Mahogany (Swietenia mahogani) Seed Dispersal: Relationship between Flight and Physical Characteristics

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APPROVAL SHEET

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Abstract

Dispersal is a way for the seed to find a suitable place away from its parent plant and to maximize its chance for survival. Mahogany fruits are examples of samaras, fruits that disperse from their parent plant through autorotation. Dispersion is affected by environmental factors and the physical structure of the fruit. The longer it stays airborne, the farther away it can be dispersed by the wind. Thus this study aims to determine the structural characteristics of a mahogany fruit that may influence its flight time.

Fruits that were newly released from the pod were collected. Then the following physical characteristics of each fruit were determined: length, total surface area, fruit mass, seed mass, and wing mass. From these the square root of the wing loading and the ratio of the wing mass and seed mass were computed. The flight time was determined by dropping the seeds from a constant height. The relationship between flight time and the seed's physical and aerodynamic properties were then investigated.

The flight time of the mahogany fruit range from 0.97 to 2.02 seconds. Pearson r correlation showed that individually, each of the following is not significantly correlated with flight time: length ($r = 0.133$, $\rho = 0.483$, min=5.80 cm, max=10.70cm), fruit mass ($r = -0.238$, $\rho = 0.205$, min=0.2464g, max=0.8007g) and total surface area ($r = 0.018$, $\rho = 0.925$, min=20.96cm^{2,} 51.81 cm^2). However, flight time is negatively correlated with the square root of the wing loading ($r = -0.578$, $\rho = 0.001$, min=0.3127gcm/s^2, max=0.4086 gcm/s^2) and positively correlated with the ratio of the wing mass and seed mass ($r = 0.633$, $\rho = 0.001$, min=0.0811, max=0.1667). Furthermore, one-way analysis of variance also showed that there is no significant difference between the mean flight times of mahogany fruits with different curvatures (α=0.05).

Within the confines of the physical characteristics under investigation, it can be concluded that to stay airborne longer, the seed must have high ratio of wing mass to seed mass and low wing loading. This information might be useful to botanists who study seed dispersal or engineers who wish to develop new technology based on natural phenomenon.

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CHAPTER I

INTRODUCTION

A. Background of the Study

Seeds are products of plants that enable the survival of their species by dispersing away from the parent plant to maximize its chance for survival (Stefferud). There are many ways to disperse seeds but the three main mechanisms are by animals, water and wind (Campbell and others 1999). In samaras, the indehiscent dry seed-bearing fruits are dispersed by wind, an example of which is the fruit of the mahogany (*Swietenia mahogani*) tree. There are six main classifications of seeds dispersed by the wind; they are the gliders, parachutes, helicopters, flutterers, cottony seeds and fruits and tumbleweeds. The mahogany seeds are classified as helicopters (Parker 1994). The mahogany seeds come from the pod of the parent tree. When the pod cracks open, it reveals one-winged fruits (Durham 1996). In releasing these fruits, they first go through an initial phase of free fall and after some time, the fruit starts spinning like a rotor (Martone 2002).

The maneuver that the fruits show during dispersal is called autorotation. The aerodynamic forces on the wing cause the fruits to generate lift causing it to descend like a rotor of a helicopter (NASA 2002). No engine is causing the fruit to fall but instead, the air stream's resistances on the wing as it passes through makes the fruit rotate (Gray and others 2000).

This example of autorotation by nature inspired other scientists to create a mechanical equivalent (Martone 2002, Mcconville 2008). These mechanical equivalents may be used for a wide variety of applications from the mundane, such as an aerodynamic toy that is generally samara seed-shaped (Barnes 2006), to the exotic, such as a rotating aircraft that was proposed for gathering data from remote planets as well as on earth (NASA 2002).

Building bio-inspired technology does not mean the recreation of the natural model in toto. Instead, it entails the selection of a desired effect or behavior, the adoption in the design of a set of factors that brings about this effect or behavior, and the recreation of the relationships between these factors to achieve the desired effect or behavior. For instance, to develop a single-bladed autorotating vehicle, structural properties such as the position of the center of mass and the shape of the wingtips were considered in the design based on the results of a study done on samaras (Kellas 2007). This shows that seminal studies to identify key factors and the relationships between these factors are important to provide designers and inventors with ideas to work on.

There are already several studies conducted on samara structure and flight (Minorsky and Willing 1999). In Aleppo pine fruits, the relationship between structural characteristics–width, length, area, mass and square root of wing loading –and flight characteristics–relaxation distance and terminal descent velocity–were investigated (Nathan and others 1996). In sugar maple, additional structural parameters, such as inner and outer angles of the wing, and wing shapes, were also investigated (Wallace and others 2002).

Samara fruits, however, come in many different shapes and there are even documented variations in morphology within populations of the same species such as in wing size in *Cardiocrinum cordatum* (Sakai and others 1997) and flight behavior in silver maples (Sipe and Linnerooth 1995 as cited by Wallace and others 2002). Hence, additional information is still needed to better understand samaras (Yamada and Suzuki 1999; Wallace and others 2002). It is also worth nothing that no previous studies have been done on mahogany fruits.

As an initial effort to describe the structure and flight of mahogany fruits, this study aimed to investigate the relationship and effect of the structure of mahogany fruits to its flight time. Furthermore, this study included an investigation of the relationship between the ratio of the wing mass to seed mass and flight time, and the effect of the curvature of the wing, which is observed on mahogany fruits, on flight time—two aspects that has not yet been investigated in previous samara studies. The information generated by this study might be useful in the design of new and alternative transports such as linked samara decelerators (Brasseur 2004) or controllable guided single bladed autorotating vehicles and nano unmanned air vehicles (Kellas 2007).

B. Statement of the Problem

This study investigates the relationship of the physical characteristics and the effect of the curvature of the wing on the flight time of mahogany (*Swietenia mahogani*) fruits.

C. General Objectives of the Study

To determine the relationship of the physical characteristics (length, mass, surface area, square root of wing loading and the ratio of wing mass to seed mass) and the effect of the curvature of the wing on the flight time of the mahogany (*Swietenia mahogani*) fruits.

Specific Objectives of the Study

1. determine the following physical characteristics of the mahogany fruits:
    a. Curvature
    b. Fruit length (centimeter)
    c. Fruit mass (grams)
    d. Surface area (centimeter^2)
    e. Seed mass (grams)
    f. Wing mass (grams)
2. measure the flight time of the mahogany fruits (seconds)
3. compute for the means of the flight time of mahogany fruits of different curvatures
4. compute for the following physical characteristics of the mahogany fruits:
    a. Square root of wing loading (gram centimeter/second^2)
    b. Ratio of the wing mass and seed mass
5. to compare the means of the flight times of mahogany fruits of different curvatures
6. compute for the Pearson r correlation coefficient between the flight time of the fruit and the following:
    a. fruit length
    b. fruit mass
    c. total surface area
    d. square root of the wing loading
    e. ratio of the wing mass and the seed mass

D. Hypothesis

1. There is no significant difference between the mean flight times of mahogany fruits with different curvatures.

2. There is no relationship between the flight time and the physical characteristics of the mahogany fruit; curvature, fruit length, fruit mass, total surface area, square root of wing loading and the ratio of wing mass and seed mass.

E. Research Paradigm

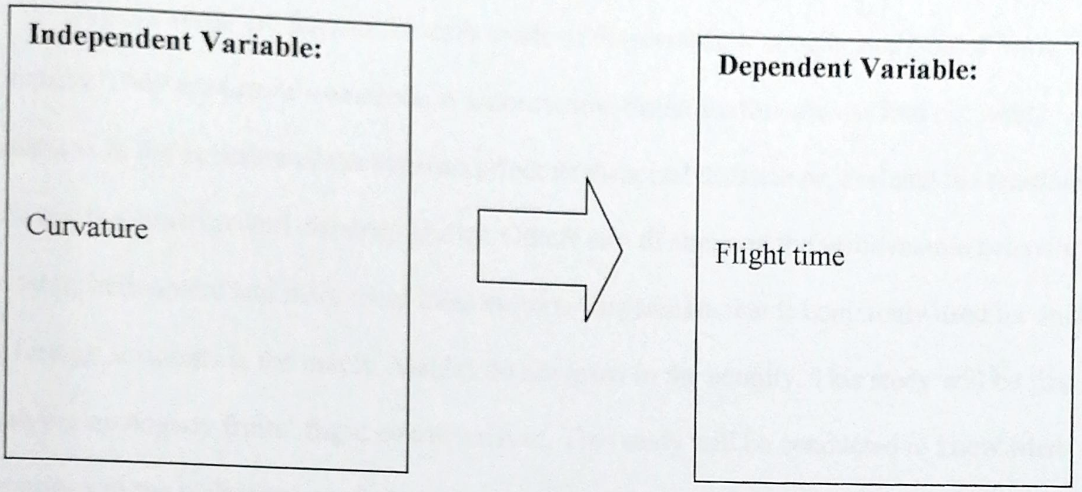

Figure 1. The research paradigm

F. Significance of the Study

Samara seeds are famous for their mode of dispersal so it attracts attention of many scientists. They are nature's example of autorotation. Some studies aims to find out what variations in the structure of the samaras affect its dispersal distance or, evaluate the relationship between the structure and dispersal ability. Others aim to compare the aerodynamic behavior of samaras, helicopters and theoretical ideal motors. One samara that is commonly used for studies by foreign scientists is the maple. Maples do not grow in the country. This study will be first on studying mahogany fruits' flight characteristics. This study will be conducted to know what variations in the mahogany seed structure would affect its flight characteristics. This is to analyze the aerodynamic and the flight-dynamics, and observe the flight behavior of the mahogany seed. By doing so, a prototype of the mahogany seed may be made to demonstrate these flight characteristics. The results and data gathered in this study could be used for the future technology. The findings on the mahogany seed flight will serve as basis for more inventions.

G. Scope and Delimitation

The fruits were collected from within the Philippine Science High School Western Visayas campus only to base my study only on the mahogany trees in the school to lessen complications. The fruits collected are assumed to have no alterations in its structure after falling from the tree and storing them in envelopes for a few months. The fruits will be tested with no moving air. Experiments involving horizontal wind were not done because there were no appropriate equipments that could be used.

Also, the terminal descent velocity was not studied because unlike other samaras, the mahogany fruit does not show a consistent and stable descent. The relaxation distance also was not studied because the relaxation distance is determined from the start of the terminal descent velocity.

H. Definition of Terms

Flight

-the movement of an object through the atmosphere or through space, sustained by aerodynamic reaction or other forces (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

In this study, the flight refers to the movement of the mahogany seed when it is released from the launching point until it reaches the ground.

Flight Time

- the elapsed time from the moment an air craft first moves under its own power for the purpose of taking off until the moment it comes to rest at the end of the flight (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

In this study, flight time of the mahogany fruit is observed during flight.

Structure

- the arrangement and interrelation of the parts of an object (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

Property

-An attribute or abstract quality associated with an object (Wiktionary).

Structural Property

In this study, the structural properties are the following: curvature, weight, center of mass, surface area, ratio of surface-area-to-weight-of-seed, ratio of weight-of-seed-part-to-weight-of-wing-part.

Mahogany

-any of several tropical trees in the family Meliaceae of the Geraniales (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

In this study, this refers to the mahogany trees in the different collection sites.

Fruit

- a fully matured plant ovary with or without other floral or shoot parts united with it at maturity.

In this study, the fruit refer to the mahogany fruit that are collected from different collection sites.

Seeds

-a fertilized ovule containing an embryo which forms a new plant upon germination (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

In this study, seeds refer to the seed part of mahogany fruit.

Wing

-a major airfoil

-an airfoil on the side of an airplane's fuselage or cockpit, paired off by one on the other side, the two providing the principal lift for the airplane(Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

In this study, wing refers to the wing part of the mahogany fruit.

Curvature

- the act of curving : the state of being curved (Merriam-Webster's Online Dictionary)

In this study, it has been observed that the wings of the mahogany fruits sometimes are curved. They will be identified as 1 if the curvature is upward, 2 if the curvature is downward and 0 if it does not have a specific curvature.

Length

-extension in space (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

In this study, the length refers to the fruit length of the mahogany fruit measured using a ruler.

Mass

-a quantitative measure of a body's resistance to being accelerated (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

In this study, mass of the mahogany fruits is determined using an analytical balance.

Surface Area

-measurement of the extent of the area (without allowance for thickness) covered by a surface (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

In this study, surface area refers to the surface area of the mahogany seed determined using aluminum foil and an analytical balance.

Seed mass

In this study, the mass of the seed part of the mahogany fruit is determined using an analytical balance.

Wing mass

In this study, the mass of the wing part of the mahogany fruit is determined using an analytical balance.

Wing Loading

-a measure of the load carried by an airplane wing per unit of wing area (Mcgraw-Hill Dictionary of Scientific and Technical Terms Fifth Edition).

Square root of wing loading

In this study, it is the square root of the weight of the seed divided by its total surface area.

Ratio of wing mass and seed mass

In this study, ratio of wing mass and seed mass is the mass of the wing divided by the mass of the seed.

CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter, the review of related literature, includes the topics (A) seed dispersal, (B) related studies and experiments, (C) autorotation, (D) flight time and the (E) structural properties of samara: (E.1) curvature, (E.2) length, (E.3) mass, (E.4) surface area, (E.5) square root of wing loading and (F) applications.

A. Seed Dispersal

Seeds disperse to propagate. There are different ways of dispersal. The three main mechanisms are by water, wind, and animals. The mahogany seeds disperse by wind. In wind dispersal, there are six main classifications of seeds; they are the gliders, parachutes, helicopters, flutterers, cottony seeds and fruits and tumbleweed (Waynesword).

Gliders include seeds with two lateral wings that glide through air in wide circles. Parachutes are seeds that have elevated, umbrella-like crown of intricately-branched hairs at the top that the wind catches, raising and propelling the seed into the air like a parachute. Helicopters include seeds called samaras that are propeller-like. Although flutterers' mode of dispersal is similar to single-winged helicopter seeds, the flutterers include seeds with papery wing around the entire seed of at each end. Cottony seeds and fruits include seeds and minute seed capsules with a tuft of cottony hairs at one end, or seeds embedded in a cottony mass (Waynesword). Tumbleweeds break off from the roots at the end of the growing season and are rolled about by the wind (American Heritage Dictionary of the English Language 2003).

The mahogany seeds are classified as helicopters. Seeds with the similar structure as the mahogany seeds are called samaras. Samaras are seeds or one-seeded fruits that have a membranous wing at one end (Waynesword).

The mahogany seeds come from the five-lobed pods. When the pod ripens, it cracks open into five parts revealing seed clusters. As the wind blows, the seed clusters will divide into individual wing-shaped seeds. The mahogany seeds disperse by rotating like a rotor away from its parent plant (Durham 1996). First the seeds will be in a state of free fall and will then start to rotate away from the plant (Martone 2002).

B. Related Studies and Experiments

Many scientists put interest on studying samara seeds, especially its way of dispersal (Martone 2002). A study shows that the mahogany seeds only establish on open land. They grow in a great distance away from the parent plant (Durham 1996).

A study was conducted on the samara's aerodynamic properties in *pinus halepensis mill.*. The variation of the morphological properties and aerodynamic predictors of dispersal capacity were reported. They investigated how the seeds' properties affect the variation in dispersal capacity. Aerodynamic properties were measured in a closed-room experiment, in order to avoid any gusts. One hundred twenty-five samaras were released one by one from a height of 2.35 meters above the ground and their descent were photographed by an 8mm video camera with a digital time control. The video tape was analyzed to estimate the aerodynamic properties (Nathan and others 1996).

One experiment is making a model fruit and evaluating the relationship between the structure and the dispersal ability. The "fruits" are dropped at a standard height of two meters while measuring the time spent with a stopwatch. Three trials are to be made for each of the "fruits" and the average will be recorded (Anonymous 2001).

On study on samaras, parameters were measured by taking strobe photographs on over two hundred samaras as they fell. The data collected were then used to compare the aerodynamic behavior of samaras, helicopters and theoretical ideal rotors (Green 1980).

According to an abstract studying the autorotation boundary in the flight of samaras, the samara's flight behavior can be analyzed by testing the samaras in a vertical wind tunnel. Its flight characteristics depend on the location of center of mass, wing loading, camber and the surface roughness near the leading edge (Yasuda and others 1996).

The determination of dispersal distance of samara seeds are the usual purpose of some studies. An experiment showed what in the structure of the maple seeds affect its dispersal distance. It showed that it is important to measure the seeds' length. The longer it is, the farther the seed goes. The results also showed that as the total time of flight increases, the distance of the seeds' flight also increases (Wallace and others 2000).

In samaras' way of dispersal, before they autorotate, they first have an initial fall or an initial state of free fall (Martone 2002). In the experiment, the shorter its initial fall distance, the greater is the distance of the seeds' travel (Wallace and others 2000). One samara seed that is usually a subject for study is the maple seed. It is one-seeded and winged (Waynesword).

C. Autorotation

Forced landing of helicopters can be put down in just about any clear area. The maneuver needed in this situation is called autorotation because the engine will no longer power the rotor

(Anonymous) but rather the energy derived from the airflow around the blades resulting from the downward movement, thus the weight is translated into the rotation of the blade (Martone 2002).

Samara seeds are nature's example of autorotation. There is no motor causing the seed to rotate as it fall instead the air resistance in the wings makes the seed turn (Gray and others 2000). However, there are also differences between helicopter and samara autorotation. The samaras first go through an initial phase of free fall during which the seed turns perpendicular to its path of descent and initiates rotation. Another is that in samaras, the wing and the seed spin together and centrifugal momentum probably becomes more important than wing aerodynamics once the seed levels and initiates spinning. In other words, the samaras act more like a spinning type than a helicopter (Martone 2002).

D. Flight time

Students must also confront the problem of what parameter to measure. Many students propose measuring the horizontal distance a dropped samara travels from the plumbline. However, because of the vagaries and weakness of indoor air currents, this approach, too, is discouraged: The samaras when dropped in still air, generally fall close to the plumbline. The simplest and most straightforward suggestion is to measure the time needed for the descent of dropped samaras in still air (Minorsky and Willing 1999).

E. Structural Properties of Samara

E.1 Curvature

It has been observed that the wings of the mahogany seeds sometimes are curved. Some seeds have curves that are downward, others are upward while some seeds don't have specific direction of its curve. The mahogany seed will be identified as C1 if the curvature is upward, C2 if the curvature is downward and C3 if it does not have a specific curvature.

E.2 Length

It appears to require the samara to have an airfoil with a length, width and pitch to counterbalance the weight of the seed. Too much or too little compensation for seed weight in terms of wing length or width would result in wobbling eccentricities in the seed flight. Similarly, reducing the length of the wing may result in significant wobbles and cork-screw trajectories, but nevertheless, the samaras fly (Martone 2002). The considerable amount of variation due to differences between trees in mass, area and length may be an expression of a high genetic control over these traits. If these variations are at least partially genetically based, natural selection might favor certain genotypes. Greene and Johnson concluded that there is a biomechanical limitation on the effectiveness of the wing as a function of size; hence larger samaras are necessarily more poorly dispersed. The large wing has an additional cost, as it might increase mortality inflicted by seed-predators. Thus, the high intraspecific variation found in samara's area and especially length, can be attributed to the effect of dispersal-predation avoidance trade-off (Nathan and others 1996).

E.3 Mass

Weight being at one end, plus the broad and inflated nature of the bladder, provides it with the helicopter action (Lukes 2002). The heavier the seed, the longer the seed stays in the air (Wallace and Others 2000). Heavy seeds with small wings (high wing-loading) would fall faster than light seeds with large wings (low wing-loading) (Nathan and others 1996).The samara will have to have an airfoil to counterbalance the weight of the seed. Too much or too little compensation for seed weight in terms of wing length or width would result in wobbling eccentricities in the seed flight (Martone 2002).

E.4 Surface Area

Having a greater surface area would allow the samara seed to receive more wind energy, therefore propelling it to greater distances (Wallace and others 2000). The samaras increase the surface area of their seeds' wing so that they too can be carried on the wind (Anonymous).

E.5 Square Root of Wing Loading

The square root of wing-loading of a seed of a plant is not significantly correlated with basal stem diameter of a plant, indicating that large plants did not necessarily produce seeds with high dispersal ability. On the other hand, the square root of wing-loading of a seed of a fruit was negatively dependent on seed number of a fruit. Thus, many-seeded fruits produced seeds with high dispersal ability. This was because the projected surface area per seed was large in large fruits and large fruits contained large numbers of seeds (Sakai and others 1997). For a given wind intensity and initial height, the distance traveled is inversely related to the square root of the wing loading. It is reasoned that, under strong winds like the Patagonian ones, the weight: area ratio would not only affect primary dispersal but also later movements on the soil surface (Fernandez and others 2002).

F. Applications

Technology and inventions today are based on nature. Airfoils of aircrafts look like the wings of a bird. Birds demonstrate that flapping-wing flight (FWF) is a versatile flight mode, compatible with hovering, forward flight and gliding to save energy. This extended flight domain would be especially useful on mini-UAVs (unmanned air vehicles). However, the design is challenging because aerodynamic efficiency is conditioned by complex movements of the wings, and because many interactions exist between morphological (wing area, aspect ratio) and kinematic parameters (flapping frequency, stroke amplitude, wing unfolding) (de Margerie and others 2007). Also, bio-inspired airfoils such as dragonfly airfoils are explored for their potential application for Micro Air Vehicles (Tamai and others 2007).

A device called linked samara decelerator has the motion of a samara. Its principle is simple: a load attached to a long rope fixed to a tough little glider. The glider flies in a circle above the load and brakes its fall just like a parachute would (Brasseur 2004).

A DARPA funded Nano Air Vehicle in the form of a maple seed is under development by Lockheed Martin. It will be rocket powered, controllable and will employ a high-speed imaging sensor to sense heading and to navigate (Kellas 2007).

Potential applications are the linked samara decelerator and the UAV. A proposed vehicle employs the form factor of the autorotating samara to create a guided precision airdrop system (Kellas 2007).

CHAPTER III

METHODOLOGY

A. List of Materials and Equipment

The following equipment were borrowed and used from the indicated sources:

Analytical balance	SRA

The following materials were bought from the indicated sources:

Personal Computer	
Sony Vegas Pro 8.0	
Box	National Bookstore
Coin Envelopes	National Bookstore
Aluminum Foil	SM Supermarket
Cutter	National Bookstore
Electrical tape	National Bookstore
Measuring tape	Ace Hardware

B. Study Site and Study Period

The collection of the mahogany fruits was conducted in the Philippine Science High School Western Visayas Campus from April to May 2008.

The testing of mahogany fruits was done in a closed room to exclude the effect of the wind in the descent of the mahogany fruits. The analysis of the videos was done on the personal computer. The measuring of physical characteristics was done in the research laboratory and research hub. All this was done from September to November 2008.

C. Collection of Mahogany Fruits

Mahogany fruits that have just fallen from the tree were collected. Only the fruits that have complete parts and no cracks were used for the study. The initial mass of each of the collected fruits were determined immediately and recorded and placed inside an unsealed envelope. Each of the envelopes was numbered and was labeled with the fruit's initial mass. The envelopes were arranged vertically in open-top boxes. The boxes were placed in a cool, dry place.

D. Recording the Flight of Mahogany Fruits

Each of the fruits was measured for their lengths using a ruler to categorize the collected fruits according to their lengths. The fruits that were used for testing were randomly selected and was insured that there were no cracks or holes on it. Thirty fruits were sampled. Each mahogany fruit was dropped thrice from a launching pad with a height of 2 meters in a closed room. The launching pad has stands at both sides against a white background. The fruit was dropped from the launching point. The fruits were dropped and their descents were recorded by a video camera adjusted such that it captured the whole descent. This procedure was done on all fruits.

E. Measurement of Physical Characteristics

E.1 Curvature

The fruits were viewed with the leading edge in the front and the seed part on the left side. The curvature of the leading edge of the wing part will be identified as upward, downward or no definite curvature.

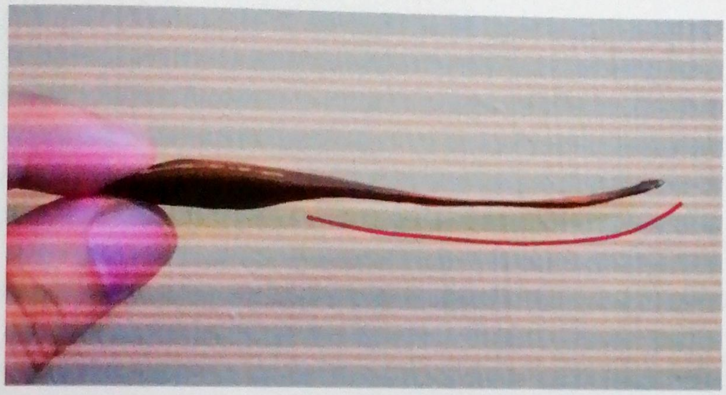

Figure 2. Mahogany fruit curved down.

E.2 Fruit Length

The lengths of each of the fruits were measured using a ruler from the tip of the seed to the tip of the wing.

E.3 Fruit Mass

The fruit was placed in an analytical balance. The mass was measured in grams (up to the hundredths of a gram).

E.4 Total Surface Area

A square of 3cm x 3cm from an aluminum foil was cut. The mass of the $9cm^2$ aluminum foil was then determined using an analytical balance in grams (up to hundredths of a gram). The whole surface of the fruit was covered with aluminum foil following the fruit's surface's shape. The aluminum foil on the fruit was taken off. The aluminum foil was then weighed using an analytical balance in grams (up to hundredths of a gram). The total surface area of the fruit was then estimated by ratio and proportion using this equation:

Surface area of foil on fruit / Weight of foil on fruit=Surface area of square / Weight of square

$$A_1 / W_1 = A_2 / W_2$$

$$A_1 = A_2 W_1 / W_2$$

E.5 Seed Mass and Wing Mass

The seed part was cut off from the wing part as shown in Figure 3. The cut was made from the points where the curvatures of the leading edge and the trailing edge changed. The masses of the seed part and the wing part were then measured in an analytical balance in grams (up to the hundredths of a gram).

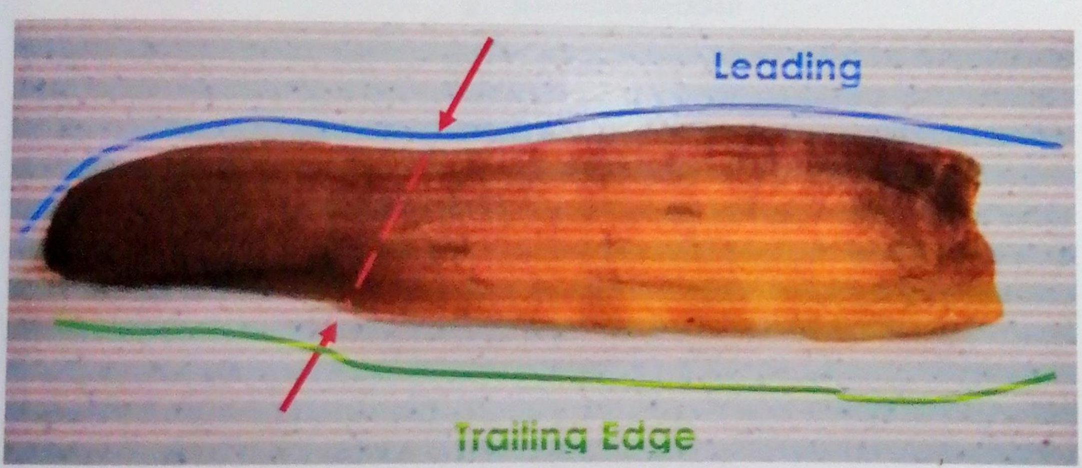

Figure 3. Seed part and wing part.

F. Flight Time

The videos were analyzed to determine the flight time. The Sony Vegas Pro 8.0 was used in analyzing the videos by looking at the frames every 0.03 seconds intervals. The flight time starts from the moment the fruits were released to the moment it touches the floor.

G. Computation of Square root of Wing Loading and the Ratio of Wing Mass and Seed Mass

G.1 Square root of wing loading

The square root of wing loading was determined by:

$$(m \square g / A)^{1/2}$$

A = surface area of wing part

m = mass of seed

g = gravity acceleration

G.2 Ratio of Wing mass and seed mass

The ratio of the wing mass to the seed mass is given by the formula:

$$\text{Ratio} = WM/SM$$

WM= wing mass

SM= seed mass

H. Statistical Analysis

H.1 Comparing the Means of the Flight Times of Mahogany Fruits of Different Curvatures

The means of the flight times of the mahogany fruits of different curvatures were compared using one-way ANOVA at a 0.05 level of significance.

H.2 Determining the Relationship between Flight Time and the Structural Characteristics of the Mahogany Fruit.

The Pearson r correlation coefficient between the Flight Time of the mahogany fruit and its length, mass, total surface area, wing loading and the ratio of wing mass to seed mass was determined.

CHAPTER IV

RESULTS AND DISCUSSION

The main purpose of the study is to determine the physical characteristics that are related to the flight time of mahogany (*Swietenia mahogani*) fruits.

Specifically, it aimed to determine the flight time and the physical characteristics of mahogany (*Swietenia mahogani*) fruits; curvature, fruit length, fruit mass, total surface area, square root of wing loading and the ratio of wing mass and seed mass.

It also aims to compare the means of the flight time of mahogany fruits with different curvatures and to determine the relationship between the flight time and the physical characteristics of the mahogany fruit; curvature, fruit length, fruit mass, total surface area, square root of wing loading and the ratio of wing mass and seed mass.

It was hypothesized that there is no significance among the means of the flight time of mahogany fruits with different curvature.

It was hypothesized that there is no relationship between the flight time and the physical characteristics of the mahogany fruit; curvature, fruit length, fruit mass, total surface area, square root of wing loading and the ratio of wing mass and seed mass.

Results

The general structural characteristics and flight time of the mahogany fruits collected from the grounds of Bitoon, Jaro, Iloilo city are summarized in Table 1 below.

Table 1. Mean and range of physical characteristics of mahogany fruits.

	Mean ± SD	Max	Min
Length (cm)	8.19 ± 1.38	10.70	5.80
Fruit mass (g)	.446 ± .122	0.801	0.246
Total surface area (cm^2)	33.19 ± 8.06	51.81	20.96
Square root of wing loading $(N/m^2)^{1/2}$	1.15 ±0.07	1.29	0.99
Ratio of wing mass and seed mass	.123 ± .002	0.167	0.081
Flight time (s)	1.45 ± .22	2.02	0.97

The distribution of the curvature of the mahogany fruits is summarized in Table 2 below. Most of the fruits are curved up and the rest are evenly divided between the fruits that are curved down and those with no definite curvature.

Table 2. Percentage of curvatures of 30 mahogany fruits.

	No definite curvature	Curved Up	Curved Down
percentage	26.7 %	46.7%	26.7%

Mahogany fruits that are curved down relatively have the highest mean flight time while the mahogany fruits that have no definite curvature relatively have the lowest mean flight time, as shown in Table 3 below.

Table 3. Flight time means of mahogany fruits with different curvatures.

	No definite curvature	Curved Up	Curved Down
Flight time	1.3958±0.2725	1.4324±0.1803	1.5325±0.2355

*values are means ± standard deviation

The one-way analysis of variance (ANOVA) in Table 4 shows that there is no significant difference between the mean flight times of mahogany fruits with different curvatures.

Table 4. One-Way Analysis of Variance (ANOVA) Table for flight time means of mahogany fruits with different curvatures (α=0.05)

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance Level	Interpretation
Between Groups	8.225x10^{-2}	2	4.112 x10^{-2}	0.835	0.445	
Within Groups	1.331	27	4.928 x10^{-2}			Not Significant
Total	1.413	29				

Pearson r correlation shows that there is no significant relationship between the mean flight time and the physical characteristics fruit length, fruit mass and total surface area while there is a significant relationship between the mean flight time and physical characteristics square root of wing loading and ratio of wing mass and seed mass. This is summarized in Table 5 below.

Table 5. Pearson r correlation between flight time and the physical characteristics of mahogany fruits ($\rho = 0.05$).

	Pearson r coefficient	Significance Level	Interpretation
Fruit length	0.133	0.483	Not significant
Fruit mass	-0.238	0.205	Not significant
Total surface area	0.018	0.925	Not significant
Square root of wing loading	-0.578	0.001	Significant
Ratio of wing mass and seed mass	0.633	0.001	Significant

Discussion

The comparison of the mean flight times of mahogany fruits with different curvature using one-way ANOVA gave an F value of 0.835. The result did not show any significant difference in the mean flight times. It means that the flight time of the fruit does not depend on whether it is curved up, curved down or possesses no definite curvature. No previous studies were done investigating the effect of curvature on the flight of samaras so this aspect still needs further studies. However, a clue to the direction of further inquiry can be glimpsed from a study done on hovering insects where it showed that the variation of the angle of attack of the wings of fruit flies increased its aerodynamic performance (Bos and others 2007). The presence of a curvature along the leading edge of the mahogany fruit means that the angle of attack is not consistent in the entire length of the wing. Further studies can be done on the effect of the magnitude of the curvature on the flight time.

The results also show that there is no correlation between the flight time and the physical characteristics–length, mass and surface area –of mahogany fruits. This agrees with a previous study on *Pinus halepensis mill.* where the same physical characteristics did not show a correlation with terminal descent velocity (TDV) (Nathan and others 1996).

However, the results show that there is a negative correlation between the flight time and the square root of wing loading of mahogany fruits. In a previous study on *Pinus halepensis mill.*, where it states that the square root of wing loading is positively correlated with the terminal descent velocity (Nathan 1996). The results are equivalent since if a fruit has a low TDV, it follows that it will fall slower to the ground, thus a long flight time. It means that heavy seeds with small wings (high wing-loading) fall faster to the ground while light seeds with larger wings (low wing loading) fall slower.

The results also show a positive correlation between flight time and the ratio of wing mass and seed mass. It means that the higher the ratio, the longer it takes for the seed to descend to the ground. The result in the ratio (wing mass/seed mass) could be interpreted in the same way as (square root of) wing loading (weight of fruit/surface area) since the two are somehow comparable.

The relationship between the ratio of wing mass and seed mass and flight time, however, might be more appropriate in the design of the linked samara decelerator (LSD). The linked samara decelerator structurally consists of a load attached by rope to a rotating glider (Brasseur 2004). Only the glider provides lift while the load does not. The difference in samaras is that the surface area of the seed contributes lift since structurally it is still part of the wing of the samara fruit. So if an LSD design with a fast descent is desired, the LSD could be created such that the ratio of the mass of the glider and the mass of the load is low. Conversely, if an LSD design with a slow descent is needed, such as for vehicles needing a long loitering period, the ratio must be high.

Thus, this study showed that the mahogany fruits' flight time is related to square root of wing loading and the ratio of wing mass to seed mass while it is not related to length, mass and surface area. Also, the curvature does not affect the flight time. Information was provided that might be useful in the design of alternative vehicles such as the LSD. However, further studies are still needed on the curvature and other physical characteristics such as center of mass (Kellas 2007) and outer and inner wing angles (Wallace 2002).

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. Summary

This study determined the relationship of the physical characteristics (length, mass, surface area, square root of wing loading and the ratio of wing mass to seed mass) and the effect of the curvature of the wing on the flight time of the mahogany (*Swietenia mahogani*) fruits.

It specifically aimed to:

1. determine the following physical characteristics of the mahogany fruits:
    a. Curvature
    b. Fruit length (centimeter)
    c. Fruit mass (grams)
    d. Surface area (centimeter^2)
    e. Seed mass (grams)
    f. Wing mass (grams)
2. measure the flight time of the mahogany fruits (seconds)
3. compute for the means of the flight time of mahogany fruits of different curvatures
4. compute for the following physical characteristics of the mahogany fruits:
    a. Square root of wing loading (gram centimeter/second^2)

    b. Ratio of the wing mass and seed mass

5. to compare the means of the flight times of mahogany fruits of different curvatures
6. compute for the Pearson r correlation coefficient between the flight time of the fruit and the following:
    a. fruit length
    b. fruit mass
    c. total surface area
    d. square root of the wing loading
    e. ratio of the wing mass and the seed mass

It was hypothesized that there is no significant difference between the mean flight times of mahogany fruits with different curvatures. Also, there is no relationship between the flight time and the physical characteristics of the mahogany fruit; curvature, fruit length, fruit mass, total surface area, square root of wing loading and the ratio of wing mass and seed mass.

B. Conclusion

There is no significant difference between the mean flight times of mahogany fruits with different curvature.

Fruit length, fruit mass, and total surface area are individually not correlated with the flight time. However, flight time is negatively correlated with the square root of the wing loading and positively correlated with the ratio of the wing mass and seed mass.

C. Recommendations

Based on the results and observations, the following recommendations are presented:

1. The correlation between the physical characteristics and other flight characteristics such as distance, direction of dispersion, relaxation distance and terminal descent velocity.
2. The correlation between other physical characteristics such as center of mass and outer and inner angle.
3. Exploring the effect of the parts of the mahogany fruits by cutting off some parts
4. Construction and manipulation of prototype of mahogany fruit.

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Appendix A

RAW DATA

Physical Characteristics

Seed number	Curvature	Length (cm)	Mass ($\times10^{-3}$ kg)	Total surface area (cm^2)	Ratio of wing mass and seed mass	Square root of wing loading
1	2	8.9	0.39	34.98	0.1471	1.092624357
10	0	9.3	0.4641	36.22	0.1463	1.255709553
11	2	8.6	0.3494	35.01	0.1667	0.97804056
13	1	8.5	0.4166	34.25	0.1053	1.192023358
14	1	9.3	0.5	34.98	0.1111	1.400800457
24	1	9.9	0.4639	36.92	0.1429	1.231370531
27	1	6.9	0.3637	26.33	0.1212	1.353687809
28	0	8.8	0.47	31.8	0.1190	1.448427673
30	0	9.9	0.5	44.52	0.1364	1.100628931
34	1	9.8	0.62	44.52	0.1071	1.364779874
40	2	10.7	0.8007	51.81	0.1081	1.514545455
45	1	9.9	0.65	44.52	0.1017	1.43081761
51	0	10.0	0.4197	36.67	0.1667	1.121641669
71	0	8.9	0.65	38.16	0.0833	1.669287212
74	1	7.7	0.4618	29.48	0.0930	1.535156038
88	1	7.2	0.39	28.62	0.1143	1.335429769
96	0	7.3	0.3697	26.97	0.1212	1.343366704
109	0	9.9	0.65	47.7	0.1228	1.335429769
113	2	7.2	0.38	31.8	0.1515	1.171069182
115	2	5.8	0.2464	20.96	0.1364	1.152061069
117	2	7.3	0.37	28.62	0.1563	1.266946191
118	1	6.8	0.42	28.62	0.1053	1.438155136
122	1	8.7	0.46	41.34	0.15	1.090469279
128	2	6.8	0.35	25.44	0.125	1.34827044
132	2	6.5	0.35	25.44	0.0938	1.34827044
137	1	6.3	0.31	22.26	0.1111	1.364779874
140	1	6.6	0.32	22.26	0.1379	1.408805031
143	1	6.7	0.3942	25.09	0.0811	1.539721004
144	1	8.2	0.48	34.98	0.1163	1.344768439
148	0	7.3	0.38	25.44	0.1176	1.463836478

Flight Time of Mahogany Fruits

Seed No.	Flight time (s)
1	1.56
10	1.54
11	2.02
13	1.56
14	1.45
24	1.57
27	1.77
28	1.3
30	1.38
34	1.43
40	1.42
45	1.47
51	1.92
71	1.28
74	1.02
88	1.46
96	0.97
109	1.29
113	1.4
115	1.65
117	1.57
118	1.27
122	1.47
128	1.41
132	1.23
137	1.38
140	1.61
143	1.35
144	1.26
148	1.49

Appendix B

Statistical Analysis

Correlation between flight time and length

		Flight	Length
Flight time	Pearson Correlation	1.000	.133
	Sig. (2-tailed)	.	.483
	N	30	30
Length	Pearson Correlation	.133	1.000
	Sig. (2-tailed)	.483	.
	N	30	30

Correlation between flight time and mass

		Flight time	Mass
Flight time	Pearson Correlation	1.000	-.238
	Sig. (2-tailed)	.	.205
	N	30	30
Mass	Pearson Correlation	-.238	1.000
	Sig. (2-tailed)	.205	.
	N	30	30

Correlation between flight time and total surface area

		Flight time	Total Surface Area
Flight time	Pearson Correlation	1.000	.018
	Sig. (2-tailed)	.	.925
	N	30	30
Total Surface Area	Pearson Correlation	.018	1.000
	Sig. (2-tailed)	.925	.
	N	30	30

Correlation between flight time and square root of wing loading

		Flight time	Square root of wing loading
Flight time	Pearson Correlation	1.000	-.578
	Sig. (2-tailed)	.	.001
	N	30	30
Square root of wing loading	Pearson Correlation	-.578	1.000
	Sig. (2-tailed)	.001	.
	N	30	30

** Correlation is significant at the 0.01 level (2-tailed).

Correlation between flight time and the ratio of wing mass and seed mass

		Flight time	Ratio of wing mass and seed mass
Flight time	Pearson Correlation	1.000	.633
	Sig. (2-tailed)	.	.000
	N	30	30
Ratio of wing mass and seed mass	Pearson Correlation	.633	1.000
	Sig. (2-tailed)	.000	.
	N	30	30

** Correlation is significant at the 0.01 level (2-tailed).

One-Way Analysis of Variance (ANOVA) Table for flight time means of mahogany fruits with different curvatures (α=0.05)

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	Significance Level	Interpretation
Between Groups	8.225x10^{-2}	2	4.112 x10^{-2}	0.835	0.445	Not Significant
Within Groups	1.331	27	4.928 x10^{-2}			
Total	1.413	29				

Appendix C

Plates

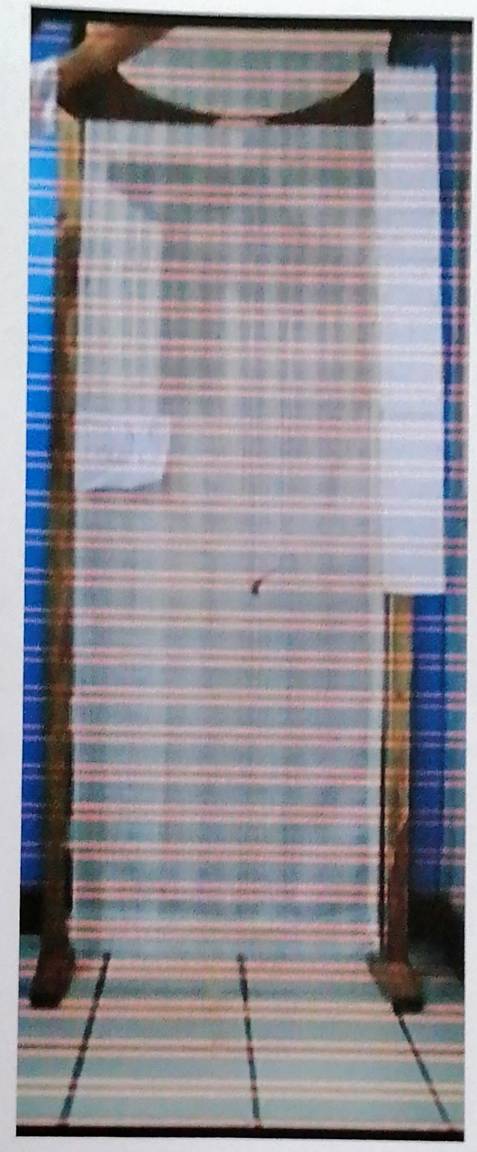

Plate 1. Dropping of mahogany fruit.

Plate 2. Measuring the length of mahogany fruit using a ruler.

Plate 3. Weighing of mahogany fruit.

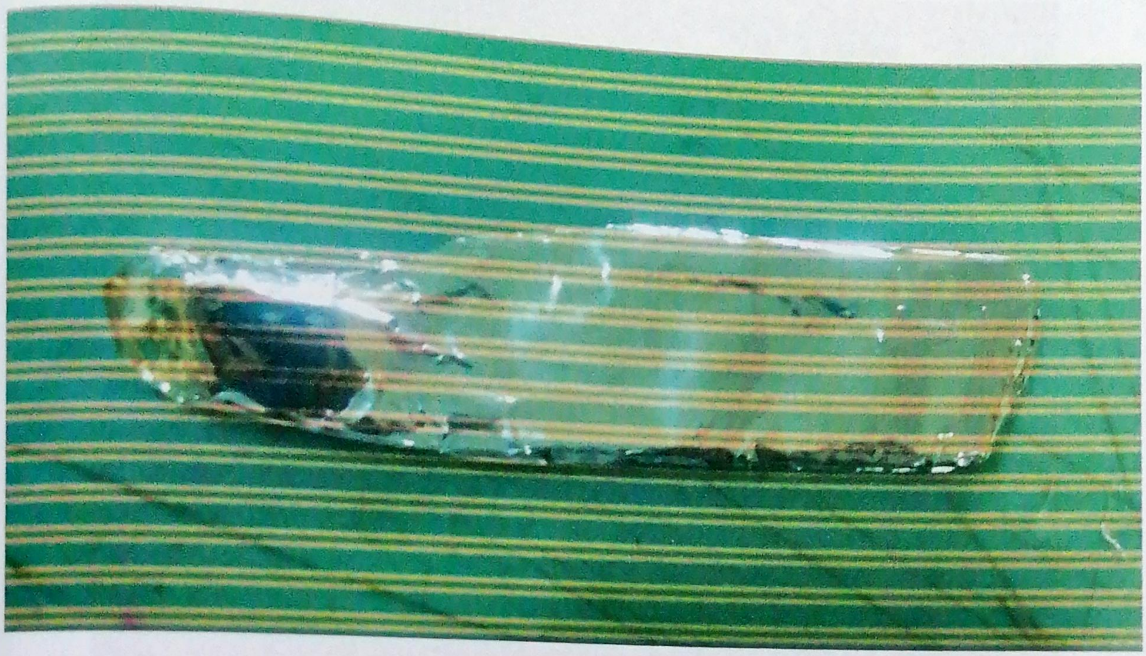

Plate 4. Covering the mahogany fruit with aluminum foil for surface area.

Plate 5. Weighing the seed part.

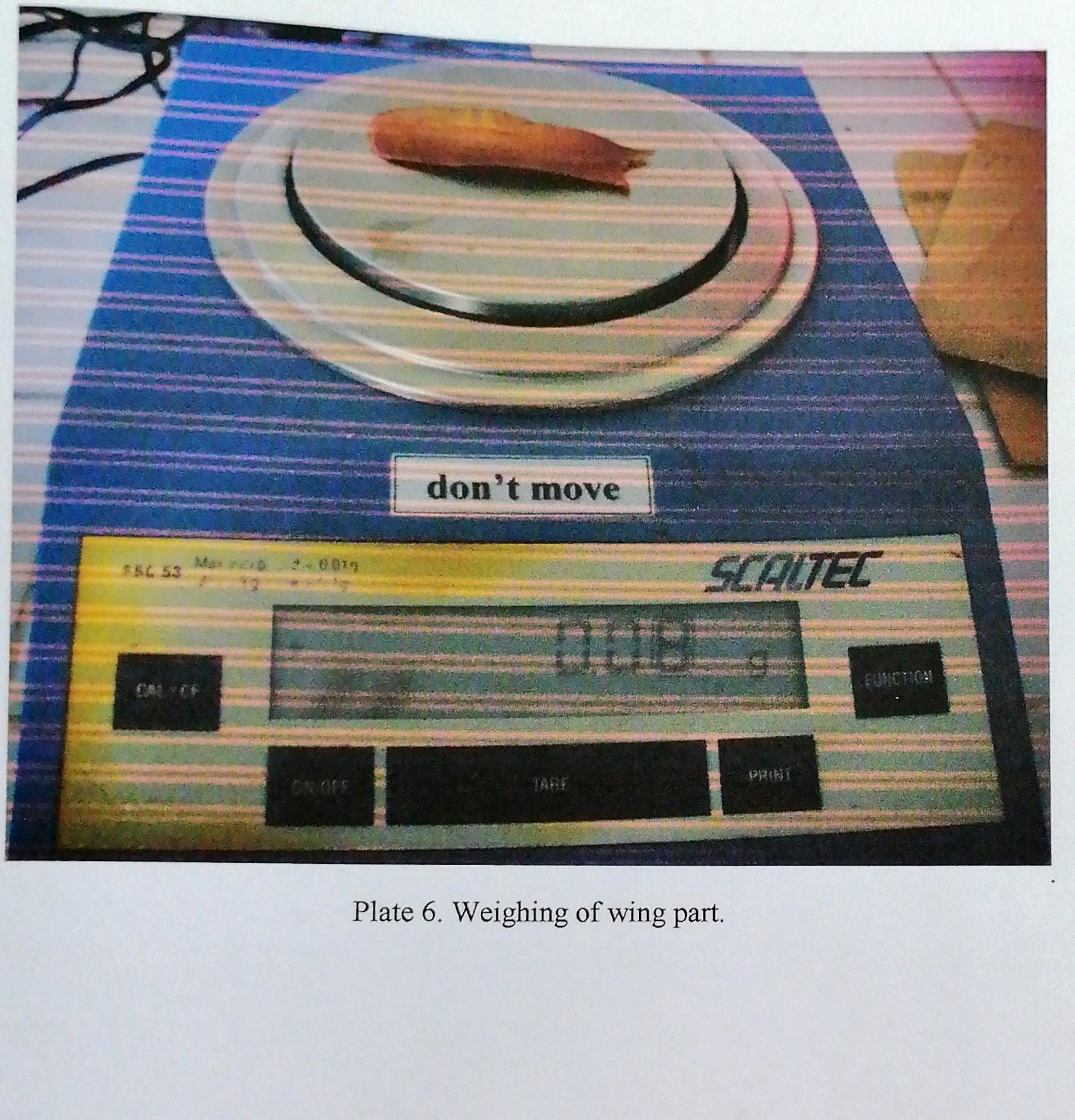

Plate 6. Weighing of wing part.