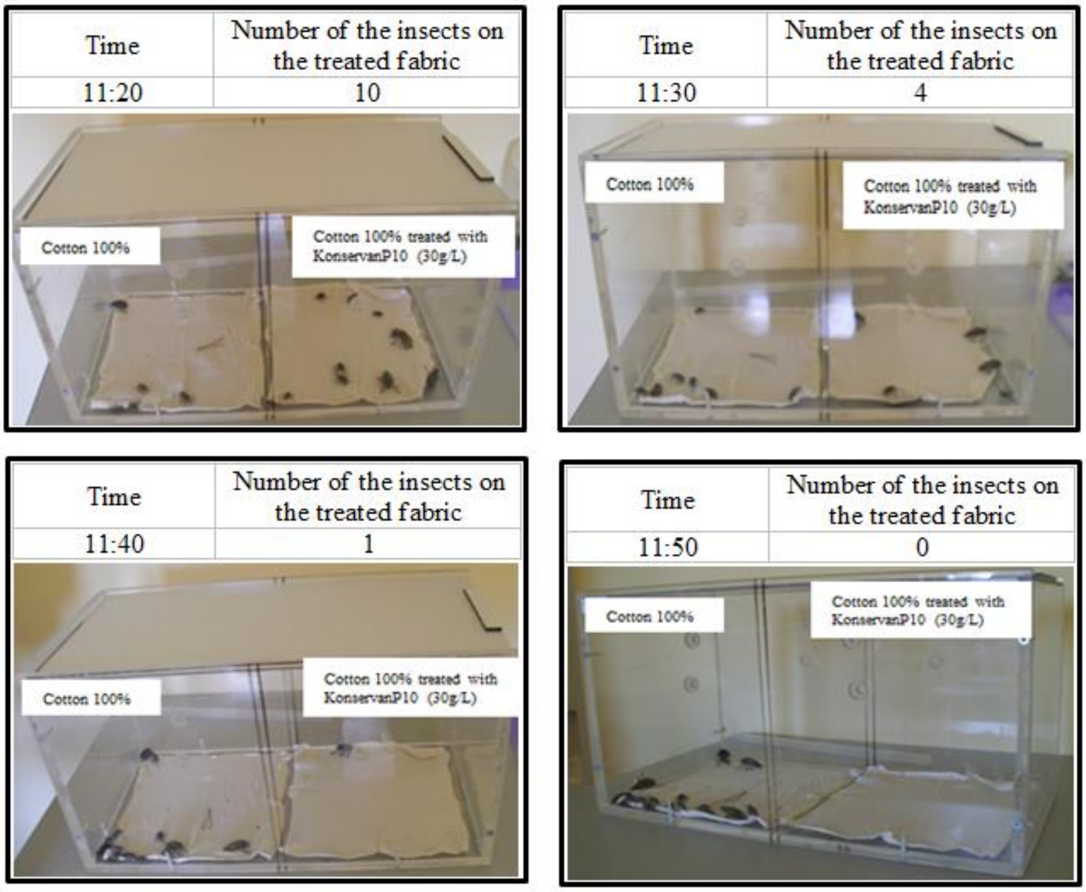


Figure 4. 9 Movements of the insects between treated cotton (30g/L) and control sample within 30 minutes

According to data obtained from this experiment, an insect repellency graph can be drawn as in Figure 4.10. In accordance with this graph, it is clear that 30g/L Konservan P10 is a good concentration for insect repellency with a repellency value 100%.

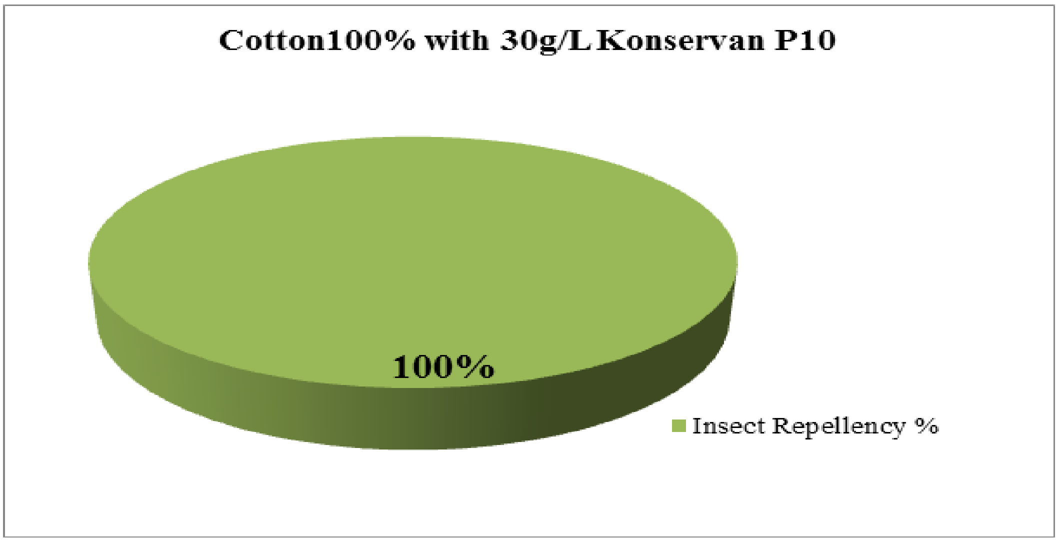


Figure 4. 10 Insect repellency percent of cotton with 30g/L Konservan P10

4.3.2 Treated Organic Cotton 100% (30g/L) Versus Untreated Organic Cotton 100%

Figure 4.11 Indicates the movements of the insects between treated organic cotton fabric sample (30g/L Konservan P10) and untreated organic cotton fabric (control sample) within 30 minutes. Quick insect movements were noticed within the first 10 minutes of the experiment and 6 insects moved.

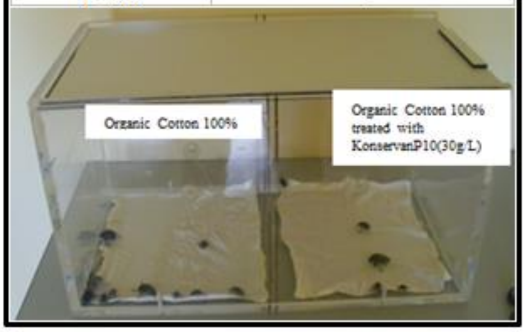
From 10 to 20 minutes stagnancy was observed and when the time was approaching the end of the second 10 minutes one insect changed its position and passed onto the control sample slowly. Thus at the end of the second 10 minutes the number of insect on the treated sample were 3.

Within the last 10 minutes of the experiment, insects were tried to leave the treated sample. Only 2 insects were managed to move on the control sample within last 10 minutes. Therefore, at the end of the experiment there was only one insect on the treated organic cotton sample.

Sample	Organic Cotton 100%
Konservan P10	30g/L

Time	Number of the insects on the treated fabric
14:45	10

Time	Number of the insects on the treated fabric
14:55	4



Time	Number of the insects on the treated fabric
15:05	3

Time	Number of the insects on the treated fabric
15:15	1

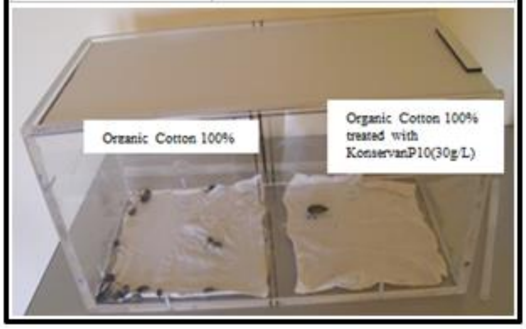


Figure 4. 11 Movements of the insects between treated organic cotton (30g/L) and control sample within 30 minutes

With the data obtained from the experiment, an insect repellency graph can be drawn as in Figure 4.12. According to the graph, organic cotton sample treated with 30g/L Konservan P10 passed the test and the result is satisfactory

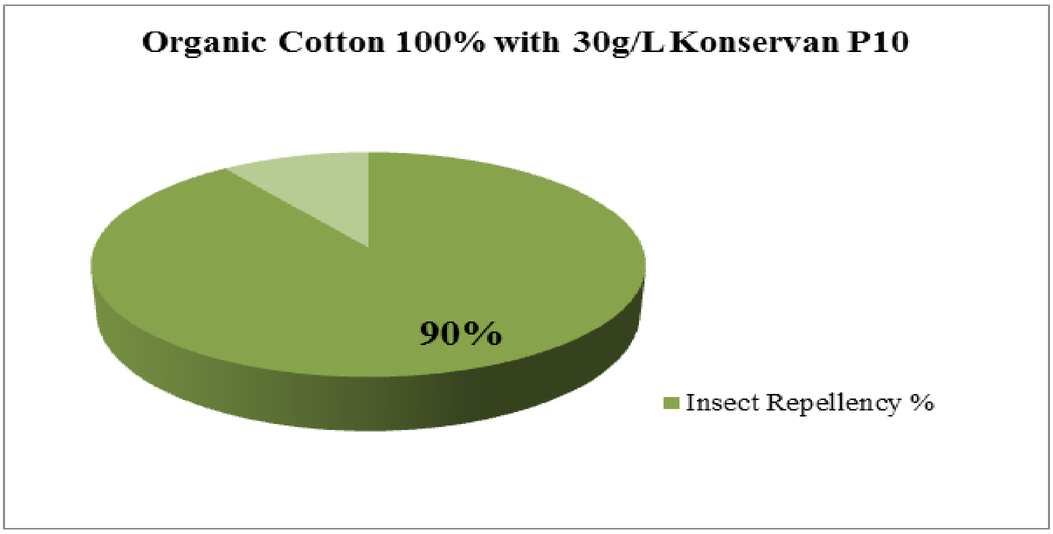


Figure 4. 12 Insect repellency percent of organic cotton with 30g/L Konservan P10

.

4.3.3 Treated Bamboo 100% (30g/L) Versus Untreated Bamboo 100%

Figure 4.13 Indicates the movements of the insects between treated bamboo fabric sample (30g/L Konservan P10) and untreated bamboo fabric (control sample) within 30 minutes. The insects were moved rapidly right after the experiment started. 6 insects were able to move on the control sample within first 10 minutes.

From 10 to 20 minutes one of the insect from the control sample came at the edge of the treated sample. Thus the number of the insect on the treated sample were raised interestingly within the second 10 minutes and become 5.

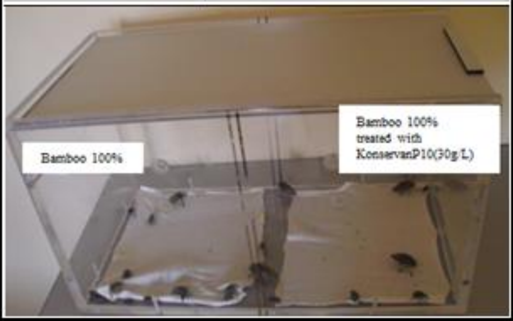
Within the last 10 minutes of the experiment 2 insects were reached to the control sample and insect number on the treated sample was 3 at the end of this experiment.

Sample	Bamboo 100%
Konservan P10	30g/L

Time	Number of the insects on the treated fabric
16:18	10

Time	Number of the insects on the treated fabric
16:28	4

Time	Number of the insects on the treated fabric
16:38	5



Time	Number of the insects on the treated fabric
16:48	3

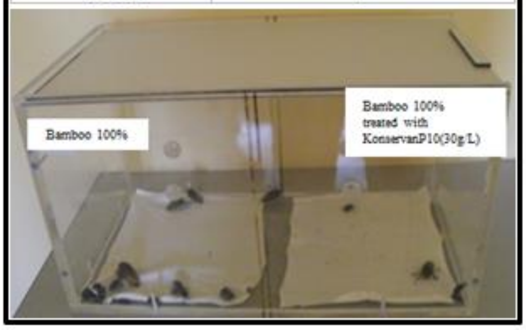


Figure 4. 13 Movements of the insects between treated bamboo (30g/L) and control sample within 30 minutes

According to the information given obtained from this experiment, an insect repellency graph can be drawn as in Figure 4.14. It is clear on the graph that bamboo sample treated with 30g/L Konservan P10 passed the test with a value of 70%.

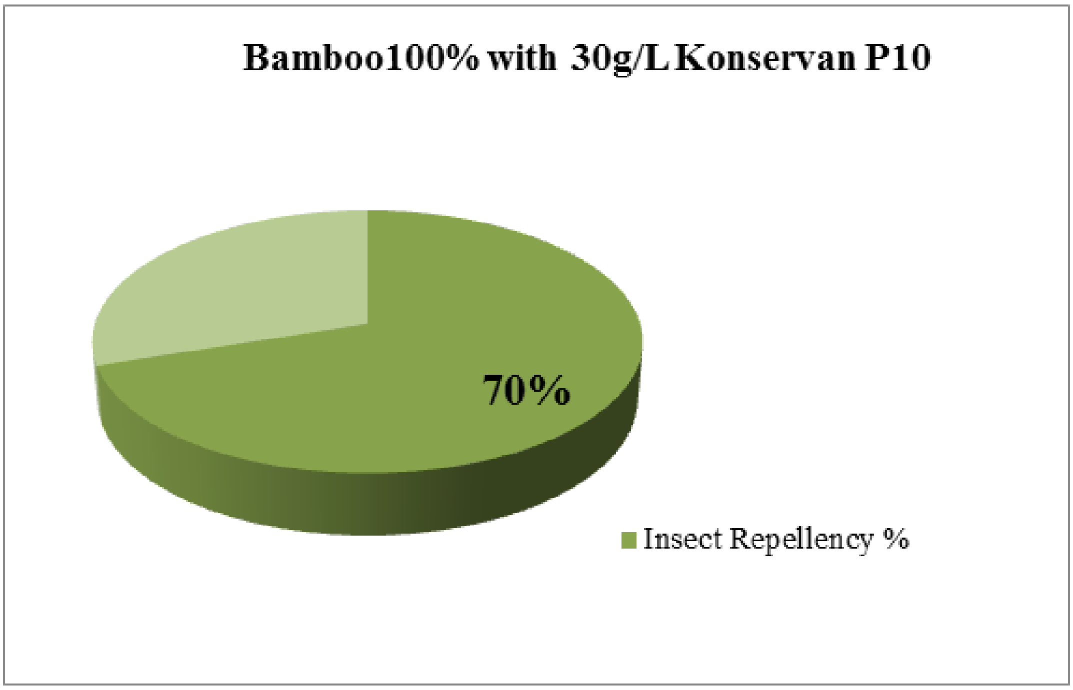


Figure 4. 14 Insect repellency percent of bamboo with 30g/L Konservan P10

4.3.4 Treated Soybean 100% (30g/L) Versus Untreated Soybean 100%

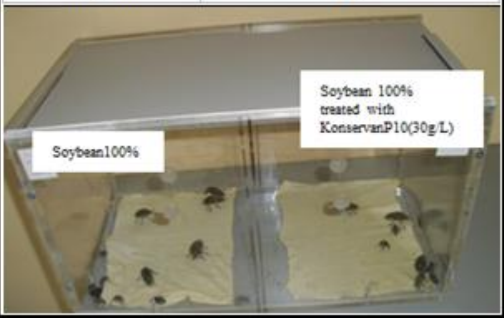
Figure 4.15 Indicates the movements of the insects between treated soybean fabric sample (30g/L Konservan P10) and untreated soybean fabric (control sample) within 30 minutes. All the insect movements were slow inside the container within first 10 minutes. Half of the insects were moved on the control sample and the number was 5 at the end of the first 10 minutes.

Between 10th and 20th minutes of the experiment one insect got involved in the group of the insects of treated sample. Thus the number was 6 at the end of the second 10 minutes. During this time interval, insect movements towards the walls of the experimental setup were also observed.

Within the last10 minutes of the experiment, 3 insects were changed leaving the treated sample as well. 2 of them passed onto the control sample and 1 was able to climb on the wall to escape from the surface of the insect treated sample. Therefore, the numbers of the insects were 3 at the end of the experiment.

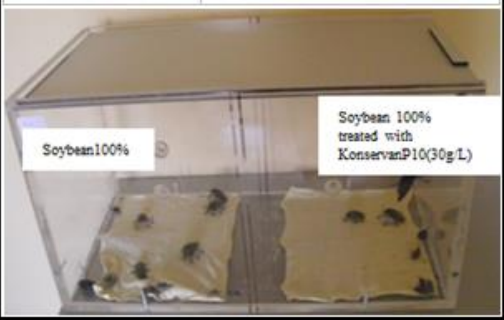
Sample	Soybean100%
Konservan P10	30g/L

Time	Number of the insects on the treated fabric
17:38	10



Time	Number of the insects on the treated fabric
17:48	5

Time	Number of the insects on the treated fabric
17:58	6



Time	Number of the insects on the treated fabric
18:08	3

Figure 4. 15 Movements of the insects between treated soybean (30g/L) and control sample within 30 minutes

According to this experimental data, an insect repellency graph can be drawn as in Figure 4.16. In regards to this graph soybean sample treated with 30g/L Konservan P10 passed the test successfully with a value of 70%.

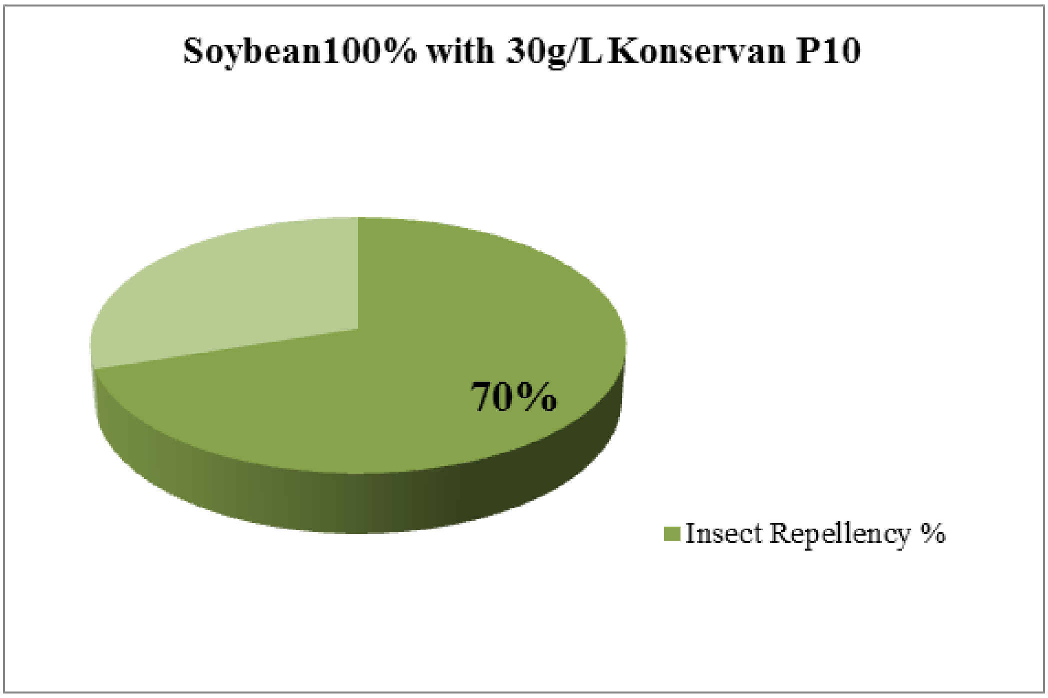


Figure 4. 16 Insect repellency percent of soybean with 30g/L Konservan P10

4.4 Calculations of Insect Repellency Values and Comparisons

4.4.1 Calculations of Insect Repellency Values

Four kinds of samples (cotton100%, organic cotton100%, bamboo100% and soybean100%) were exposed to insect repellency test separately and insect repellency percent was calculated as follows.

$$\frac{\begin{bmatrix}\text{Number of Insects on the Treated Sample} \\ \text{When Test Started (initial)}\end{bmatrix} - \begin{bmatrix}\text{Number of Insects on the Treated Sample} \\ \text{When Test Finished(after 30 min)}\end{bmatrix}}{\begin{bmatrix}\text{Number of Insects on the Treated Sample} \\ \text{When Test Started (initial)}\end{bmatrix}} X100$$

4.4.2 Insect Repellency Comparison of Samples with respect to 10g/L Concentration

Figure 4.17 indicates the comparison of insect repellency values of the samples. According to the test results it is obvious that the insect repellency is not satisfactory with 10g/L concentration of the insect repellent chemical. Nevertheless, among these 4 fibers, insect repellency values from high to low can be listed as follows:

1. Organic Cotton 100%
2. Cotton 100% = Bamboo100%
3. Soybean100%

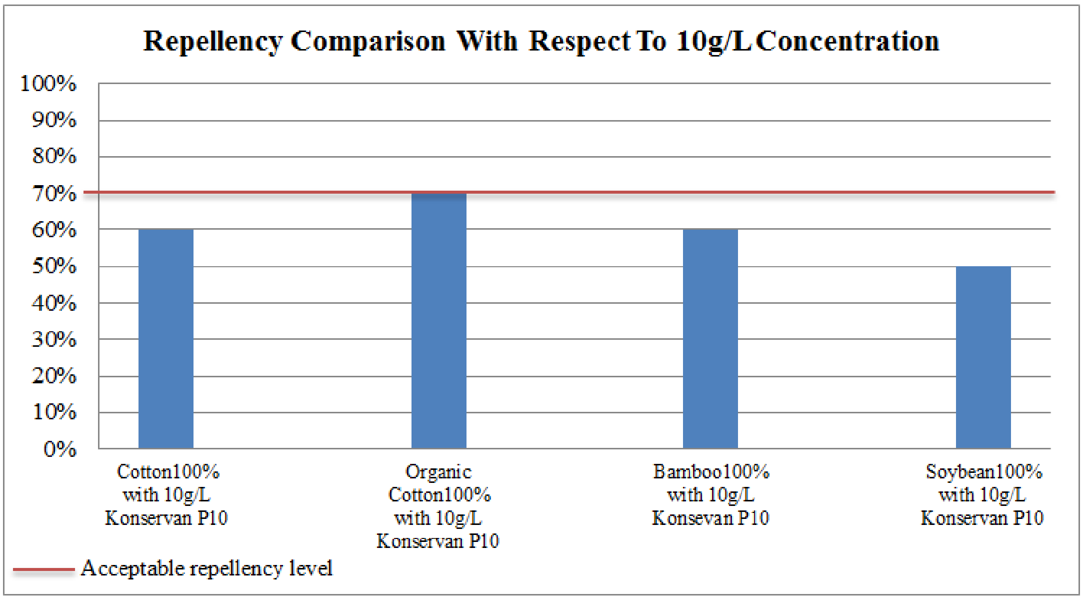


Figure 4. 17 Repellency comparison with respect to 10g/L concentration

4.4.3 Insect Repellency Comparison of Samples With Respect to 30g/L Concentration

Figure 4.18 shows the comparison of insect repellency values of the samples with 30g/L concentration. With this concentration high to low insect repellency character of these fibers with 30g/L concentration can be listed as follows.

1. Cotton 100%
2. Organic Cotton 100%
3. Bamboo100%=Soybean100%

This study shows that rising of chemical concentration directly affects the insect repellency character of the fibers. Successful results for all the samples were obtained at 30g/L concentration.

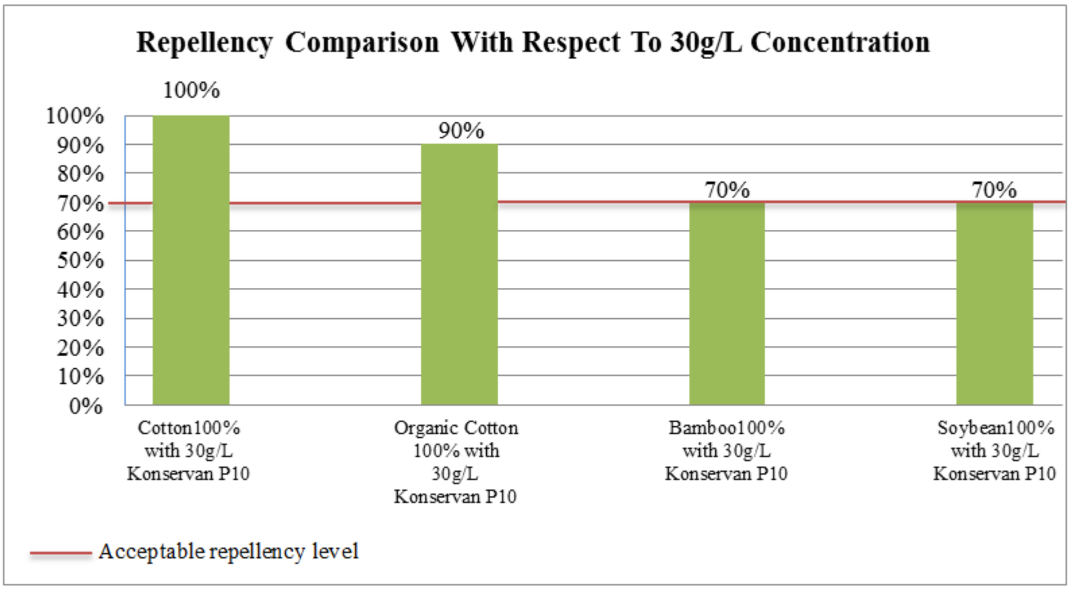


Figure 4. 18 Repellency comparison with respect to 30g/L concentration

In this study it is clarified that there is a relation between fiber type and insect repellency character. Konservan P10 is more suitable to be used with cotton and organic cotton fibers than soybean and bamboo fibers in order to manufacture insect repellent fabrics. Soybean and bamboo fibers are moderate fibers to be applied insect repellency features. For these fibers with higher concentration of Konservan P10 better results might be obtained.

4.4.4 Insect Repellency Comparisons with Respect to Chemical Concentration

According to the graph in Figure 4.19, it is clear that cotton sample provides an excellent insect repellency with 30g/L application of KonservanP10. It is also obvious that 10g/L chemical concentration is not enough to provide sufficient insect repellency value for cotton.

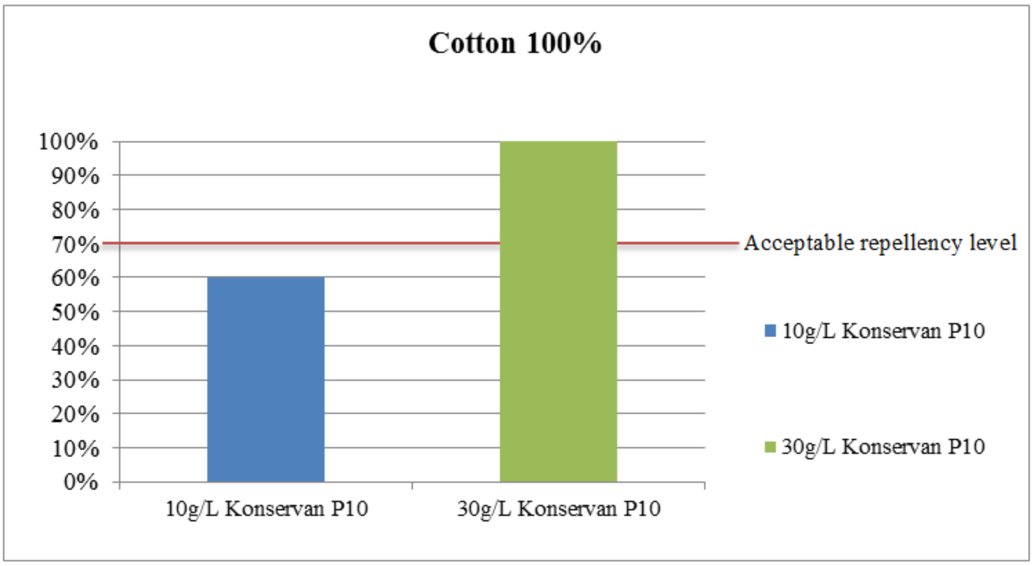


Figure 4. 19 Insect repellency values of cotton with different concentrations

In regards to Figure 4.20, it is clear that organic cotton passed the insect repellency test with both 10g/L and 30g/L concentrations. According to this graph, organic cotton is one of the suitable fibers to be used for manufacturing of insect repellent textiles.

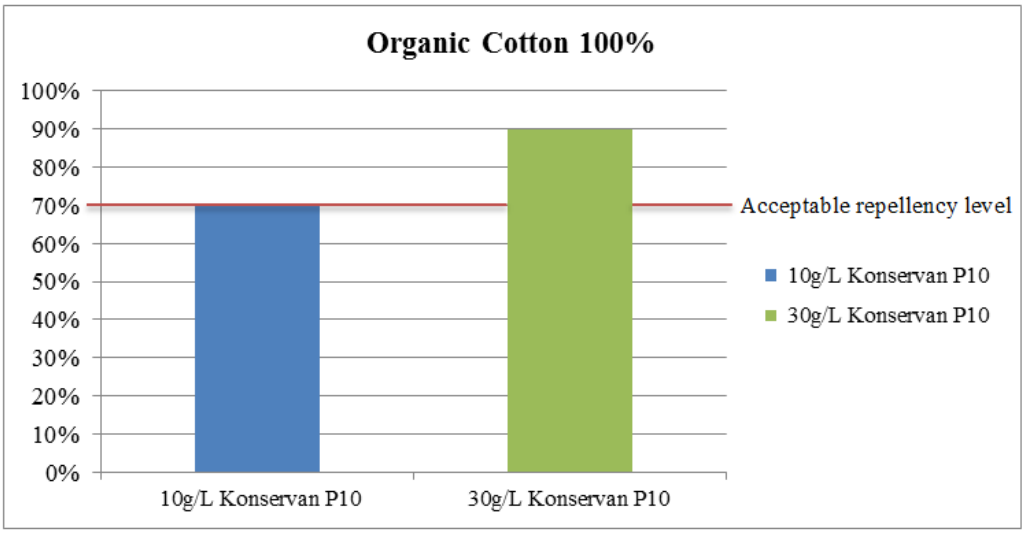


Figure 4. 20 Insect repellency values of organic cotton with different concentrations

Figure 4.21 Indicates comparison of insect repellency feature of bamboo sample with different concentrations. According to the graph, it can be said that bamboo sample provides moderate insect repellency character with 30g/L concentration. Although it passed the test with 30g/L application of KonservanP10, it is not a good repellent fiber as cotton and organic cotton.

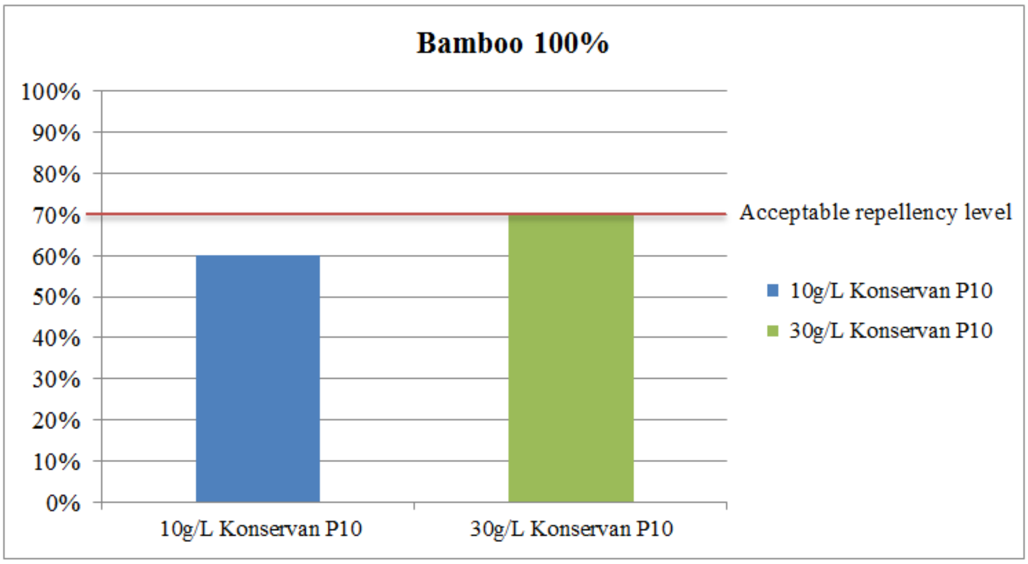


Figure 4. 21 Insect repellency values of bamboo with different concentrations

As in Figure 4.22, soybean sample provides an acceptable repellency value with 30g/L application of Konservan P10. It is clear from the graph that soybean only reached the critical acceptance value with high concentration. Under the light of this information, it is obvious that soybean shows insect repellency feature less than that of cotton and organic cotton.

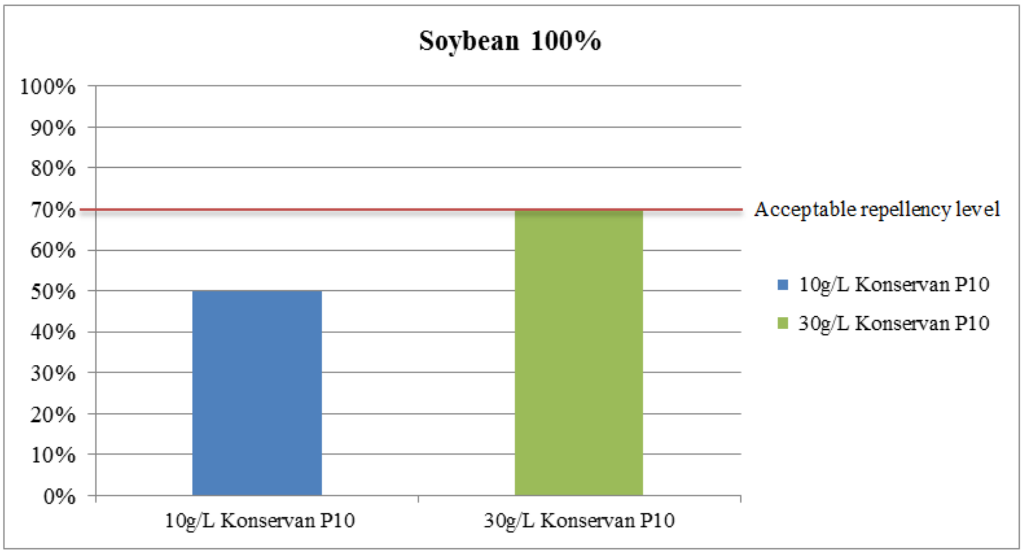


Figure 4. 22 Insect repellency values of soybean with different concentrations

4.5 Antimicrobial Test Results

Antimicrobial test were conducted on the fabrics having 30g/L chemical concentration according to ASTM E2149-01 Antimicrobial Test Method and the results were obtained as Table 4.1.

Table 4. 1 Antimicrobial activity values according to ASTM E2149-01 antimicrobial test method using E. coli (ATCC 35218)[a]

Samples	Results of Antimicrobial Activity After 24 Hours	
	%	log
Sample Without Chemical Treatment	-32,89	-0,12
Bamboo 30/1 (-)	-86,05	-0,27
Bamboo 30/1 (+) 30 g/l	-63,46	-,021
Organic Cotton 30/1 (-)	-112,62	-0,33
Organic Cotton 30/1 (+) 30 g/l	-15,61	-0,06
Cotton 30/1 g/l (-)	-72,76	-0,24
Cotton 30/1 (+) 30 g/l	-32,89	-0,12
Soybean 32/1 (-)	-99,34	-0,30
Soybean 32/1 (+) 30 g/l	-70,10	-0,23

[a] bacteria concentration was calculated as $92x10^8$(log8,28)cfu* for 1 gram of each sample

Note: (+) values % bacteria values, shows increase number of bacteria

(-) values % bacteria values shows reduce the number of bacteria. Value of 100% indicates that all the bacteria on the surface were died.

* cfu : colony forming units

According to the test results, there was no an acceptable antimicrobial activity for all of the samples which were subjected to the antimicrobial test.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Insect repellent fabrics gained importance due to widespread insect borne diseases. To increase manufacturing amounts of insect repellent cloths and make them widespread will be an important step to battle against insect borne diseases.

In this experimental work, insect repellency values of cotton, organic cotton, bamboo and soybean knitted fabric samples were tested by visual observation method as described in chapter 4. 70% of repellency was accepted as satisfactory repellency level and the results were compered. General comparison graph (Figure 5.1) indicates the repellency values of all the samples with applications of insect repellent chemical in two different concentrations.

General comparison of insect repellency values for all the tested samples were indicated in the Figure 5.1

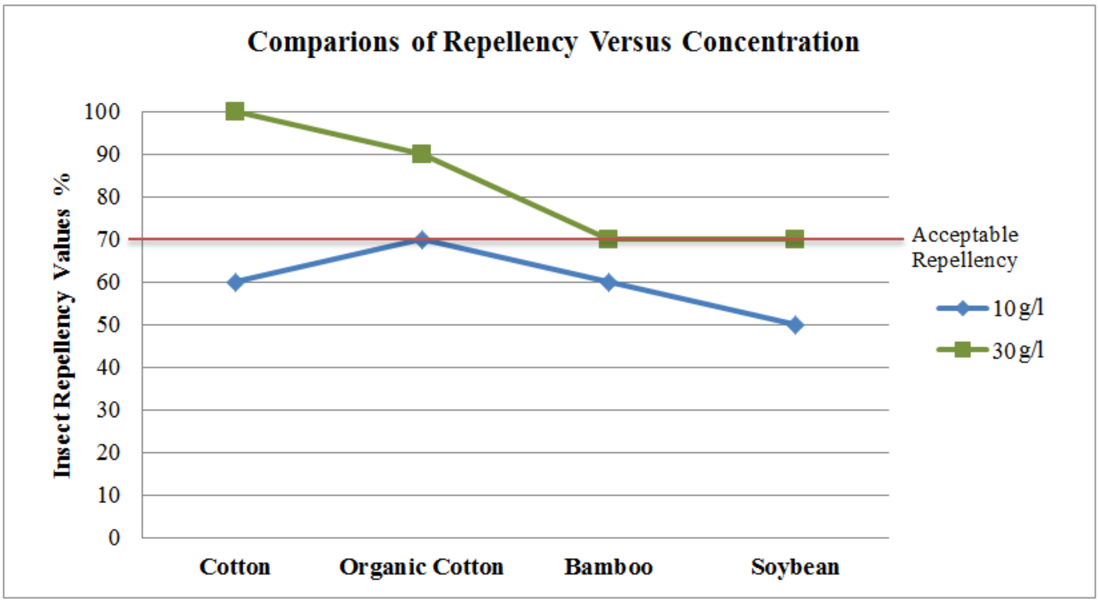


Figure 5. 1 Repellency comparisons of 4 kinds of samples with respect to 10g/l and 30g/l KonservanP10 concentrations

As a sum of all the results according to the graph, followings can be said.

Insect repellency values with 10g/l concentration, the best repellency value was obtained from organic cotton with a percent of 70% repellency. It can be said that the other samples with this concentration do not provide enough repellency and the repellency values are below of the acceptable repellency level.

When looking at the results with 30g/L chemical concentration, it is clear that an acceptable repellency value was obtained for all the samples. Cotton shows the best repellency value at 30g/L concentration and organic cotton is also provides pretty good repellency with a value of 90%. Insect repellency values of bamboo and soybean samples are same and moderate with a value of 70% at this concentration. Under the light of these evaluations, it is clear that 30g/l is a satisfactory concentration to provide repellency for all the samples.

The chemical structure of permethrin clearly indicated the existence of chlorine leaving group and carbonyl group. It is concluded that these two functional groups would make permethrin show higher affinity to cellulose via primary and secondary alcohol within the polymer structure than that of protein polymer.

This study also proves that insect repellent fabrics with application of Konservan P10, do not provide antimicrobial effect. Thus, it can be said Konservan P10 can only be used to gain the fabrics insect repellency effect not for antimicrobial effect.

Considering overall findings and graphical results; it is seen that organic cotton is the most suitable type to gain insect repellency feature. Since only organic cotton provides satisfactory repellency values at both 10g/l and 30g/l concentrations among all the samples. As a consequence, if it is aimed to manufacture an insect repellent knitted garment with application of KonservanP10, organic cotton should be preferred among these four kinds of fabrics.

It can also be inferred from the test results that Konservan P10 provides different repellency feature depending on kinds of fibers. Because it was found out that at the same chemical concentrations each sample types shows different repellency values.

The results of this study should not be considered as accurate and final results in terms of comparing the insect repellency performance of the fibers. Since, the study was carried out with limited number of insects and replacements of one insect from treated sample to untreated sample affected the percentage considerably (10%). That's why conducting similar test with lots of insects simultaneously might provide more precise results.

This study is an encouragement for further studies because in both concentrations of insect repellent chemical the fiber tendencies are the same.

5.2 Recommendations for Further Studying

The experimental work presented here was carried out with limited number of insects. The reason behind this limitation is that it was difficult to find the same insect species and keep them alive for a long time to carry out experiment properly.

Further study on this subject might be structured as follows.

a) The presented study may be further developed conducting the repellency test with woven fabrics and knitted fabrics separately to determine if there is a relationship between surface structure and repellency.
b) Conducting similar experiment with various concentrations to find critical concentration value to obtain desired repellency value.
c) A similar study can be done with more insects in order to calculate insect repellency values more precisely.
d) Similar study can be done on the other samples with different kinds of fibers such as polyester, wool, and acrylic, viscose. Therefore, the best suitable fiber for an insect repellent cloth can be discovered comparing the results.

REFERENCES

[1] Tanveer M., Krishna G. and Anmol K. (2015). Mosquito repellent textiles: An overview. Available at: http://www.fibre2fashion.com/industry-article/4/317/mosquito-repellent-textiles1.asp, [Accessed at: 06.01.2015].

[2] Lawrence H.S. (1998). Cotton's Importance in the Textile Industry. Symposium, Lima, Peru.

[3] Raghavendra R.H., Atul D., Kamath M.G. (2004). Available at: http://www.engr.utk.edu/mse/pages/Textiles/Cotton%20fibers.htm, [Accessed at: 06.05.2014].

[4] NPTEL. (2015). Available at: http://www.nptel.ac.in/courses/116102026/6, [Accessed at: 11.08.2015].

[5] Menzes E. (2015). Organic Cotton Processing Source: New Cloth Market. Available at: http://www.fibre2fashion.com/industry-article/12/1125/organic-cotton-processing7.asp, [Accessed at: 06.02.2015].

[6] Karthikeyan M.R. (2013). Organic Cotton Knitted Fabric vs. Regular Cotton Knitted Fabric. Available at: http://www.fibre2fashion.com/industry-article/46/4528/organic-cotton-knitted-fabric1.asp, [Accessed at: 10.03.2015].

[7] Cotton Briefings. (2011). Available at: http://farmhub.textileexchange.org/upload/learning%20zone/Cotton%20Briefings%20separate/Organic%20Cotton_An%20Introduction.pdf, [Accessed at: 10.04.2013].

[8] Fibre2fashion. (2014). Available at: http://www.fibre2fashion.com/industry-article/textile-industry-articles/properties-of-bamboo-fibre/properties-of-bamboo-fibre1.asp, [Accessed at: 7.06.2014].

[9] Textile Store. (2015). Available at: http://textilestore.blogspot.com.tr/2014/02/a-brief-review-on-bamboo-fiber.html, [Accessed at: 20.08.2015].

[10] Zhang X., Min B. and Kumar S. (2003). Solution Spinning and Characterization of Poly(vinyl alcohol)/Soybean Protein Blend Fibers, *Journal of Applied Polymer Science* **90**, 716.

[11] Swicofil. (2014). Available at: http://www.swicofil.com/soybeanproteinfiberproperties.html, [Accessed at: 02.04.2014].

[12] Reek A. (2008). Wipe materials comprising regenerated plant-protein fibres, PCT/US2009/059406 WIPO.

[13] Fletcher H.A. (1942). Synthetic Fibers and Textiles, *Kansas Bulletin* **300**, 8-10.

[14] Globalspecs. (2015). Available at: http://www.globalspec.com/reference/22398/203279/chapter-9-thermal-and-mechanical-properties-of-soy-proteins, [Accessed at: 20.08.2015].

[15] Kranthia K.E., Jadhav D.R., Kranthi S., Wanjari R.R., Ali S.S., Russell D.A. (2002). Insecticide resistance in five major insect pests of cotton in India. *Crop Protection* **21**, 449–460.

[16] Chio E.H., Yang E.C. (2008). A bioassay for natural insect repellents. *Journal of Asia-Pacific Entomology* **11,** 225–227.

[17] Specos M.M., Garcia J.J., Tornesello J., Marino P., Vecchia M.D., Tesoriero D., Hermida L.G. (2010). Microencapsulated citronella oil for mosquito repellent finishing of cotton textiles. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **104,** 653–658.

[18] Hebeish A., Fouda M.G., Hamdy I.A., El-Sawy S.M., Abdel-Mohdy F.A. (2008). Preparation of durable insect repellent cotton fabric: Limonene as insecticide. *Carbohydrate Polymers* **74**, 268–273.

[19] Wikipedia. (2013). Available at: https://en.wikipedia.org/wiki/Insect_repellent, [Accessed at: 03.05.2013].

[20] Rodie B.J. (2015). Keeping the Insects at Bay. Available at: http://www.textileworld.com/Articles/2008/June/Quality_Fabric_Of_The_Month/Keeping_The_Insects_At_Bay, [Accessed at: 14.03.2015].

[21] NPIC. (2014). Available at: http://npic.orst.edu/factsheets/PermGen.html#howwork, [Accessed at: 18.05.2014].

[22] Toynton K., Luukinen B., Buhl K., Stone D. (2009). Permethrin Technical Fact Sheet. Available at: http://npic.orst.edu/factsheets/Permtech.pdf, [Accessed at: 03.06.2013].