PHILIPPINE SCIENCE HIGH SCHOOL WESTERN VISAYAS
Doña Lawa-an H. Lopez Campus
Iloilo City

FOLDING ENDURANCE, OIL ABSORPTION, WATER RETENTION, TEXTURE AND MARKET ACCEPTABILITY OF PAPER FROM MANGO FRUIT FIBER

A Research Paper Presented to the
Faculty of Philippine Science High School Western Visayas
Iloilo City

In partial fulfillment
of the requirements in
Science Research II

By

Concepcion, Ariane L.
Labinghisa, Ruby S.
Pait, Ivy Grace U.

February 2004

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APPROVAL SHEET

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Concepcion, Ariane L., Labinghisa, Ruby S., Pait, Ivy Grace U. "Folding Endurance, Oil Absorption, Water Retention, Texture and Market Acceptability of Paper from Mango Fruit Fiber". Research Proposal. Philippine Science High School Western Visayas, Iloilo City, February 2004.

Abstract

This study in Completely Randomized Design determined the quality of paper made from mango fruit fibers in terms of folding endurance, oil absorption, water retention, texture and market acceptability. This study also determined the significant difference in the quality of the paper products made from different mango fiber-pulp concentrations, i.e., 25%-75% mango fiber-pulp, 50%-50% mango fiber-pulp, and 75%-25% mango fiber-pulp concentrations. Each treatment group underwent three (3) trials for each of quality test except that of texture and market acceptability tests which was subjected to panel judgment. In analyzing the data that was gathered from this study, the mean and standard deviation was used as descriptive statistical tools while the One-Way ANOVA was used as inferential statistical tool.

The results of this study showed that the mango fruit fiber was able to enhance the paper's folding endurance; however, the paper's texture is negatively affected as mango concentration is

increased.

As for the oil absorption and water retention abilities of the paper products, a specific mango fiber-pulp concentration is required to attain the best results. There was no evident relationship between the amount of mango fiber and the enhancement of the said abilities. And in this study, it was the 25%-75% mango fiber-pulp concentration for the oil absorption, and the 50%-50% mango fiber-pulp concentration for the water retention.

As judged by a panel of experts in paper products and marketing, not all mango fiber-pulp concentrations produce paper products that are excellent in texture and commercially competent. And in terms of the five measures of quality of paper products made from mango fiber, there was no specific mango fiber-pulp concentration whose quality is very similar to that of the commercial handmade paper.

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FOLDING ENDURANCE, OIL ABSORPTION, WATER RETENTION, TEXTURE AND MARKET ACCEPTABILITY OF PAPER FROM MANGO FRUIT FIBER

Chapter 1

Introduction to the Study

Background of the Study

Mango, *Mangifera indica L.*, is considered the most esteemed of all Philippine Fruits (Blanco, 1978). Its pale green and elongated kidney-shaped fruit is a common raw material for food products (Oligado, 1984). However, it is usually the flesh of the fruit which is eaten or processed. The skin is peeled off and often thrown away. The husk, which is the hard protection of the seed, is also not edible. Although they are biodegradable and could be good fertilizers for plants, these things we regard as wastes might actually be a raw material for the production of another important commodity: paper.

Paper is a widely used medium for written communication (Goetz, 1986). It is needed to publish books, print newspapers, or plainly just something to write on (Aguila, Alemani, Tirazona, 2002). And because of its importance, there is a high demand for it. However, fiber sources for paper production are gradually deteriorating so a need for new source of fiber arises.

The husk of the mango fruit is said to have fibers clinging to its surface (Morton, 1987). And in this study, the researchers tested the possibility of using mango fiber as an alternative fiber source for making paper. Mango samples were taken from the different markets of Iloilo and Guimaras. The researchers adopted the traditional hand papermaking process, which included beating, pulping and drying. They also designed a setup involving different concentrations of mango fiber.

It has been observed that the husks of mangoes are often thrown away. It challenged the researchers to find a potential use out of this leftover which contain abundant fibers. Since fibers can be used as a raw material for paper production, a papermaking process using mango as source of fiber and the quality analysis of the paper products was the main concern of this study.

The independent variables of this study were the different concentrations of the mango fiber and pulp for each treatment group. The dependent variables of this study were the quality of the paper product in terms of folding endurance, oil absorption, water retention, texture and market acceptability.

The relationship between these variables is presented in Figure 1.

Statement of the Problem and Hypothesis

This study aimed to determine the quality of paper products made from mango fruit fiber using different mango fiber-pulp concentrations.

Specifically it aimed to determine:

1. the (a) folding endurance, (b) oil absorption ability, (c) water retention ability, (d) texture and (e) market acceptability made from (1) 25%-75% mango fiber-pulp, (2) 50%-50% mango fiber-pulp, and (3) 75%-25% mango fiber-pulp concentrations.

2. the significant difference in the (a) folding endurance, (b) oil absorption ability, (c) water retention ability, (d) texture and (e) market acceptability made from (1) 25%-75% mango fiber-pulp, (2) 50%-50% mango fiber-pulp, and (3) 75%-25% mango fiber-pulp concentrations.

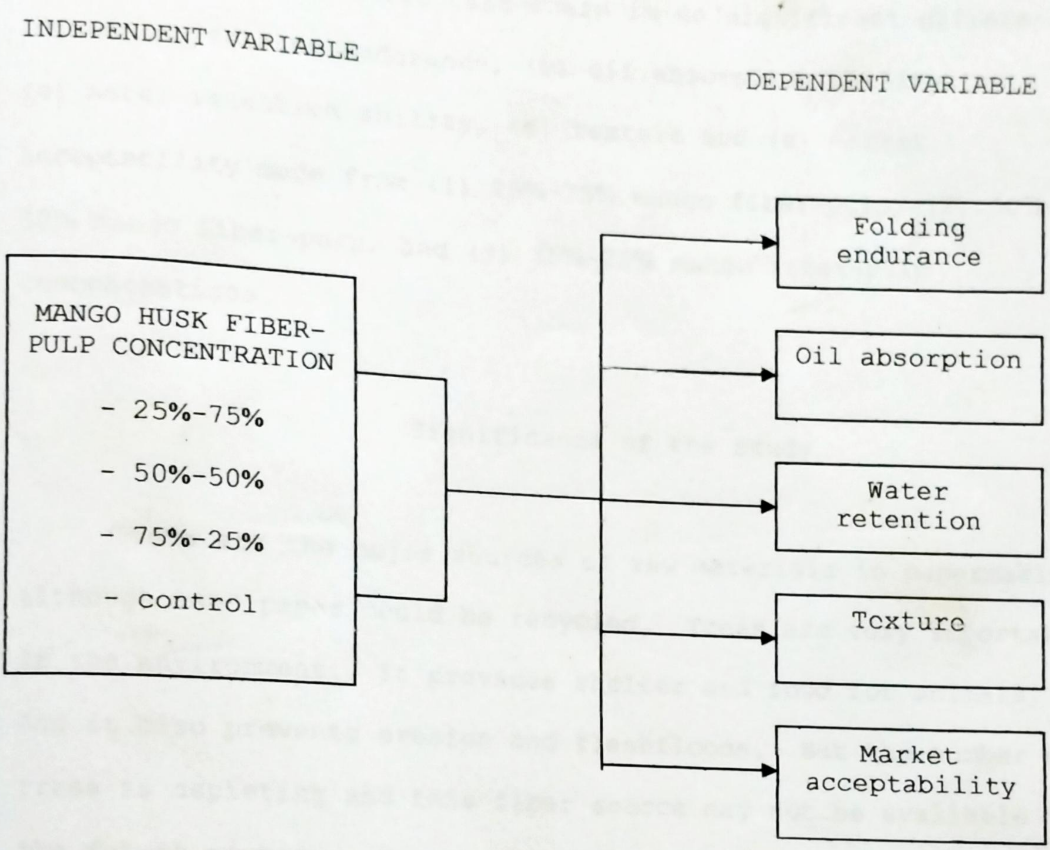

Figure 1. Quality of paper product made from different mango husk fiber-pulp concentration in terms of tearing strength, folding endurance, oil absorption, water retention, texture and market acceptability.

It was hypothesized that there is no significant difference in the (a) folding endurance, (b) oil absorption ability, (c) water retention ability, (d) texture and (e) market acceptability made from (1) 25%-75% mango fiber-pulp, (2) 50%-50% mango fiber-pulp, and (3) 75%-25% mango fiber-pulp concentrations.

Significance of the Study

Trees are the major sources of raw materials in papermaking although used paper could be recycled. Trees are very important in the environment. It provides shelter and food for animals. And it also prevents erosion and flashfloods. But the number of trees is depleting and this fiber source may not be available in the future anymore. Due to this, the supply of paper will fall.

By designing a papermaking process with mango husk as a source of fiber, not only were the researchers able to contribute in the preservation of the trees but also introduce a new fiber source to the paper industry. And granting that the quality of the paper product from mango husk fiber is comparable to that of the commercially available handmade paper, it could be sold at a lesser price because high capital is not needed. One will just utilize what's often thrown away. There will now be a use for low quality mango fruits which are in fact very fibrous and those that are overripe and can no longer be sold in the market.

Definition of Terms

The following terms used in this study are given their respective conceptual and operational meanings:

Concentration- is the amount of substance per unit volume in a solution; it is the amount of substance dissolved by a given quantity of the solvent (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "concentration" referred to the amount of substance per unit volume of the mango paper fiber and pulp, i.e., 25%-75% mango fiber-pulp, 50%-50% mango fiber-pulp, and 75%-25% mango fiber-pulp concentrations.

Fiber- is any hair like raw material directly obtainable from an animal, vegetable, or mineral source and convertible into nonwoven fabrics such as felt or paper (The New Encyclopedia Britannica, 1986).

In this study, the term "fiber" referred to the fibers clinging to the husk of the mango fruit.

[Folding] Endurance- is the capacity or power to endure, withstand or tolerate (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "folding endurance" referred to the ability of the paper product to resist damage when folded many times.

Market Acceptability- is the paper's ability to be fit for sale and to be chosen by the purchasers (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "market acceptability" referred to the potential of the paper product for marketing, as judged by a panel of experts on sales and marketing.

Oil absorption ability- is the act of absorbing or sucking up an amount of oil (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "oil absorption ability" referred to the time in minutes at which an amount of oil can be absorbed by the paper product. The longer time it takes the better the paper.

Paper- is a thin layer of intertwined fiber; it is a sheet of interlaced fibers-usually cellulose fibers from plants (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "paper" referred to the paper product from mango husk fibers.

Pulp- a mixture of wood fibers or rags, reduced to a pulpy consistency, and forming the basis from which paper is made (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "pulp" referred to the recycled paper pulp.

Quality- is a distinguishing element, condition or characteristic regarded in determining its relative goodness and value (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "quality" referred to the tearing strength, folding endurance, oil absorption, water retention, texture and market acceptability of the paper product.

Texture- is the arrangement or character of the threads of woven fabric; it is the mode of union or disposition of constituent parts with minute structure or structural order (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "texture" referred to the degree of smoothness of the paper product, as judged by a panel of experts on paper products.

Water retention ability- is the act of retaining, keeping up or maintaining of approximately same amount of water (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

In this study, the term "water retention ability" referred to the time in minutes at which the paper product dries up after being totally immersed in water. The shorter time it takes the better the paper.

Scope and Delimitation of the Study

This study designed a papermaking process with mango husk fiber as raw material. Although there are many different mango varieties in the Philippines, this study was conducted using mango varieties from Iloilo and Guimaras markets only. We limited ourselves to 25%-75% mango fiber-pulp, 50%-50% mango fiber-pulp, and 75%-25% mango fiber-pulp concentrations.

The paper products were then subjected to quality analysis tests that will only determine the papers' folding endurance, oil absorption, water retention, texture and market acceptability.

In analyzing the data that were gathered from this study, the mean and standard deviation were used as descriptive statistical tools while the One-Way ANOVA, set at 0.05 alpha level of significance, was used as inferential statistical tool.

This study was conducted at the Philippine Science High School Western Visayas research laboratory this school year 2003-2004.

Chapter 2

Review of Related Literature

This chapter consists of three topics, namely, (1) Paper, (2) Mango, (3) Papermaking Process, (4) Related Studies and Researches, and (5) Summary.

Paper

Paper is the basic material used for written communication and dissemination of information (Goetz, 1986). It is basically a sheet of interlaced cellulose fibers from plants, but sometimes from cloth rags or other fibrous materials. Used newsprints, spent packaging and other waste papers could serve as fiber sources (Aguila et al., 2002). Paper is formed by pulping the fibers and causing them to felt, or mat, forming a solid surface ready for writing (Goetz).

A Chinese, Ts'ai Lun, first made paper (Lorimer, 1981). He discovered that certain plant materials could be broken down into fibers and pressed into a sheet which made a good writing material. Specifically, he used vegetable fibers, tree bark, rags and old fish netting (Brown). Until the mid-1800s, most paper was handmade from rags or from grass such as hemp and esparto. Then it was discovered that paper could be made from wood pulp. Later, people realized that anything that has fibers can be used as raw material in making paper (Hunter, 1992). And so people sought other fiber sources for the demand for paper increased dramatically.

Mango

It is a matter of astonishment to many that the luscious mango, *Mangifera indica L.*, one of the most celebrated of tropical fruits, is a member of the family Anacardiaceae (Morton, 1987). It is native to Southern Asia, especially Burma and Eastern India. It spread early on to Malaya, Eastern Asia and Eastern Africa (Grisewood, 1995). The original wild mangoes were small fruits with scant, fibrous flesh, and it is believed that natural hybridization has taken place between *M. indica* and *M. sylvatica Roxb.* in Southeast Asia. Selection for higher quality has been carried on for 4,000 to 6,000 years and vegetative propagation for 400 years (Morton, 1987). The mango exists in two races, one from India and the other from the Philippines and Southeast Asia (Oligado, 1984). The Indian race is intolerant of humidity, has flushes of bright red new growth that are subject to mildew, and bears monoembryonic fruit of high color and regular form (Oligado). The Philippine race tolerates excess moisture, has pale green or red new growth and resists mildew. Its polyembryonic fruit is pale green and elongated kidney-shaped.

Mango trees are erect and fast growing with sufficient heat, and the canopy can be broad and rounded or more upright, with a relatively slender crown (Goetz, 1986). It is ultimately a large tree which grows up to 65 ft. The tree is long-lived with some specimens known to be over 300 years old and still fruiting. In deep soil the taproot descends to a depth of 20 ft, and the profuse, wide-spreading feeder roots also send down many anchor roots which penetrate for several feet.

The leaves are dark green above and pale below, usually red while young. The midrib is pale and conspicuous and the many horizontal veins distinct (Morton, 1987). Full-grown leaves may be 4 to 12-1/2 in. long and 3/4 in. wide, and are generally borne in clusters separated by a length of naked stem bearing no buds. These naked stems mark successive flushes of growth. Each flush of growth will harden off to a rich green color before the next flush of growth begins (Goetz, 1986).

The yellowish and reddish flowers are borne in inflorescences which appear at branched terminals, in dense panicles of up to 2000 minute flowers (Morton, 1987). These flowers respire a volatile substance, causing allergic and respiratory problems for some persons. Pollinators are flies, hoverflies and rarely bees. Few of the flowers in each inflorescence are perfect, so most do not produce pollen and are incapable of producing fruit. Pollen cannot be shed in high humidity and rain. Fertilization is also ineffective when night temperatures are below 55° F. Mangoes are monocots and self-fertile, so a single tree will produce fruit without cross-pollination. Polyembryonic types may not require pollination at all. Branches may be ringed to induce flowering, but the results are mixed (Morton).

The fruits grow at the end of a long, string-like stem (the former panicle), with sometimes two or more fruits to a stem. The fruits are 2 to 9 in. long and may be kidney-shaped, ovate, or (rarely) round. They range in size from 8 ounces to around 24 ounces. The flower scar at the apex is prominent, in some cultivars bulging from the fruit (Goetz). The skin is leathery, waxy, smooth, fairly thick, aromatic, and ranges from light or dark-green to clear yellow, yellow-orange, yellow and reddish-pink, or more or less blushed with bright or dark-red or purple-red, with fine yellow, greenish or reddish dots, and thin or thick whitish, gray or purplish bloom, when fully ripe (Morton, 1987). Some have a "turpentine" odor and flavor, while others are richly and pleasantly fragrant (Blanco, 1978). It is inedible and contains a sap that is irritating to some people, especially to their skin (Goetz, 1986). The flesh ranges from pale-yellow to deep orange. It is essentially peach-like but much more fibrous (in some seedlings excessively so-actually "stringy"). It is extremely juicy, with a flavor range from very sweet to subacid to tart (Morton, 1987). There is a single, longitudinally ribbed, pale yellowish-white, somewhat woody stone, flattened, oval or kidney-shaped, sometimes rather elongated. It may have along one side a beard of short or long fibers clinging to the flesh cavity, or it may be nearly fiberless and free. Within the stone is the starchy seed, monoembryonic (usually single-sprouting) or polyembryonic (usually producing more than one seedling). The quality of the fruit is based on the scarcity of fiber and minimal turpentine taste. It is impossible to distinguish true-to-type from zygotic seedlings from the same fruit (Goetz, 1986). Some seedlings produce numerous tiny, parthenocarpic fruits which fail to develop and abort (Morton, 1987). Mango trees tend to be alternate bearing (Goetz).

Papermaking Process

Improving and discovering new things in the line of papermaking did not stop from searching for other fiber sources. Papermaking machineries were invented to help in the mass production of paper (Aguila et al., 2002). And so after many years, the papermaking process evolved. Yet although almost all steps in papermaking have become highly mechanized, the basic process of papermaking has remained unchanged (Goetz). Paper pulp is the raw material for paper manufacturing. It contains vegetable, mineral or man-made fibers. It forms a matted or felted sheet on a screen when moisture is removed (Goetz). Handmade paper is done by separating the fibers from woods, grass, stalks and other materials. Papermakers promote the bonding of cellulose: a carbohydrate which is the chief constituent of plant cell walls. Tasteless and odorless, cellulose is a type of polymer, a relatively weighty compound of similar molecules often grouped end-to-end to form a chain. Plant fibers are thread-like accumulations of cellulose. Through soaking, beating, and sometimes chemically treating the plant materials, individual fibers can be separated and suspended in water. The fibers must also be bruised a bit to help the cellulose become hydrated. This hydration is ultimately responsible for the chemical bonding that happens once sheets are pulled, pressed, and dried (Hunter, 1998). Some of the most important sources of pulp aside from plant fiber are the fiber recovered from old papers, rags, and cardboard boxes (Goetz, 1986).

While some may think that the best paper comes from the mixture containing only pulped fiber and water, there are many beneficial chemical additives which are used in hand papermaking. These materials are added to the pulp either during the mixing stage or in the vat itself before sheet forming (Hunter, 1992a).

Most hand papermakers use dyes or pigments to change the color of a pulp. There are many different ways to color fiber and many variables involved in selecting the best method for a particular fiber and desired effect. In general, colorants are mixed in with pulp before it is added to the vat. Most pigments require an additive called a retention aid or agent to help them adhere to the fiber (Hunter, 1992b).

Other additives used in hand papermaking include fillers, whiteners and bleach. Fillers occupy some of the gaps between fibers in paper and make the paper somewhat dense and more opaque. They may also serve as buffering agents to make paper less acidic. Calcium Carbonate and Magnesium Carbonate are the most commonly used fillers. Whiteners, like Titanium Oxide, also end up in the spaces between fibers, but their specific purpose is to create a brighter finished sheet. Because both of these types of additives may inhibit fiber-to-fiber bonding, they may diminish the strength of paper made from pulp to which they have been added (Hunter, 1992b). Starch is another example of filler and it can also be used as an additive to enhance paper's resistance to water penetration (Baldiva, Lazaro, Liad, Villadoz, and Reyes, 1995). Bleach is used to whiten the fibers or the pulp itself (Webster's Comprehensive Dictionary Encyclopedic Edition, 1995).

Fibers are also boiled in solutions of caustic soda or NaOH in order to free the cellulose fibers from lignin (Austin, 1984). Lignin is a complex natural polymer that provides support and protects plant cells in woody plants (Lorimer, 1981).

Related Studies and Researches

A parallel study was conducted by Aguila, Alemani, and Tirazona (2002) entitled "Feasibility of Carabao Grass *Axonopus Compressus* as Substitute in Papermaking". They used 3 Treatments: Treatment A with 35% cogon grass and 65% newspaper pulp, Treatment B with 50% cogon grass and 50% newspaper pulp, Treatment C with 65% cogon grass and 35% newspaper pulp. Treatment A was the poorest paper. Treatment C was the best paper with highest results in breaking strength and water retention and Treatment B was the highest in Qualitative test. The results showed that Carabao grass, *Axonopus Compressus*, is feasible for papermaking.

Another study of Mejares, Olarte, and Lim (2002) entitled "The Feasibility of Sugarcane Leaves (*Saccharum officinarum*) as Fiber Source in Paper Production", used sugarcane leaves with NaOH solution, in different concentrations, to produce pulp. Products were tested in terms of their folding endurance, water retention and appearance. Paper with 40g starch and 40g aluminum sulfate has the highest folding endurance and the most water retention. They recommended using lower concentration of bleach because it affects the strength of paper causing it to be easily torn. Upon conducting the experiment, it was determined that sugarcane leaves can be used as fiber source in paper.

A research about "Comparative Study on the Physical Quality of Paper Produced from Cogon Grass (*Imperata cylindrica*) and Rice Stalk (*Oryza sativa*)" conducted by Diaz, Militar, and Pama (2002) compared the characteristics of produced paper and determined which of the two materials was more efficient to use. Their test results in firmness, oil retention and water retention showed that there was no significant difference in the paper produced from cogon grass and rice stalks except for their water retention.

The "Banana and Water Hyacinth Fibers as Wood Pulp Additives in Papermaking" study conducted by Callao, Palapag, Climaco, Dulnuan, and Segarra (1996) aims to produce quality paper from hardwood pulp mixed with additives from banana and water hyacinth. Samples with the highest water hyacinth concentration had the highest tearing strength. The presence of banana fibers in the pulp did not significantly affect the quality of paper samples. Their test results showed a significant difference in tearing strength but not in folding endurance among the experimental samples.

The study of Baldiva, Lazaro, Liad, Villadoz, Reyes (1995) entitled "Packaging Material from Corn Husks and Feathers", aimed to produce packaging paper from wastes such as corn husks and feathers. Powdered alum was added to give the bleached effect and starch and rosin to produce strongly bound fibers. After samples were tested by the panelist, according to strength, water retention and appearance, results showed that corn husks and feathers were feasible materials for the product packaging paper.

Summary

Paper is the basic material and foundation used for written communication and dissemination of information in today's industry. It is a sheet of interlaced cellulose fibers from plants, or any fibrous materials that are pulped and felted, forming a solid surface ready for writing.

Mango trees have dark green leaves at its crown and pale below, yellowish and reddish flowers, and fruits grow at the end of a long, string-like stem. Mango fruits, *Mangifera Indica L.*, are edible. Its husk, usually discarded, has fibers clinging on its surface. This could be used as a fiber source in paper production.

In papermaking, aside from pulp, chemical additives are added during the mixing stage, like dyes, pigments, and starch to enhance the quality of handmade paper.

Parallel studies were conducted by other groups of researchers using carabao grass (*Axonopus Compressus)*, sugarcane (*Saccharum officinarum*) leaves, and corn husks and feathers as fiber source in paper production. A comparative study was conducted about the physical quality of paper from cogon grass (*Imperata cylindrica*) and rice stalk (*Oryza sativa*), and about the feasibility of banana and water hyacinth fibers as additives in papermaking. These studies used additives as quality-enhancers and different concentration of pulps.

Chapter 3

Research Design and Methodology

This study aimed to determine the quality of paper products made from different mango fiber-pulp concentrations. It determined and compared the folding endurance, oil absorption ability, water retention ability, texture and market acceptability made from different mango fiber-pulp concentrations. It specifically determined whether significant differences exist in the above mentioned measures of quality of paper when the paper was made using different mango fiber-pulp concentrations.

It was hypothesized that there is no significant difference in the folding endurance, oil absorption ability, water retention ability, texture and market acceptability of the products, made from different mango fiber-pulp concentrations, i.e. 25%-75% mango fiber-pulp, 50%-50% mango fiber-pulp, and 75%-25% mango fiber-pulp.

The Research Design

This One-Spot Case Study determined the significant differences in the tearing strength, folding endurance, oil absorption, water retention, texture and market acceptability of the products, made from different mango fiber-pulp concentrations.

The study was composed of four (3) treatments, each representing the mango fiber-pulp concentrations, i.e., 25%-75% mango fiber-pulp, 50%-50% mango fiber-pulp, and 75%-25% mango fiber-pulp. Each treatment group underwent three (3) replicate testings for the folding endurance, oil absorption, water retention, while for the texture and market acceptability the treatment groups were subjected to jury analysis.

Data from the tests and jury analyses were subjected to appropriate statistical testings.

Materials and Equipment

The materials used in the study were mango husk fiber, wooden frame mounted with a screen, knife, scissors, basin, oil, water, sponge, rolling pin, used bond papers, cheese cloth, caustic soda, bleach, and starch. The equipment used were analytical balance, stirring rods, beakers, graduated cylinder, blender, hot plate and timers.

General Procedures

This study involved the following phases:

Removing the Fibers from the Mango

Mango husks were taken from various places in Iloilo and Guimaras. The husks were dried under the heat of the sun for 1-2 days. The fibers were then pulled out or scraped from the husk.

Papermaking

Pulping. The materials and equipment needed were prepared and set for the experiment. Used bond paper were shredded to bits for easier pulping and were further beaten to pulpy consistency using the blender.

The mango fibers were washed and were reduced to shorter lengths using the blender. Afterwards, they were boiled in a solution of 40 mL caustic soda in 1 L of water for least one (1) hour, and were washed again for several times.

Bleaching. The paper pulp and the mango fibers were bleached overnight using the commercial bleach Zonrox. For mango fibers that were not whitened after a day, an extension of another day was given.

Preparation. Different concentrations of mango fiber and paper pulp were prepared, i.e., 25%-75% mango fiber-pulp, 50%-50% mango fiber-pulp, and 75%-25% mango fiber-pulp. Each concentration was placed in a big basin containing water and starch at a ratio of 1.5 L:2 g.

Molding of Paper. To form a sheet of paper, the mold was dipped in the water edge first, until the edge was on the bottom at one side of the basin. The rest of the mold was slowly slipped to the bottom of the pulp solution screened side up.

Once the mold had settled to the bottom, a side-to-side motion was used to avoid trapping pulp between the screen and the bottom. The dilute pulp was agitated with the free hand and was firmly pulled up on the mold.

Drying and Removing Paper from Mold. The sponge was used to absorb water from the sheet in the mold. And the mold together with the paper was air-dried for several hours. The paper was then slowly peeled off from the mold edges first.

Quality Testing

Folding Endurance. This was conducted to test the resistance of the paper samples to folding. The paper samples made from different mango fiber-pulp concentrations and the control, which is the commercial handmade paper, were folded in the middle and then opened. This process was repeated fifty (50) times. The paper samples were ranked according to the degree of damage, with 1 as the least damage and 4 as the most damaged.

Oil absorption. This was determined by measuring the time, in minutes, it took for the paper samples made from different mango fiber-pulp concentrations and the control, which is the commercial handmade paper to totally absorb 0.5 mL of oil.

Water retention. Water retention was tested by totally immersing the paper samples made from different mango fiber-pulp concentrations and the control, which is the commercial handmade paper into the water. The paper samples were hanged and dried outdoor. The time it took, in minutes, for the paper samples to totally dry up was recorded.

Texture. The texture of the paper samples was determined by subjecting the paper samples made from different mango fiber-pulp concentrations and the control, which is the commercial handmade paper to a panel of five (5) experts on paper products and marketing. A survey was conducted, rating the texture of the paper samples ranging from the smoothest, as one (1), average as three (3), and the roughest, as five (5).

Market Acceptability. The market acceptability of the paper samples was determined by subjecting the paper samples made from different mango fiber-pulp concentrations and the control, which is the commercial handmade paper to a panel of five (5) experts on paper products and marketing. A survey was conducted, rating the market acceptability of the paper samples ranging from the highest acceptability level, as one (1), average as three(3), and the lowest acceptability level, as five (5).

Statistical Data Analysis

Data gathered from this study was treated statistically, with the mean and the standard deviation as descriptive statistical tools, and the One-Way Analysis of Variance (ANOVA), set at 0.05 alpha level of significance, as inferential statistical tool.

The mean was employed to express the average of all values gathered after the quality testings of paper products made from the different concentration and the control, while the standard deviation was employed to evaluate the spread of the individual independent values from their respective means.

The One-Way ANOVA was employed to determine the significant differences in the strength, oil absorption ability, water retention ability, texture, market acceptability and folding endurance of the paper product made from different mango fiber-pulp concentrations. The Scheffe test was employed as a post hoc multiple comparison test.

Chapter 4

Results

This study aimed to determine the quality of paper products made from different mango fiber-pulp concentrations. It determined and compared the folding endurance, oil absorption ability, water retention ability, texture and market acceptability made from different mango fiber-pulp concentrations. It specifically determined whether significant differences exist in the above mentioned measures of quality of paper when the paper was made using different mango fiber-pulp concentrations.

It was hypothesized that there is no significant difference in the folding endurance, oil absorption ability, water retention ability, texture and market acceptability of the products, made from different mango fiber-pulp concentrations, i.e. 25%-75% mango fiber-pulp, 50%-50% mango fiber-pulp, and 75%-25% mango fiber-pulp.

Folding Endurance of Paper Products made from Different Mango Fiber-Pulp Concentrations

Among the paper samples tested for folding endurance, the control ranked first (1.00) followed by the 75%-25% mango fiber-pulp (2.00). The 50%-50% mango fiber-pulp concentration ranked third (3.33), closely followed by the 25%-75% mango fiber-pulp concentration (3.67).

Table 1 shows the data.

Oil Absorption Ability of Paper Products made from Different Mango Fiber-Pulp Concentrations

Among the paper samples tested for oil absorption, the 50%-50% absorbed oil the fastest with the mean time of 1.34 minutes, while the 25%-75% mango fiber-pulp concentration absorbed oil the slowest with the mean time of 2.75 minutes.

Table 1 shows the data.

Table 1

Means of folding endurance, oil absorption ability, water retention ability, texture and market acceptability of paper made from different mango fiber-pulp concentrations

Paper	Samples	Folding Endurance	Market Acceptability	Oil Absorption	Texture	Water Retention
25%-75%	Mean	3.67	1.40	2.75	1.20	17.33
	N	3	5	3	5	3
	Std. Deviation	0.58	0.89	0.38	0.45	8.39
50%-50%	Mean	3.33	2.80	1.34	3.40	16.33
	N	3	5	3	5	3
	Std. Deviation	0.58	0.45	0.15	0.55	1.53
75%-25%	Mean	2.00	2.60	1.71	3.00	25.67
	N	3	5	3	5	3
	Std. Deviation	0.00	0.55	0.27	0.00	3.79
Control	Mean	1.00	2.60	2.22	3.20	14.67
	N	3	5	3	5	3
	Std. Deviation	0.00	1.52	0.19	1.3	2.08

Water Retention Ability of Paper Products made from Different Mango Fiber-Pulp Concentrations

Among the paper tested for water retention, the control dried up the fastest with the mean time of 14.67 minutes. The 75%-25% mango fiber-pulp concentration dried up the slowest with the mean time of 25.67 minutes.

Table 1 shows the data.

Texture of Paper Products made from Different Mango Fiber-Pulp Concentrations

Among the paper samples tested for texture, the 25%-75% mango fiber-pulp concentration was ranked as having the smoothest texture (1.20), followed by the 75%-25% mango fiber-pulp concentration (3.00) and the control (3.20) respectively. The 50%-50% mango fiber-pulp concentration was chosen as the roughest (3.40).

Table 1 shows the data.

Market Acceptability of Paper Products Made from Different Mango Fiber-Pulp Concentrations

Among the paper samples tested for market acceptability, the 25%-75% mango fiber-pulp concentration was the most commercially acceptable (1.40), followed by both the control and 75%-25% mango fiber-pulp concentration (2.60). The least commercially acceptable was the 50%-50% mango fiber-pulp concentration (2.80).

Significant Difference in the Folding Endurance of Paper Products made from Different Mango Fiber-Pulp Concentrations

According to One-Way ANOVA, there was a significant difference between the folding endurance of the paper samples, as reflected by $\underline{F}(3) = 27.33$, $\underline{p} < 0.05$.

Table 2 shows the data.

Since One-Way ANOVA shows there was a significant difference, the Scheffe test was conducted to specifically determine among what concentrations this difference existed. It was found out that there was significant difference in the folding endurance of the mango fiber-pulp concentrations 25%-75% vs.75%-25%, 50%-50% vs.75%-25%, the control vs. 25%-75% and

Table 2

One-Way ANOVA of folding endurance, oil absorption ability, water retention ability, texture, and market acceptability of paper made from different mango fiber-pulp concentrations

		Sum of Squares	df	Mean Square	F	Sig.
Folding Endurance	Between Groups	13.67	3	4.56	27.33	0.000
	Within Groups	1.33	8	0.17		
	Total	15.00	11			
Oil Absorption	Between Groups	3.37	3	1.12	16.88	0.001
	Within Groups	0.54	8	0.07		
	Total	3.91	11			
Water Retention	Between Groups	216.33	3	72.11	3.16	0.086
	Within Groups	182.67	8	22.83		
	Total	399.00	11			
Texture	Between Groups	15.4	3	5.13	9.33	0.001
	Within Groups	8.80	16	0.55		
	Total	24.20	19			
Market Acceptability	Between Groups	6.15	3	2.05	2.28	0.119
	Within Groups	14.40	16	0.90		
	Total	20.55	19			

the control vs. 50%-50%, as reflected by their $p < 0.05$. This shows that the 75%-25% mango fiber-pulp concentration and the control are better than the 50%-50% and 25%-75% mango fiber-pulp concentrations. And since there is no significant difference between the control and 75%-25% mango fiber-pulp concentration, their oil absorption is comparable.

Table 3 shows the data.

Significant Difference in the Oil Absorption of Paper Products made from Different Mango Fiber-Pulp Concentrations

According to One-Way ANOVA, there was a significant difference between the oil absorption of the different paper samples, as reflected by $F(3) = 16.68$, $p < 0.05$.

Table 2 shows the data.

Since One-Way ANOVA shows there was significant difference, the Scheffe test was conducted to specifically determine among what concentrations this difference existed. It was found out that there was significant difference in the oil absorption of the mango fiber-pulp concentrations 25%-75% vs. 50%-50%, 25%-75% vs.75%-25%, and the control vs. 50%-50%, as reflected by

Table 3

Results of the Scheffe test for the folding endurance of paper samples

Paper Samples	Mean Difference	Standard Error	Sig.
25%-75% vs. 50%-50%	0.33	0.33	0.802
25%-75% vs.75%-25%	1.67	0.33	0.008
50%-50% vs.75%-25%	1.33	0.33	0.00
control vs. 25%-75%	2.67	0.33	0.026
control vs. 50%-50%	2.33	0.33	0.001
control vs. 75%-25%	1.00	0.33	0.095

their $p < 0.05$. This shows that the paper product made from 50%-50% is even better than the control. And since there is no significant difference between the control and 25%-75% mango fiber-pulp concentration, their folding endurance is very comparable.

Table 4 shows the data.

Table 4

Results of the Scheffe test for the oil absorption of paper samples

Paper Samples	Mean Difference	Standard Error	Sig.
25%-75% vs. 50%-50%	1.41	0.21	0.001
25%-75% vs.75%-25%	1.03	0.21	0.009
50%-50% vs.75%-25%	0.53	0.21	0.184
control vs. 25%-75%	0.37	0.21	0.428
control vs. 50%-50%	0.88	0.21	0.021
control vs. 75%-25%	0.51	0.21	0.207

Significant Difference in the Water Retention of Paper Products made from Different Mango Fiber-Pulp Concentrations

According to One-Way ANOVA, there was no significant difference between the water retention of the different paper samples, as reflected by $\underline{F}(3) = 3.16$, $\underline{p} > 0.05$.

Table 2 shows the data.

Since One-Way ANOVA shows that there was no significant difference, the water retention of the paper samples are very comparable.

<u>Significant Difference in the Texture of Paper Products made from Different Mango Fiber-Pulp Concentrations</u>

According to One-Way ANOVA, there was a significant difference between the texture of the different paper samples, as reflected by $\underline{F}(3) = 9.33$, $\underline{p} < 0.05$.

Table 2 shows the data.

Since One-Way ANOVA showed there was a significant difference, the Scheffe test was conducted to specifically determine among what concentrations this difference existed. It was found out that there was significant difference in the texture of the mango fiber-pulp concentrations 25%-75% vs. 50%-50%, 25%-75% vs.75%-25% and the control vs. 25%-75%, as reflected by their $\underline{p} < 0.05$. This shows that the 25%-75% mango fiber-pulp concentration is the best among the other mango fiber-pulp concentrations. And since there is no significant difference between the 50%-50% mango fiber-pulp concentration, 75%-25% mango fiber-pulp concentration and control, their oil absorption is comparable.

Table 5 shows the data.

Table 5

Results of the Scheffe test for the texture paper samples

Paper Samples	Mean Difference	Standard Error	Sig.
25%-75% vs. 50%-50%	2.20	0.47	0.003
25%-75% vs.75%-25%	1.80	0.47	0.013
50%-50% vs.75%-25%	2.00	0.47	0.006
control vs. 25%-75%	0.40	0.47	0.865
control vs. 50%-50%	0.20	0.47	0.980
control vs. 75%-25%	0.20	0.47	0.980

Significant Difference in the Market Acceptability of Paper Products made from Different Mango Fiber-Pulp Concentrations

According to One-Way ANOVA, there was no significant difference between the market acceptability of the different paper samples, as reflected by $F(3)=2.28$, $p>0.05$.

Table 2 shows the data.

Since One-Way ANOVA shows that there was no significant difference, the market acceptability of the paper samples are very comparable.

Chapter 5

Summary, Conclusions and Recommendations

This study aimed to determine the quality of paper products made from mango fruit fiber using different mango fiber-pulp concentrations.

Specifically it aimed to determine:

1. the (a) folding endurance, (b) oil absorption ability, (c) water retention ability, (d) texture and (e) market acceptability made from (1) 25%-75% mango fiber-pulp, (2) 50%-50% mango fiber-pulp, and (3) 75%-25% mango fiber-pulp concentrations.

2. the significant difference in the (a) folding endurance, (b) oil absorption ability, (c) water retention ability, (d) texture and (e) market acceptability made from (1) 25%-75% mango fiber-pulp, (2) 50%-50% mango fiber-pulp, and (3) 75%-25% mango fiber-pulp concentrations.

It was hypothesized that there is no significant difference in the (a) folding endurance, (b) oil absorption ability, (c) water retention ability, (d) texture and (e) market acceptability made from (1) 25%-75% mango fiber-pulp, (2) 50%-50% mango fiber-pulp, and (3) 75%-25% mango fiber-pulp concentrations.

Summary

The findings of this study are summarized as follows:

1. a. In terms of folding endurance, the paper product made from 75%-25% mango fiber-pulp concentration provided the best results, although it is only second the control.

1.b. In terms of oil absorption, the paper product made from 50%-50% mango fiber-pulp concentration provided the best results.

1.c. In terms of water retention, the paper product made from 50%-50% mango fiber-pulp concentration provided the best results, although it was only second to the control.

1.d. In terms of texture, the paper product made from 25%-75% mango fiber-pulp concentration provided the best results.

1.e. In terms of market acceptability the paper product made from 25%-75% mango fiber-pulp concentration provided the best results.

2.a. There was no significant difference in the folding endurance the paper product made from 75%-25% mango fiber-pulp and the control. This shows that even though the product made from 75%-25% mango fiber-pulp ranked second, it is very comparable to the control in terms of folding endurance.

2.b. There was a significant difference in the oil absorption of the paper product made from 50%-50% mango fiber-pulp and the control. This shows that the paper product made from 50%-50% mango fiber-pulp is better in terms of oil absorption.

2.c. There was no significant difference in the water retention ability of the paper samples, so in terms of the mentioned measures of quality, they are very much comparable.

2.d. There was a significant difference in the texture of the paper product made from 25%-75% mango fiber-pulp and the control. This shows that the paper product made from 25%-75% mango fiber-pulp is better in terms of texture.

2.e. There was no significant difference in the market acceptability of the paper samples, so in terms of the mentioned measures of quality, they are very much comparable.

Conclusions

The researchers were successful in producing paper from mango fruit fiber in 25%-75%, 50%-50% and 75%-25% mango fiber-pulp concentrations.

The results of this study showed that the mango fruit fiber was able to enhance the paper's folding endurance; however, the paper's texture is negatively affected as mango concentration is increased.

As for the oil absorption and water retention abilities of the paper products, a specific mango fiber-pulp concentration is required to attain the best results. There was no evident relationship between the amount of mango fiber and the enhancement of the said abilities. And in this study, it was the 25%-75% mango fiber-pulp concentration for the oil absorption, and the 50%-50% mango fiber-pulp concentration for the water retention.

As judged by a panel of experts in paper products and marketing, not all mango fiber-pulp concentrations produce paper products that are excellent in texture and commercially competent. And in terms of the five measures of quality of paper products made from mango fiber, there was no specific mango fiber-pulp concentration whose quality is very similar to that of the commercial handmade paper.

Recommendations

The researchers would like to recommend the use of mango fibers to enhance folding endurance.

Parallel studies could also be conducted about the use of other mango fiber-pulp concentrations to determine if these concentrations might provide even better results.

Other additives could also be used to further promote the quality of paper made from mango fiber, such as resin which enhances paper's resistance to water penetration.

The researches would also recommend the determination of the tearing strength of the paper products made from mango fiber, since the researchers were unable to conduct this test. It would be very helpful in finding out if the paper product is durable.

Parallel studies could also be conducted regarding the enhancement of the paper's texture as mango fiber concentration is increased.

The 25%-75% mango fiber-pulp concentration is recommended to be used in paper products intended for invitations and decorative purposes.

The 50%-50% and 75%-25% mango fiber-pulp concentrations are recommended to be used in paper products intended for support and packaging, as well as for decorative purposes.

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