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POTENTIAL OF CITRONELLA OIL AS NATURAL MOSQUITO REPELLENT AGENT IN FORMULATED FABRIC SOFTENER FINISHES

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ABSTRACT

This study is focused on formulating a natural-based fabric softener using baking soda and vinegar with the addition of insect repellent finish of citronella oil and vanillin. The effectiveness of the fabric softener was evaluated by conducting a fabric stiffness test on both untreated and treated fabric samples with the softener formulated in this study. The assessment for the efficacy of insect repellence was carried out using 3 human participants of the same gender and build but different blood type, positioned at a mosquito infested area. Three tests; negative, positive, and normal tests were conducted to evaluate the effectiveness of the formulated mosquito repellent finishes in the fabric softener. The results show that the formulated fabric softener is good mosquito repellent and it is good at giving a soft effect on the treated fabric.

Keywords: Fabric softener, Insect repellent, Citronella oil, Vinegar, Baking soda

ABSTRAK

Kajian ini memberi tumpuan kepada penghasilan pelembut kain berasaskan bahan semula jadi menggunakan serbuk penaik dan cuka dengan penambahan penghalau serangga, minyak citronella dan vanillin. Keberkesanan pelembut kain telah dinilai dengan melakukan uji kekakuan kain pada kedua-dua sampel kain yang tidak dirawat dan dirawat dengan pelembut yang dirumuskan dalam kajian ini. Penilaian ke atas keberkesanan penghalau serangga telah dijalankan di kawasan di mana terdapat habitat nyamuk, menggunnakan 3 lelaki, setara ketinggian dan berat namun berbeza jenis darah. Tiga ujian telah dijalankan iaitu ujian negatif, positif, dan normal untuk menilai keberkesanan pelembut kain yang dirumuskan. Hasilnya menunjukkan bahawa pelembut kain yang dirumuskan adalah baik untuk menangkis, dan juga memberikan kesan lembut terhadap kain yang dirawat.

Kata kunci: Pelembut kain, Penghalau serangga, Minyak citronella, cuka, serbuk penaik

1. Introduction

Fabric softeners are cleaning additives used in care procedure of textile products. They are used to improve the fabric handle by minimizing the static charges and stiffness of fabric and to give fabrics a fragrance (Kadolph *et al*. 2016). According to the U.S. Environmental Protection Agency (EPA) and industry-generated Material Safety Data Sheets (MSDS), too much exposure to petrochemicals found in fabric softeners, such as chloroform, phthalates and camphor can cause health problems like asthma, hormone disruption, heart disease and cancer (Robbins 2010). Moreover, the disposal of effluent chemicals from commercial fabric

softeners can pollute the environment. Therefore, an alternative, natural homemade fabric softeners which use natural products such as vinegar, baking soda and Epsom salt have been introduced.

Another chemical based products used in the prevention of insect-borne diseases, are insect repellents. The usual types of insect repellent come in the form of sprays, lotions, and stickers and they are applicable on skin, clothing or other exposed surfaces. However, chemical based insect repellents contain DEET (*N,N*-diethyl-*m*-methylbenzamide), which can be harmful to the users (Tseghai 2011).

Mosquito repellent essential oils are produced as an alternative to DEET (*N,N*-diethyl-*m*-methylbenzamide) but the chemical reactions of these essential oils can cause toxic reactions and damage synthetic fabric (Geethadevi & Maheshwari 2015). Studies on citronella leaf extract as mosquito repellent have found that the extract does not only have citrus scent but it is natural and environmental-friendly compared to DEET (Nandini *et al*. 2013). Today, the use of natural essential oils in the production of mosquito repellents is also used on textile substrates for its insect-repellent properties and distinctive smell.

There are several methods that can be used to evaluate the efficacy of mosquito repellents, such as the cage test, cone test, excito-repellency chamber and field test. It is a standardized test method used by the World Health Organization (WHO) 1996, and the American Society for Testing Materials (ASTM) Standards 2006 (Aufa & Nurain 2016). According field test method approved by WHO, the test is performed using human subjects in the vicinity of human domiciles. The field test method resembles a real-life situation than performing a test on mosquito repellent in a laboratory (Barnard *et al*. 2007).

Thus, this study emphasizes the formulation of an insect repellent finish embedded into a natural-based fabric softener such as vinegar which is a biodegradable substance. This will minimize the chemical waste from laundry effluent leaking directly into the environment. Vinegar is used to reduce the electrostatic charge in fabric because it provides hydrogen ions with the chain of anionic groups. In addition, vinegar is also receptive to sensitive skin (Zabawski 2010).

The test is conduced due to reports that insect-borne diseases have caused millions of deaths every year. In Malaysia, there were 96,300 cases of dengue as of 16th of September 2019, compared with 53,800 cases for the same period in 2018. In terms of death cases, 143 deaths have been reported from 1st January to 21st September 2019. Specifically, in Negeri Sembilan, a total of 1,799 cases of dengue fever had been recorded as of 30th September 2019 (iDengue untuk komuniti 2019).

2. Materials and Methods

This study is conducted at UiTM Negeri Sembilan, Kuala Pilah campus, specifically near Sri Pilah 4 residential college which has been identified as mosquito habitat. Three UiTM Kuala Pilah students are used as human volunteers to assess the suitability of the repellent.

All tests follows a standard procedure as shown in Table 1.

Table 1. Standard Methods

Standard Method	Type of Test
American Society for Testing of Materials (ASTM) D3776	Fabric weight test
American Society for Testing of Materials (ASTM) D1388	Fabric stiffness test
World Health Organization (WHO) Field Method	Field test

2.1. *Test participants selection*

Table 2 shows the variables of the selected participants for the field test. Each participant has a different blood type in line with a study by The United States National Institutes of Health (NIH) that found mosquitoes prefer a certain human blood type, besides other several factors, such as temperature and colour that attract mosquitoes (Shirai *et al.* 2004).

Table 2. Content variables

Participant	A	B	C
Weight	61.0 kg	66.2 kg	52.3 kg
Blood type	B +	O	AB
Gender	Male	Male	Male

2.2. *Materials*

100% cotton fabric is applied with the softener produced for testing purpose. The description for each sample is shown in Table 3.

Table 3. Samples description

Samples	Description
Insect repellent (IR) formulated sample	Fabric softener with insect repellence – 125 g of baking soda – 500 ml of distilled water – 125 ml of vinegar – 2.5 ml of citronella essential oil – 1 g of vanillin powder – 10 ml of ethanol solution
Normal samples	Fabric softener without insect repellence
Control samples	1. Commercial fabric softener (Downy Expert Sports Concentrated Fabric Softener) 2. Commercial insect repellent spray (Amber Shield Dengue Defender Insect Repellent)

2.3. *Data collection*

2.3.1. *Fabric stiffness test*

The effectiveness of the fabric softener is tested by conducting a stiffness test (ASTM D1388) on the fabric samples before and after treatment with the softener for comparison. The equipment used for this test is Bending Stiffness Tester. Three course and three wale directions are cut from the fabric samples following the size of the template of the Bending Stiffness Tester.

Four readings of bending length are taken from each surface. Thus, the number of reading for one edge is 8. The total number of readings taken for each sample is 16. The bending length is the total average of stiffness for the wales and courses for each fabric sample. The flexural rigidity of the fabric is obtained by using formula (1) as follows: -

$$G = 0.10W^1C^3\ mg.cm$$

Where,
G = flexural rigidity
C = bending length
W^1 = weight of fabric in g/m^2 (1)

2.3.2. *Field test*

According to the World Health Organization (WHO) (WHO 1996), and American Society for Testing Materials (ASTM) (Standards 2006), the efficacy of the insect repellence can be evaluated by conducting a human assessment from a field test. The assessment of repellence in this study is based on physical observations of mosquitoes counts that encounter with the treated fabric sample, specifically on the marked area on the reversed side of the sample as shown in Figure 1.

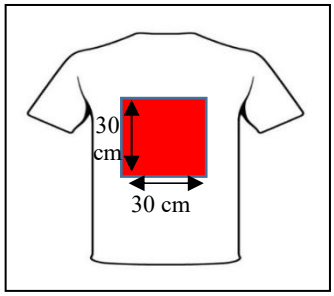

Figure 1. The area on fabric sample for evaluation during field test

The three participants selected for the field test evaluation is based on their body command of height and weight, but different blood types. The time range for this test was 5 p.m. to 7 p.m. The duration for each field test was 20 minutes with the interval of observation period every 5 minutes. Each subject was asked to sit 10 meters apart from each other as shown in Figure 2.

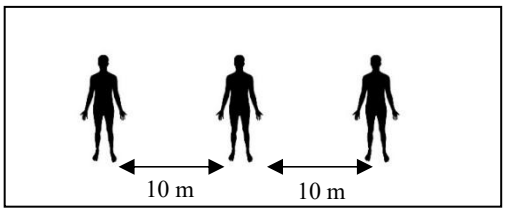

Figure 2. The distance between the test participants.

Table 4: Description of samples for field test.

Tests	Samples	Conditions
Negative test	Using Normal Sample	
Positive test	Using Control Sample	
Normal test	Using IR Formulated Sample	1. Sweaty 2. No sweat

(1) Negative test
The test participants were given a Normal sample T-shirt testing evaluation. The washing method of the sample used was 1:5 ratio of softener to water.

(2) Positive test
This test was conducted as the control sample. Dengue Defender Mosquito Repellent spray which is a commercial insect repellent was used to compare the effectiveness of the IR formulated sample. Its effectiveness was evaluated during the field test.

(3) Normal test
The fabric samples were washed using the IR formulated sample using 1:5 ratio of water to softener solution. The efficacy of the IR properties of the solution was evaluated in two conditions (sweaty and no-sweat). The two conditions were tested as a comparison because mosquitoes are attracted to body odour and heat (Breugel *et al.* 2015). Skin-microfluora on human skin produces various chemical and odour. There are certain types of bacteria that can break down triglycerides on skin to form short and long chain fatty acids that signal mosquitoes (Keswani & Bellare 2006).

3. Results and Discussion

3.1. *Fabric stiffness test*

The stiffness characteristics of the fabric samples are evaluated through fabric stiffness test. Table 5 below shows the results of bending length and flexural rigidity of each wales and courses for the fabric samples.

Table 5. Fabric stiffness results

Fabric sample	Normal sample	IR formulated sample	Control sample
Bending length of wales (cm)	1.06	0.99	0.90
Bending length of course (cm)	0.99	0.98	0.85

Flexural rigidity of wales (mg.cm)	20.6	18.05	14.00
Flexural rigidity of course (mg.cm)	16.78	16.03	11.79

Based on Table 5, the bending length and flexural rigidity for the fabric sample which have been treated with the control sample shows the least values among other samples. Thus, the commercial fabric softener proved to be excellent in softening fabric. Furthermore, the results for the fabric treated with the IR formulated sample are found to be higher than the fabric treated with the controlled sample. However, the values are lower compared to the results for normal sample fabric. This shows that IR formulated fabric softener could improve the bending and flexibility of fabric.

3.2. *Field Test*

The field test was conducted to assess on the negative, positive, and normal test with different treatments of fabric samples for each test. The three tests were conducted at the designated mosquito habitat area in a single day between 5 p.m. to 7 p.m.

3.2.1. *Negative test*

The negative test was conducted using the fabric sample treated with normal test sample without insect repellent finishes, with the participants in no-sweat condition. The field test result is shown in Table 6.

Table 6. The number of mosquitoes encountered with the fabric samples for negative test

	Participants		
Time (mins)	**A**	**B**	**C**
01-05	10	6	12
06-10	8	2	3
11-15	1	1	2
16-20	2	1	3
Total	**21**	**10**	**20**

In the first 5 minutes, the number of mosquitoes landed on Participant C is 12 which is higher than Participant A with 10 mosquitoes, and Participant B with 6 mosquitoes. However, the number then drastically fell to 3 for Participant C, and Participant A attracted more mosquitoes than Participant B and C in the second 5 minutes intervals. Meanwhile, during the last 10 minutes intervals of the test, the number of mosquitoes encountered with the fabric samples for all three participants are lower in numbers compared to the numbers in the first 10 minutes intervals of the test.

Generally, the total number of mosquitoes which landed on Participant A is more than the mosquitoes on Participants B and C. Nevertheless, Participant A and Participant C had about the same number of mosquitoes with Participant A having 21 mosquitoes while Participant C having 20 mosquitoes: a difference of one mosquito.

3.2.2. *Positive test*

Table 7 shows the results for the positive test. As shown in the table, the first 5 minutes intervals showed no mosquito encounters, but for the second 5 minutes intervals, the presence

of mosquitoes were detected on participant B with 3 mosquitoes, and Participant C 1 mosquito. The number of mosquitoes is constant by one during the third 5 minutes and there were no mosquitoes landing on the participants at 16 to 20 minutes for all participants.

The insect repellent test for positive sample shows the most effective compared to the normal test because it used a commercial product that contains Thiamine-Vanillin, which acts as an insect repellent. Thiamine alters blood chemistry and human smell, making users less attractive to mosquitoes, besides vanilla being proven as good mosquito repellent (Rodriguez *et al.* 2015). The control sample also contains chemicals, such as methylparaben which is an antimicrobial substance and gives longevity effects to the insect repellent (Benedict *et al.* 2009).

Table 7. The number of mosquitoes encountered with the fabric samples for positive test

	Participants		
Time (mins)	**A**	**B**	**C**
01-05	0	0	0
06-10	0	3	1
11-15	1	1	1
16-20	0	0	0
Total	**1**	**4**	**2**

3.2.3. *Normal test*

The results for normal test are shown in Table 8 below. This test was conducted to evaluate the efficacy of insect repellent finishes contained in the IR formulated sample, which are citronella oil and vanillin.

Table 8. The number of mosquitoes encountered with the fabric samples for normal test

	Participants					
	No-Sweat			**Sweaty**		
Time (mins)	**A**	**B**	**C**	**A**	**B**	**C**
01-05	3	2	0	4	3	5
06-10	1	3	2	4	0	5
11-15	0	1	3	2	1	1
16-20	1	1	2	0	6	1
Total	**5**	**7**	**7**	**10**	**10**	**12**

For no-sweat condition, the results show consistency in the number of mosquitoes encountered with the fabric samples for all the participants during the test. The total number of mosquitoes landed on the fabric sample worn by Participant A is 5, which is lower than Participant B and C who had 7 mosquitoes each.

For sweaty condition, there was an increase in the number of mosquitoes encountered with the fabric samples for all participant compared to the no-sweat condition. The number rose to 10 for Participant A and B, whereas Participant C the number of mosquitoes increased to 12. This might be due to several factors, but research has found that mosquitoes are highly

attracted to carbon dioxide (CO_2) produced from breathing, body odour, heat, moisture, and visual cues (Joshua *et al*. 2019).

Research also indicates that the use of vanillin as a fixative for mosquito repellent volatile oils could improve the repellent effects (Songkro *et al*. 2012). Thus, the addition of vanillin in the sample of this study aids the volatility of citronella oil and enhances the repellent effect.

3.2.4. *Field test results of each participant*

The field test of negative, positive and normal test are compared in the condition of no-sweat. Based on Figure 3, the bar chart illustrates the number of mosquitoes encountered with the fabric samples worn by Participant A.

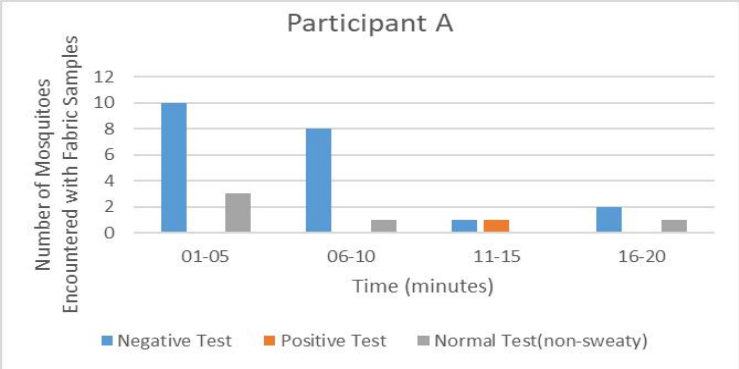

Figure 3. Graph of field test for Participant A

It can be seen from the graph that the number of mosquitoes encountered for the negative test has the highest value during the first 5 minutes with 10 mosquitoes. The numbers then fell slightly to 8 mosquitoes and it started to decrease drastically after 10 minutes. There was only 1 mosquito in the 11 to 15 minutes interval, and 2 mosquitoes in the final 5 minutes of the test. As for the positive test, there was only 1 mosquito during 11 to 15 minutes interval of the test and there was no mosquito encounters in the other times. Meanwhile, the number of mosquitoes during the normal test decreased from the first 5 minutes to 15 minutes of the test. During the last 5 minutes of the test, only 1 mosquito was encountered with the fabric sample.

Figure 4 below shows a bar chart of all field tests for Participant B. Based on the graph; it it can be seen that the number of mosquitoes encountered in negative test decreased during the first 10 minutes of the test from 6 to 2 mosquitoes. In contrast, the number of mosquitoes extended to 3 for positive test and normal test, from 0 and 2 mosquitoes respectively.

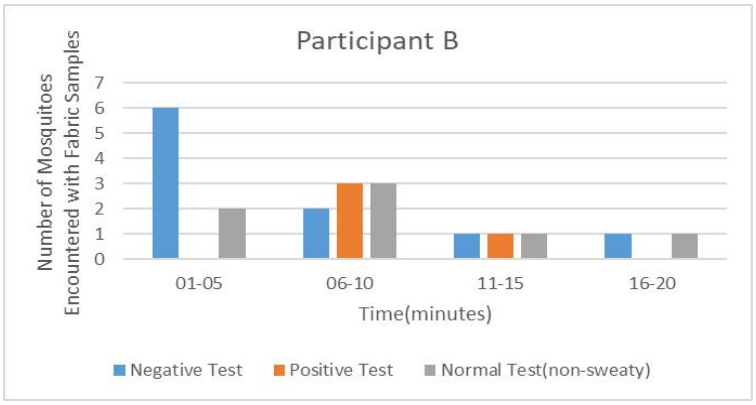

Figure 4. Graph of field test for Participant B

Though, the time the test conducted was different for each test, it was held within the range of 5 p.m. to 7 p.m. in a single day. Moreover, the area where participant B sat was more spacious with fewer bushes compared to participant A and C. According to a research, mosquitoes tend to rest on tall grass and herbage (Service 2012). Thus, this could be the factor for the difference in the results obtained during 6 to 10 minutes of the test, where the number of mosquitoes was higher for the positive and normal test, compared to the negative test. The number of mosquitoes then decreased for all three tests in the last 10 minutes of the study whereby the study recorded only 1 mosquito for the last 5 minutes interval, except for the positive test where there was no record of mosquitoes during the 16 to 20 minutes of the test.

As seen in the graph, Participant B has a rather constant higher number of mosquito encounters in each test compared to Participant A and C. With regards to the Participant B's blood type, which is type O, research indicates that blood type O attracts more mosquitoes compared to other blood types (Shirai *et al*. 2004).

The bar chart of Figure 5 below shows the results for the field test conducted on Participant C. As seen in the illustration, no mosquito landed on the fabric samples for positive test and normal test in the first 5 minutes, compared to negative test, which has 12 landings of mosquitoes. The number for negative test decreased to 3 in the 6 to 10 minutes and has approximately constant values for the rest of the second 5 minutes interval.

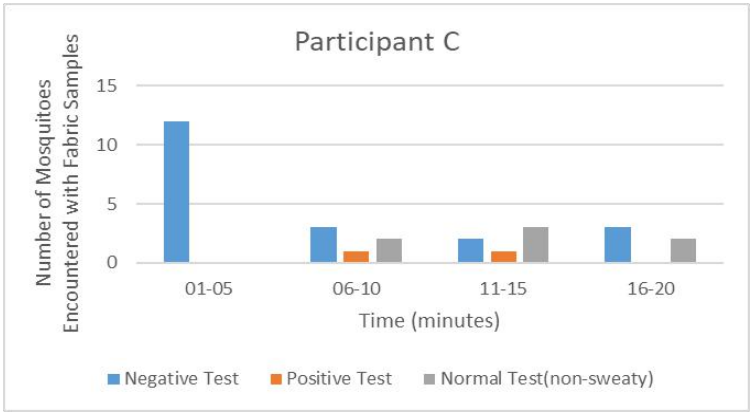

Figure 5. Graph of field test for Participant C

As for the positive test and normal test, there is a slight difference in the number of mosquitoes encountered by the fabric samples. The number of mosquitoes for both tests rose after the first 5 minutes, then decreased in the 16 to 20 minutes. It is clear from the chart that the positive test and normal test results show a comparable number of mosquitoes landed on the fabric samples.

Overall, it can be seen from the results that the negative test for all three participants have the highest number of mosquitoes compared to other tests. This is due to the absence of citronella oil in the softener solution used to treat the fabric sample for the negative test. As for the results for normal test, the number of mosquitoes is consistency and is comparable with the results obtained for the positive test.

4. Conclusion

The formulated fabric softener with insect repellent finishes not only served as good softening fabric but also as good mosquito repellent. Based on the results, this study found that the use of vinegar and baking soda can improve the flexibility and softness of fabric. As for the insect repellent finishes, citronella oil and vanillin can be an effective repellent. Thus, the fabric softener with insect repellent finishes formulated in this study is capable to be an alternative to commercialized chemical-based fabric softener and insect repellent products with the use of minimal amount of chemicals.

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