A Comparative Study on the Cost-Effectiveness of a Homemade Mixture and Ultraviolet Light in Luring Mosquitoes

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Abstract *–A comparative study between two different stationary mosquito attractants, particularly between a homemade mixture and an ultraviolet (UV) light, was conducted. Other existing attractants and subjects were not considered in this study. The purpose of this study is to prove the cost-effectiveness of the homemade mixture as compared to the UV light, where results may be used in depressed areas in order to help reduce the population of mosquitoes, thus, reducing as well the probability of people, particularly children, being infected with mosquito-borne diseases. The effectiveness of both products along with other factors such as cost, environmental impact and life span were evaluated in this study through cost-benefit analysis and experimentation, where both attractants were exposed to a population of Aedesaegypti mosquitoes which resulted to statistical data analyzed through the use of t-test analysis. The researchers obtained a p-value of 0.0005 which is less than the value of the significance level (α) at 0.05, indicating that the homemade mixture is more effective. In terms of cost-efficiency, the total benefit-cost difference of the homemade mixture and UV light computed were ₱ 1388.29 and ₱ 920.24, respectively. This proved that the homemade mixture is more effective, thus, better than the UV light.*

Keywords *–dengue, Aedesaegypti, homemade mixture, carbon dioxide, and ultraviolet light*

INTRODUCTION

Mosquitoes are capable of transmitting serious diseases such as malaria, yellow fever and dengue reported as significant causes of hospitalization and death among children. According to American Mosquito Control Association [1], more than one million people worldwide die every year from diseases caused by mosquitoes. Moreover, the Philippines' geographical location and tropical climate aggravates mosquito infestation in the country as mosquitoes thrive in warm, humid environments with high-variable rainfall. As a result, different mosquito-borne diseases are extremely widespread. Among these, it was found that dengue is the most prevalent vector-borne disease present in the country.

For the past 20 years, dengue fever is considered as a major public health problem in the Philippines with cases continuously increasing every year [2]. An estimate of 500,000 people with severe dengue is in need of hospitalization each year, most of them are children and about 2.5% die [3]. In 2015, a 59.5% increase in the number of dengue cases in the country, as compared to the previous year [3]. This led to Philippines ranking fourth, among the 10 Association of Southeast Asian Nations (ASEAN), in terms of the countries with the most number of dengue cases [4].

A continuous increase every year was reported as well by the Department of Health (DOH) in which it corresponds to an economic and disease burden in the Philippines, as reflected in the average annual direct medical cost of dengue cases by setting and sector from 2008 to 2012 with an estimate of $345 million [4]. This shows major threat to public health and safety and justifies the existence of several kinds of mosquito traps and killers, using various repellents and attractants, in the market.

The use of ultraviolet (UV) light as an attractant emerged due to the capability of insects, including

mosquitoes, to detect ultraviolet radiation [5]. However, aside from these widely available products, homemade, improvised traps and killers are being introduced as well. Last June 2014, West Zone concessionaire Maynilad Water Services, Inc. (Maynilad) won an award for its Anti-Dengue Mosquito Trap which requires only a plastic bottle containing a mixture of brown sugar, water, and yeast, deduced to be producing carbon dioxide (CO_2), which serves as its attractant [6].This deduction was made since yeast, a single-celled organism that feeds on glucose or carbohydrates, and through fermentation converts carbohydrates to alcohols while releasing carbon dioxide (CO2). From studies, mosquitoes are attracted to CO_2, which is a by-product of humans.

According to McMeniman, Corfas, Matthews, Ritchie, &Vosshall [7], CO_2 strongly activates mosquito flight and was proven among other cues, as the most potent in behavioural activator and attractant for mosquitoes (2014). Moreover, in the study entitled, "The role of carbon dioxide in host-finding by mosquitoes (Diptera: Culicidae): a review", Gilles stated that the most important sensory cue used by mosquitoes to find humans is carbon dioxide [8]. These supported the formulated hypothesis and the attempt of the researchers to primarily prove the cost-effectiveness of the homemade mixture, ascertained to be producing CO_2, in luring mosquitoes, as compared with the use of UV light.

The results of this study redounded to the benefit of the Philippine population as a whole since it may be used to address several problems and issues concerning mosquito-borne diseases, such as its severe threat and risk to public health and safety, its economic and disease burden in the Philippines brought by the annual direct medical cost of dengue cases, and the increasing number of recorded mosquito-borne disease cases and deaths, particularly with children.

OBJECTIVES OF THE STUDY

The researchers aimed to replicate the mixture deduced to be producing CO_2 and prove its cost-effectiveness as compared to the UV light. This was achieved with the use of both statistical and engineering economic tools which analyzed the results of the experiment conducted and considered the corresponding benefits and costs of each attractant, respectively. Moreover, the purpose of the researchers for conducting this study is to initiate, encourage, and pursue the implementation and use of homemade mosquito traps, particularly in depressed areas.

MATERIALS AND METHODS

Research Design

The researchers used comparative research which aims to make a comparison between different variables, focusing more on the quantitative method of research involving numerical data analyses using statistical tests. Moreover, an experimental study was also used. As defined by The American Heritage Dictionary of the English Language [9], an experiment is a test done under controlled conditions in order to observe a result or an outcome. This involves validating a hypothesis, demonstrating a fact, or testing new solutions.

Subjects and Study Site

The main test subject of this study was Aedesaegypti – a common type of mosquito and the primary carrier of major vector-borne diseases in the Philippines. The study was focused in determining which among the two attractants, the UV light device and the homemade mixture, best lure this specific type of mosquito. For the homemade mixture, the researchers used 200 mL of water mixed with 100 g of brown sugar, added with a tablespoon of yeast. The ratio used for the water, brown sugar, and yeast was 14:7:1. The researchers decided to perform the experiment in a controlled setting, inside a plastic covered cage with specified dimensions of 75 cm x 55 cm x 46 cm.

Data Measure

The data were gathered by counting the dead or attracted mosquitoes to each attractant for every trial and were tallied through the use of an experiment recording sheet. These were then recorded and compiled separately in Microsoft Excel which was used to perform the statistical tests necessary for the analysis of these data.

Data Gathering Procedure

The researchers released two mosquitoes equidistant from both attractants placed apart inside the cage. This made the experiment purposefully controlled by the researchers so as to prevent external factors from influencing the result of the experiment and as an attempt to minimize error and bias, thus, increasing the researchers' confidence that the data gathered are not spurious.

The data were gathered through recording and tallying the number of dead or attracted mosquitoes found in the perimeter of each attractant, given thirty (30) minutes to account for the reaction and responsiveness to the environment of the mosquitoes. This process was repeated for twenty (20) times during the experiment conducted in order to gather sufficient statistical data that would be used for the t-test analysis. Moreover, these are raw and reliable data as it was gathered directly from the effect of the attractants on the test subjects, thus, allowing it to be used in the comparison of the two mentioned attractants.

Ethical Considerations

The following ethical aspects were established and observed throughout the study in order to accomplish the research paper with proper research guidelines, ensuring that the study was conducted as systematically and morally as possible:

- An official letter was issued to the University of the Philippines – Los Baños to completely inform them as to why the researchers need to purchase mosquitoes and the objectives of the study being conducted.
- Permission to conduct the experiment was issued to authorized individual/s for the chosen location of experimentation. Individuals, directly and indirectly involved and might be affected due to the experiment, were informed of the potential dangers and threats brought by the experiment.
- Safety practices were observed during the experimentation. Wastes from the experimentation were disposed properly and did not result to any environmental degradation.
- Falsification and fabrication of data from the experiment conducted were strictly prohibited and were considered as form of cheating. Students involved may be sanctioned, as stated from the UST Student Hand Book [10], under PPS 1027.
- All collected data, information, and research result from books, journals, and articles were credible and authoritative to ensure accuracy of the study.
- All sources of data, information, and research result used in the research paper were cited clearly. Citations followed the format of The American Psychological Association or APA format.
- Adapted from the Vancouver Protocol [11], authorship credit should be based only on substantial contributions to (1) conception and design, or analysis and interpretation of data; and to (2) drafting the article or revising it critically for important intellectual content; and on (3) final approval of the version to be published. All conditions were met by the researchers to claim their authorship to the study.

Mode of Data Analysis

The data gathered from the experiment were then compiled and analyzed through the use of data analysis available in Microsoft Excel. These were considered first hand data, ensuring that the researchers' inputs in the analysis software are authentic to guarantee that the results would be reliable. Cost-benefit analysis was also used to analyze and evaluate the two attractants, considering several variables deemed by the researchers to be necessary in the comparison. All results were then interpreted with the help of related literatures that further deepened the researchers' understanding of the study.

Statistical Tools

T-test Analysis

T-test analysis was used as the data gathered by the researchers was below 30. Such analysis was used due to the presence of two population means that would be statistically tested. According to Trochim [12], t-test analysis is appropriate to use in order to compare the means of two groups and determine whether they are statistically different from each other. Moreover, it indicates whether or not this difference represents a difference in the population from which the groups were taken, as stated in Statwing [13]. The result from this analysis proved which among the two hypotheses formulated by the researchers is true, thus, served as a strong basis on the comparison of the attractants' effectiveness.

F-test Analysis

The F-test is a statistical tool to determine whether the variances of two groups of samples are equal or not [14]. Since this research is a comparative analysis of two small groups of samples, T-test will be utilized. However, T-test has two models- one for samples which have equal variances and the other for unequal variances. It is for this reason that F-test was done first to determine the equality of variances. Since the F-test proved that variances are unequal, the T-test tool for unequal variance was utilized.

Engineering Economic Tool

Cost-benefit Analysis

An article published by the Department of Economics of San Jose State University [15] defined cost-benefit analysis as a tool which estimates and sums up the equivalent monetary value of both benefits and costs of a course of action to the society. Therefore, such tool would help in deciding whether or not a certain course of action is worth pursuing through determining if the estimated total benefit of the action exceeds the total cost associated with it. The researchers compared the two attractants not just based on their effectiveness, but also on their life span, financial cost, health impact, and other factors deemed by the researchers as necessary to be included in the comparison. The result of this analysis determined which among the two attractants is more cost-effective as compared to the other.

RESULTS AND DISCUSSION

The experiment resulted to twenty varying numerical data needed by the researchers to perform the necessary statistical tests. The number of mosquitoes observed in the perimeter of each attractant was recorded and served as the input for the t-test analysis performed for this study to achieve its objectives.

F-test Analysis Result

The researchers first tested whether the data gathered assumes equal variances or unequal variances through the f-test analysis.

Table1. F-Test Analysis Two-Sample for Variances

	Homemade Mixture	UV Light
Mean	0.75	0.15
Variance	0.407894737	0.134210526
Observations	20	20
Df	19	19
F	3.039215686	
P(F≤f) one-tail	0.009793047	
F Critical one-tail	2.168251601	

F-test Analysis:
H_0: $\sigma^2_{HM} = \sigma^2_{UV}$
H_1: $\sigma^2_{HM} \neq \sigma^2_{UV}$
$\alpha = 0.05$
p-value = 0.0196

Conclusion: Reject H_0, since the significance level (α) is greater than the p-value. Data resulted to have unequal variances as summarized above. Therefore, t-test analysis assuming unequal variances was used to determine which hypothesis should be rejected or accepted.

T-test Analysis Result

T-test analysis assuming unequal variances was used by the researchers. The results of the t-test analysis became the researchers' basis of comparison for both attractants' effectiveness in luring mosquitoes. It also proved that the Alternative Hypothesis (H_1) formulated by the researchers is true. The result from the t-test analysis two-sample assuming unequal variances is summarized below.

Table 2. T-Test Analysis Two-Sample Assuming Unequal Variances

	Homemade Mixture	UV Light
Mean	0.75	0.15
Variance	0.407894737	0.134210526
Observations	20	20
Hypothesized Mean Difference	0	
Df	30	
t Stat	3.64438656	
P(T≤t) one-tail	0.000502116	
T Critical one-tail	1.697260851	
P(T≤t) two-tail	0.001004232	
t Critical two-tail	2.042272449	

T-test Analysis:
H_0: $\mu_{HM} \leq \mu_{UV}$
H_1: $\mu_{HM} > \mu_{UV}$
$\alpha = 0.05$
Critical Region: t > 1.6973
Test Statistic t: 3.6444

Conclusion: Reject H_0, since the researchers obtained a p-value of 0.0005 which is less than the value of significance level (α) at 0.05. This allowed the researchers to accept H_1 and conclude that the mean number of mosquitoes attracted to the homemade mixture is greater than the mean number of mosquitoes attracted to the UV light.

Cost-benefit Analysis

The cost-benefit analysis was used by the researchers to analyze and evaluate both attractants, considering all possible direct and indirect costs and benefits. Through the use of the cost-benefit analysis, the attractant that resulted with the highest difference between benefit and cost would be chosen.

All costs associated with the homemade mixture

were based on the prices in the Philippine local market. On the other hand, costs for the UV light device was computed through averaging the prices of different UV light products available, considering as well the average electricity consumption of the device. This resulted to total costs per unit for the homemade mixture and UV light amounting to ₱ 292.90 and ₱ 760.95, respectively.

Both of the attractants' main objective was to lure mosquitoes, with a possibility of capturing them which can result in the reduction of the number of cases of mosquito-borne diseases. Through the prevention of such diseases, various expenditures for medical purposes could be saved. Moreover, this could also avoid low productivity rate through the prevention of absences of infected employees. The monetary value of these benefits was derived from the study conducted by Edillo, Halasa, Largo, Erasmo, Amoin, Alera, Yoon, Alcantara, &Shepard [4]. This is computed through estimating the annual average dengue cases between 2008 and 2012, with an adjustment factor of 7.2 and estimating the average direct medical cost of dengue episode provided by setting and sector [4]. As a result, direct medical cost related to dengue was estimated at $ 344,542,000 or $ 3.26 per capita which is equivalent to ₱ 17,227,100,000 or ₱ 162.19 per capita.

Table 3. Cost-Benefit Analysis of Homemade Mixture and UV Light **(Per Household)**

COST (Homemade Mixture)			
Item	Quantity	Price (in ₱)	Total
Bottle	1	48.50	48.50
Yeast	26 (1 tbsp.)	4.50	117.00
Brown Sugar	26 (100 g)	4.90	127.40
Water	26 (200 mL)	2.318E-07	6.0268E-06
		Total Cost per Unit	**₱292.90**
COST (UV Light)			
Item	Quantity	Price (in ₱)	Total
UV Light	1/3	1,124.75	374.92
Electricity	45.63 kW/year	8.46 per kWh	386.03
		Total Cost per Unit	**₱760.95**
BENEFIT			
Financial and Medical Savings			162.19
Productivity			1,519.00
		Total Benefit per Person	**₱1681.19**
		BENEFIT-COST (Homemade Mixture)	**₱1388.29**
		BENEFIT-COST (UV Light)	**₱920.24**
		Difference	₱468.05

For the productivity, it is calculated by multiplying the minimum daily wage rate with the lowest pay according to region and sector [16] to the number of days to fully recover from the disease of the suspected dengue cases, estimated through the annual average dengue cases between 2008 and 2012, by age group of 20 to 59 years old. Average daily basic pay used was ₱ 217 and the number of days to fully recover with Dengue were estimated from 2 to 7 days [17]. Estimated overall annual average dengue cases were 842,867 [4] and 22% of the overall average dengue cases consists of the age group of 20 years old and above [18]. It garnered ₱ 1681.19of savings per person. As shown in Table 3, the benefits overpowered the costs for both attractants.

CONCLUSION AND RECOMMENDATION

The researchers obtained results from the t-test analysis proving that the homemade mixture is more effective than the UV light. This also supported the claim of McMeniman, Corfas, Matthews, Ritchie, and Vosshall [7] that CO_2, among other cues, was the most potent in behavioral activator and attractant for mosquitoes. In terms of cost-efficiency, the total benefit-cost difference of the homemade mixture and UV light computed were ₱ 1388.29and ₱ 920.24, respectively. Although both attractants' benefits overpowered its costs, it is evident in the cost-benefit analysis that the plastic bottle mosquito trap is more cost-effective, hence, better than the UV light device.Since the homemade mixture is intended for the lower economic class, it will help them to protect themselves from mosquito-borne diseases without investing on expensive repellents and insecticides.Materials for the mixture are also widely available and cheap.

On the other hand, the researchers suggest trying the uncontrolled setting, feeding mosquitoes with fresh human blood, and improving the conducted experiment through increasing the number of mosquitoes per trial, providing a larger space intended for the experiment, changing the observed time considering when mosquitoes are most active, increasing the number of trials, and increasing the duration of observation per trial. Moreover, it is recommended by the researchers to produce a product which would utilize the proven attractant in eliminating mosquitoes as the attractant would not be of much benefit to the community if used alone. However, the product is preferred to be designed appropriately for depressed areas, thus, requiring the

product to function without any energy sources and its materials to be widely available in the market, as well as cheap.

The current homemade mixture tested in this study may be improved also by future researchers through exploring other possible attractants or mixtures which could possibly produce CO_2 as well, in a cheaper, more effective, and more eco-friendly manner. These mixtures may also be further improved by integrating other compounds into the mixtures in an attempt to enhance its attraction rate. In addition, future researchers may conduct studies, researches and experiments wherein both adult female mosquitoes and its eggs will be killed at once in order to stop its reproduction. Also, future researchers may also improve the cost-benefit analysis presented by the researchers in this study by considering other benefits and costs, such as those related to tourism, environmental cost, and waste disposal cost, associated with the elimination of mosquitoes.

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