THE UTILIZATION OF OIL PALM EMPTY FRUIT BUNCHES (OPEFB) FOR BIODEGRADABLE POT'S RAW MATERIALS AS AN ALTERNATIVE CONTAINER FOR SUSTAINABLE NURSERIES

BACHELOR`S THESIS

by:
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175100200111014

AGRICULTURAL ENGINEERING DEPARTMENT
FACULTY OF AGRICULTURAL TECHNOLOGY
BRAWIJAYA UNIVERSITY
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As One of The Requirements for Obtaining A Bachelor`s Degree in Engineering

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APPROVAL PAGE

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BIOGRAPHY

The author was born on 8th June 1999 at Ngawi, East Java. Her father was Istangin and her mother was Istiqomah. The author spent her childhood in Aisyah Kindergarten, and started her study at SDN 1 Kedunggudel Elementary School and graduated in 2011, then continued her study at SMPN 1 Widodaren Junior High School and graduated in 2014. The Author was graduated from the SMAN 1 Widodaren Senior High School in 2017. In the same year, the author passed the SBMPTN selection for Agricultural and Biosystem Engineering Study Progam of Brawijaya University in Malang. During college, the author was active in several student organizations and committees, such as UAKI (Unit Aktivitas Kerohanian Islam), Forkita (Forum Kajian Islam Fakultas Teknologi Pertanian), HIMATETA, KERABAT 2017, HARMONI 2018, PEMILWA 2018, and ICGAB (International Conference on Green Agroindustry and Bioeconomy) 2019.

In the academic field, the author had passed for the PKM-KC in 2019 by the Ministry of Education of Indonesia. And in the same year, the author became the top 10 finalists for Technology Innovation in Malang and won a gold award in International Youth Scientific Seminar and Expo. The author also had the opportunity to take part in the Sakura Exchange Program at Miyazaki University, Japan. And in 2020 the author passed the palm oil research funding by BPDPKS (Badan Pengelola Dana Perkebunan Kelapa Sawit). In addition, the author had also been an assistant of laboratory activities for food processing and agricultural products engineering courses.

DEDICATION

Alhamdulillah ala kulli hal. Thank you Allah for everything you have given and taken from me, for all blessings that I am unable to thank you. Many thanks go to my besties, Dhita, Vira, Tsania, Grace, I am blessed to have you all in my life guys. To all BE (English class) squad, you are such precious persons, thank you for all the memorable memories you have been shared. I would also send much thanks to Mr. Phoe and family for enthusiastically supporting me. I greatly benefited from the discussions and the ideas about hopes, dreams, and hard work. And of course, for Tsukishima Kei, you have made my day going better day by day, by just simply existing

I dedicated this thesis to all my family members, for my amazing father, Istangin, for my beloved mom, Istiqomah, for my sister Mariana Hidayati, for my brothers Nur Ali Mustofa and Ahmad Ibnu Syafi`i and for my cutie little sister Laila Maftukhatu Rosyidah. Thank you for always supporting me no matter what. Throughout this effort, my parents are a source of inspiration, kind help, steady supporters, and impressive, hardworking human beings..!!

Last but not least, I dedicated this lovely work to myself. Thank you for having been strong to face every challenge on your path in order to set up the goals. Just continue to chase your dreams, Zub! No matter what happens or how challenging the situations are. I learned that I have had to believe in myself, my ideas, and my dreams in order to accomplish the goals I have set out, and I need to always believe that:

"I have to do something today that my future Zub will be proud of"

"We`re not hung up winning or losing in this life, but we`re craving for the process"

-Tsukishima Kei-

STATEMENT LETTER

I, the undersigned below:

Name of Student	:	Zubaidah Widya Putri
NIM	:	175100200111014
Program Study	:	Agricultural and Biosystem Engineering
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Hereby state that,

The Thesis was originaly work of the author above. If in the future it is proven that this statement is not true, I am willing to be prosecuted according to the applicable law.

Malang, 27th Mei, 2021

Sincerely,

Zubaidah Widya Putri
NIM. 175100200111014

ZUBAIDAH WIDYA PUTRI. 175100200111014. Oil Palm Empty Fruit Bunches (OPEFB) for Biodegradable Pot`s Raw Materials as An Alternative Container for Sustainable Nurseries. Bachelor`s Thesis. Supervisors: Dr. Ir. Musthofa Lutfi, MP and Darmanto. ST, MT.

SUMMARY

The lack of management of Oil Palm Empty Fruit Bunches (OPEFB) waste harmed the development of the palm oil industries in the global market, whereas OPEFB contained high cellulose fiber and nutrients that could be used as raw material for biodegradable pots as an alternative container for sustainable nurseries. Recently the agriculture cultivation activities were still oriented on the use of polybags, which provided a negative impact to crops as well as to the environment. The former nursery polybags became a source of plastic wastes from the agricultural sector. Besides, the use of polybags had the potential to reduce the level of plant tolerance to drought, cause roots damage, and bring difficulty in the transplanting process. This research aims to determine the effect of the biopot`s materials composition and the effect of the addition of NaOH with different concentrations on the physicomechanical properties of biopots. The research method used in this research was an experimental method with a Factorial Completely Randomized Design (CRD), and the two factors used were the mass ratio of OPEFB to banana stems as raw materials, namely 100%:0%, 80%:20%, 60%:40%, 40%:60%, and 0%:100%. The concentrations of NaOH used were 3%, 5%, and 7%. An observation was done on biopots including the mass, moisture content, water uptake, biodegradation test, and tensile strength test. The results show biodegradable pots have a mass range from 9.58-18.48 grams, moisture content of 50.42%-65.89%, water uptake of 2.72%-4.82%, biodegradation potential of 40.54%-76.39%, and tensile strength of 8091-23418 Pa. The treatment combination of R2C2 (80% OPEFB: 20% banana stems; 5% NaOH) is the best treatment formulation due to having faster biodegradability also can support the durability of biodegradable pots through high tensile strength and water resistance. However, the fiber density of biodegradable pots needs some improvement caused by irregular fiber dispersion inside biodegradable pots.

Key Words: Oil Palm Empty Fruit Bunches (OPEFB), Banana Stems, Biodegradable Pots (Biopots), NaOH, Nurseries Container

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RINGKASAN

Kurangnya pengolahan limbah Tandan Kosong Kelapa Sawit (TKKS) menghambat perkembangan industri kelapa sawit di pasar global, padahal TKKS memiliki serat selulosa dan unsur hara yang tinggi sehingga dapat digunakan sebahan bahan baku Pot Biodegrdadable sebagai alternatif wadah pembibitan perkelanjutan. Terlebih saat ini kegiatan budidaya pertanian masih berorientasi pada penggunaan polybag yang memberikan dampak negatif bagi tanaman maupun lingkungan. Polybag bekas pembibitan menjadi sumber sampah plastik dari sektor pertanian. Selain itu, penggunaan polybag berpotensi menurunkan tingkat toleransi tanaman terhadap kekeringan, merusak akar, dan mempersulit proses pindah tanam. Penelitian ini bertujuan untuk mengetahui pengaruh komposisi bahan baku Biopot dan pengaruh penambahan NaOH dengan konsentrasi yang berbeda terhadap sifat fisiko-menanik Biopot. Metode penelitian yang digunakan dalam penelitian ini adalah metode eksperimen dengan Rancangan Acak Lengkap (RAL) Faktorial, dengan dua faktor yang digunakan yaitu perbandingan massa TKKS terhadap batang pisang sebagai bahan baku sebesar 100%:0%, 80%:20%, 60%:40%, 40%:60%, dan 0%:100%. Konsentrasi NaOH yang digunakan adalah 3%, 5%, dan 7%. Pengamatan dilakukan pada biopot meliputi massa, kadar air, water *uptake*, uji biodegradasi, dan uji kuat tarik. Hasil penelitian menunjukkan pot biodegradable memiliki rentang massa 9.58-18.48 gram, kadar air 50.42%-65.89%, water uptake 2.72%-4.82%, potensi biodegradasi 40.54%-76.39%, dan kuat tarik 8091-23418 Pa. Kombinasi perlakuan R2C2 (80% TKKS: 20% batang pisang; 5% NaOH) merupakan formulasi perlakuan terbaik karena memiliki biodegradabilitas yang lebih cepat juga dapat mendukung daya tahan pot biodegradable melalui kekuatan tarik yang tinggi dan ketahanan terhadap air. Namun, pada kerapatan dinding pot biodegradable memerlukan beberapa perbaikan akibat dari dispersi serat yang tidak merata.

Kata Kunci: Tandan Kosng Kelapa Sawit (TKKS), Batang Pisang, Pot Biodegradable (Biopots), NaOH, Wadah Pembibitan

PREFACE

All praises are to Allah SWT, the Merciful, the All – Beneficient, and also prayers and peace be upon Prophet Muhammad SAW. Only by His Grace and Blessings, the author could finish writing the thesis with the title “Oil Palm Empty Fruit Bunches (OPEFB) for Biodegradable Pot`s Raw Materials as An Alternative Container for Sustainable Nurseries. The author would like to thank to:

1. Dr. Ir. Musthofa Lutfi, MP as Head of Agricultural and Biosystem Study Program, as well as the fisrt supervisor who has guided and directed the author.
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4. Dr. Eng. Akhmad Adi S. STP., MT., M.Eng as the Head of Agricultural Engineering Department, Brawijaya University.
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8. All colleagues who give encouragement and supports.

The author hopes this thesis will be useful for anyone and any institution who is working in this field.

Malang, 27th Mei, 2021

Author

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PICTURES

LIST OF APPENDICES

CHAPTER I INTRODUCTION

1.1 Background

Oil palm (*Elaeis guineensis*) is a plantation commodity with a large amount of production and consumption in the world. Concerning the above condition, Indonesia was the largest producer of oil palm by contributing 58% or as much as 43.5 million tons to total production in the world (United States Department of Agriculture, 2020). It is recorded that the total area of oil palm plantations reached up to 14.3 million hectares with total CPO (Crude Palm Oil) production of 42.9 tons in 2018 and is predicted will increase continuously in the following years (Directorate General of Ministry of Agriculture of Republic Indonesia, 2019). As a commodity that is consumed globally, the CPO commodity became the mainstay industry that contributed most significantly to Indonesia`s economy with increasing national income and foreign exchange, which can be viewed from the value of CPO exports were worth US$ 17.46 billion in 2014 (Rame,2018).

However, the development of the palm oil industry in the global market is still constrained by the issue of a black campaign regarding the environment, sustainability, and society. One of the crucial aspects that are closely related to the environment is oil palm waste management. According to Dewanti (2018), there was at least 23% waste of oil palm empty fruit bunches (OPEFB) of Indonesia`s total palm oil production, yet the handling of OPEFB waste only reached 10% of the total waste generated. On the other hand, non-strategic management and utilization of OPEFB waste can leave large emissions, which might potentially harm oil palm land and even have an effect on the environmental system (Rame, 2018). The availability of OPEFB will increase in line with the increasing production of Fresh Fruit Bunches (FFB). The utilization of OPEFB as one of the largest wastes of the palm oil industry needs to be done to increase productivity, added value, efficiency, and to have principles of environmental sustainability. Based on the chemical structures, OPEFB contained 38.76% cellulose, with fiber content reaching 72.67% (Dewanti, 2018). OPEFB could improve the physical, chemical, and biological performance of soil characteristics. In addition, OPEFB contained nutrients such as N (1.91%), K (1.51%), Ca (0.83%), P (0.54%), and Mg (0.09%) (Hayat and Andayani, 2014). The existence of cellulose and high nutrients cause oil palm empty fruit bunches to have the potential to be used as biodegrdable pots raw material.

According to Supraptiningsih (2012), other organic wastes that were abundant and affordable in the community environment were banana stems. This is because banana stems were underutilization by society after harvesting process. In general, banana stems are processed as animal feed or used as fertilizer. Banana stems as organic waste could be used as an economical and potential source of natural fiber, because it had fairly high cellulose content, up to 65% (Jaya, 2011). Isolation of cellulose from natural fibers could be carried out using alkaline treatment (NaOH) by degrading the lignin content in the lignocellulosic structure of the fibers, thereby improving the quality and phycomechanical properties of the fibers (Fitriasari *et al.*, 2019).

In addition, agricultural cultivation activities in Indonesia are still be primarily oriented toward the use of polybags as planting container, especially in the nursery. According to Dewanti (2018), the use of plastic in Indonesia was reaching up to 2.6 million tons per year, and polybags become one source of plastic that were widely used in the agricultural sector for plant nurseries (Jaya, *et a*l., 2019). Polybags made from raw materials polyethylene takes hundreds of years to decompose. Other than that, the use of polybag as container for planting in the nursery had the potential to reduce the level of plant tolerance to drought, as well as to cause root damage that occurs when the roots reached the bottom of the polybag. Trouble on the time of transfer (transplanting) is also a weakness of the use of polybags as a planting media (Salisu, *et al*., 2018).

To replacing the non-renewable plastic container in the agricultural sector and to increase the quality of the plants produced from the nursery, an alternative environmentally friendly container for the nursery is needed. Organic nursery container made from Oil Palm Empty Fruit Bunches OPEFB and the mixture of banana stems as a physical structure strengthening agent become a potential solution, at the same time answers the problem of oil palm solid waste management.

1.2. Problems

Based on the background above, the problems can be drawn as follows:

1. How is the effect of the composition of constituent materials to the physicomechanical properties of biodegradable pots?
2. How is the effect of adding NaOH with different concentrations to the physicomechanical properties of biodegradable pots?

1.3. Research Objectives

The objectives to be achieved by the research are as follows:

1. Knowing the effect of the composition of constituent materials to the physicomechanical properties of biodegradable pots.
2. Knowing the effect of adding NaOH with different concentrations to the physicomechanical properties of biodegradable pots.

1.4. Research Benefits

The benefits of research for various parties are as follows:

1. Government and Palm Oil Industry
   a. Can contribute to optimize the management of OPEFB waste.
   b. Biodegradable pots become a potential solution in dealing with and reducing OPEFB waste abundance.
2. Society
   a. Can reduce the use of polybags that cause environmental pollution.
   b. As a solution to overcome problems in the nurseries process with the application of technology, thus it can increase plant productivity.
3. Student
   a. The novelty of research idea can provide opportunities to improve an innovation related to the making of biodegradable pots and eco-agriculture.

1.5. Problem Limits

The limitations of the research problems are as follows:

1. This research was conducted on a laboratory scale.
2. This research did not consider the type of banana plant in the banana stems waste that was used as a mixture of biodegradable pots.
3. This research only analyzed the effect of the composition of the constituent materials (OPEFB: Banana Stems: NaOH) to the physicomechanical properties of biodegradable pots.
4. The soil conditions as burying media for the biodegradation test were considered the same.
5. This research did not pass the biodegradable pots applications test in the plant nursery process.

CHAPTER II LITERATURE REVIEW

2.1. Nursery

Plant cultivation is generally done by procuring young plants (seeds), which could be started by sowing seed (generatively) or using the parent plant (vegetatively). Before the seeds are planted in cultivated land, it needs to be maintained in the nursery system to produce tree seedling that meets the requirements of age, size, and certain qualities before transfer in the planting field. The nursery was the process of providing plant materials derived from tree seeds or seeds from the vegetative part of the plant to produce plant materials that were ready to be planted on cultivated land (Susilo, *et al*., 2014). The plants that require a nursery stage generally have an intermediate until a long time harvest cycle, as well as have relatively small seeds.

Many types of forest plants require a nursery process first, before planting in the field, such as teak, mahogany, calliandra, and others. There are also many plantation crops in need of nurseries, such as oil palm, tobacco, and rubber. Some types of horticultural crops including chilies and tomatoes require a nursery process before ready to be planted in the field (Sumarni and Isnantyo, 2017). According to Harum and Soren (2010), the nursery maintenance process includes:

1. Watering
2. Weeding
3. Fertilization (if needed)
4. Pest and disease control
5. Light control
6. Sorting seeds
7. Transfer of seeds
8. Acclimatization
9. Planting

2.2. Nursery Containers Media

2.2.1. Plastic Container Media (Polybag)

In the agricultural sector, polybags are generally used as a container media to grow the seeds in the nursery process as well as to save agricultural land. In the research of Pasir and Hakim (2014), it is said as a planting container media for agricultural cultivation, polybags had several advantages i.e low price, rust-resistant, durable, uniform shape, and easily obtained.

But on the other hand, the use of polybags as planting container media is not eco-friendly because, during the transplanting of seeds in the field, farmers often throw away polybags and eventually pilled up into garbage or agricultural waste. Trash polybags are inorganic waste, which is difficult to break down by bacteria so it will not be destroyed if it is just left on the ground. Inorganic waste that is allowed to accumulate in the soil will lead to soil pollution which ultimately makes it difficult for plant roots to penetrate the soil. Furthermore, the microorganisms in the soil would continuously disappear, along with decreasing the water and minerals that nourished the soil. Regarding the condition above, it would make the plants difficult to grow because plants did not get enough nutrients (Nursyamsi, 2015).

Cultivation of plants in polybags also has necessary drawbacks attention, including the factor of water availability and density of planting media. The availability of water greatly determines the results of plant production. Lack of water during the nursery process could cause stunted plant growth, withered and even plants die (Kusumawati, *et al*., 2016). Besides, the use of polybags in the nursery process has a weakness. It is not efficient because people have to tear the polybags during the transplanting process. The tearing process could destroy the planting media and roots damage, which leads to stagnation after seedlings were transplanted. In addition, root damage during transplanting affected the adaptation process and plant growth in the field (Pudjiono, *et al*, 2012).

2.2.2. Organic Growing Container Media

The organic growing container is a container for the planting process used to conduct nurseries as alternative polybags. An effort to reduce the use of polybags is carried out by developing planting media made from organic materials, such as straw, wood-bark, sawdust, coconut husk, reeds, and water hyacinth (Nugroho, *et al*., 2013). The organic materials would be decomposed by microorganisms that could produce carbon dioxide (CO2), water (H2O), and minerals. The released minerals would become a source of nutrients for plants (Nugroho, *et al*., 2013).

The growing container media made from organic materials are known by several terms, such as organic block seedling and biodegradable pot (biopots).

The use of organic planting containers began to be developed in the nursery and greenhouse industry because it had the advantage of being biodegradable, it could be degraded after the transplanting process on the ground (Rapa *et al.*, 2011). In the transplanting process, organic growing container could be used directly by burying it with the seeds in the ground. Thus was supposed to speed up and simplify the transplanting process, as well as was zero waste because it did not leave any wastes (Al-ahmed, 2020).

As a good growing cointainer media, biodegradable pots must have physical, chemical, biological, and mechanical properties that suitable for plant growth. According to Saraswati (2012) in Pasir and Hakim (2014), the biodegradable pot at least could provide growing space for roots as well as being able to support plants, had good porosity, and had the ability to absorbed water (hygroscopic) so it could retain humidity and porosity. It also had good drainage and good aeration. Besides, it could provide macronutrients and micronutrients, and it must have also been free of fungi and pests.

Thus, biodegradable pots as an alternatives growing container media are expected to have low moisture content, low percentage of water uptake, relatively high tensile strength, and high degradation value. To support sustainable agriculture, the use of biodegradable pots is increasingly needed because biodegradable pots are eco-friendly, efficient, do not lead to roots damage, and can decompose quickly, so they do not have negative impacts on the environment. The properties of growing container media from oil palm solid waste are shown in **Table 2.1.**

Table 2.1 Properties of Organic Growing Container from Oil Palm Solid Wastes

No.	**Parameters**	**Average Value**		
		Jaya *et al.* (2019)*	**Effendi (2012)****	**Silalahi (2017)*****
1.	Moisture Content	10.11-10.6%	31.23-32.15%	28.09-31.9%
2.	Water absorption	129.25-155.48%	-	
3.	Mass	-	251.91 g	192.67-218.09 g
4.	Thickness	-	1.33 cm	1.13 cm

Note: *) Palm oil fiber

**) OPEFB, midrib and stem of palm oil

***) OPEFB, midrib and stem of palm oil, newspaper

2.3. Raw Materials for Making Biodegradble Pots

2.3.1. Oil Palm Empty Fruit Bunches

Oil Palm Empty Fruit Bunches (OPEFB) were left natural fibers after the process of separating the fruit from Fresh Fruit Bunches (FFB) (Rahmasita, *et al.*, 2017). So far, the utilization of OPEFB waste is still very limited. The solution that is often used is to recycle the wastes. In the agricultural sector, the recycling process of Oil Palm Empty Fruit Bunches (OPEFB) waste is fixated on processing into compost. However, the OPEFB composting that contains lignocellulose took a long time. It might reach up to 3 months (Warsito, *et al.*, 2016).

Figure 2.1 Oil Palm Empty Fruit Bunches (a) Overall Part (b) Bunch Part and (c) Flower Part

Source**:** Wardani (2013)

According to Salmina (2017), because the composting process took a long time, most palm oil industries in Indonesia carried out open dumping and waste incineration in an incinerator as an effort to overcome the abundant wastes. However, that way had been banned by the government because it harmed public health and the environment and not prospective solution to be applied continuously to overcome the abundance of Oil Palm Empty Fruit Bunches waste. The availability of Oil Palm Empty Fruit Bunches (OPEFB) in Indonesia will continuously increase in line with the increase in production of Fresh Fruit Bunches (FFB). In 2013, approximately 25 million tons of Oil Palm Empty Fruit Bunches were produced by Indonesia and would be continued to increase along with the increase in plantation areas (Erwinsyah, *et al.*, 2015). Oil Palm Empty Fruit Bunches (OPEFB) is an organic material, which is cheap, decomposed, non-toxic, and is a natural fiber widely used for various purposes. According to Erwinsyah *et al.*, (2015), Oil Palm Empty Fruit Bunches (OPEFB) had a chemical content that could be utilized to the maximum. The chemical composition of Oil Palm Empty Fruit Bunches (OPEFB) can be seen in **Table 2.2**

Table 2.2 Chemical Composition of Oil Palm Empty Fruit Bunches (OPEFB)

No.	Parameters	Value (%) Herawan and Rivani (2010)	Value (%) Erwinsyah *et al*. (2012)
1.	Extract	7.78	5.22
2.	Ash content	6.23	2.00
3.	Cellulose	37.50	41.09
4.	Hemicellulose	28.57	-
5.	Holocellulose	-	69.33
6.	Pentosan	26.69	29.37
7.	Solubility in 1% NaOH	29.96	24.69

Source: Erwinsyah, *et al* (2015)

OPEFB fiber also contained organic elements such as C of 42.800-54.760%, K 2.285%, N 0.350%, Mg 0.175%, Ca 0.149% and P 0.028% (Erwinsyah, *et al*,. 2015). These nutrients can be used as soil improvement components. Chemical components such as cellulose, lignin, and hemicellulose content in Oil Palm Empty Fruit Bunches (OPEFB) can be processed into high-value products such as biofuel (bioethanol), lactic acid, cellulose acetate, microcrystalline cellulose, as well as biopolymers or bioplastics. In addition, many environmentally friendly products can be made lignin-based, such as sugar, polylactic acids (PLA) as a bioplastic material, lignin-based adhesive, activated carbon, vanillin of lignin, food additives, and others.

2.3.2. Banana Stems

Banana (*Musa Paradisiaca*) is an annual plant that can bear fruits in all seasons. The most unutilized part of the banana plant is the banana stems. According to Martirawati (2017), the banana stem was one of the potential and strategic agricultural waste that categorized as organic waste. Besides, at a cost issue, it was relatively low in the process of acquisition and handling. In general, people used the banana stem waste as animal food, fertilizer, or handicrafts. However, considering that there is still a large amount of banana stem waste, alternative waste-treatment efforts are needed to handle banana stem waste appropriately.

Figure 2.2 Banana Stems
Source: Martirawati (2017)

The banana stem waste can be used as a source of fiber which has economic value. The banana stem was a type of fiber that had good quality and potential to be used as an alternative making material for biodegradable pots, banana stem waste was one of the cheap materials and easy to obtained (Supraptiningsih, 2012). According to Prayoga (2016), banana stems which were called *gedebog* in Bahasa Indonesia were a pseudostem consisting of a layered midrib that functions as a support for banana leaves and fruit on a banana plant.

Banana stems contained more than 80% water and contained high glucose and cellulose. The α-cellulose contained in banana stems was up to 83.3% and the lignin content was 2.97% (Bahri, 2015). The high content of cellulose in banana stems made it an organic material that was able to strengthen the physical structure of biodegradable pots produced. Therefore, the banana stem has the potential to be used as a raw material or a mixture material for making biodegradable pots. The chemical composition of banana fiber according to the Building Material and Technology Promotion Council is shown in **Table 2.3**.

Tabel 2.3 Chemical Composition of Banana Fiber

Chemical composition	Content (%)
Lignin	5-10
Cellulose	60-65
Hemicellulose	6-8
Water	10-15

Source: Building Material and Technology Promotion Council *(*1998*)* in Syafaiisab (2010)

2.4. Cellulose Fibers and The Potential

Cellulose is a glucose polymer in the form of linear chains and is linked by ß -1.4 glycosidic bonds. Cellulose fibers can be obtained from various types of plants and also can be produced by the bacteria which are called Bacterial Cellulose (BC). However, cellulose fibers produced by plants had several advantages including the abundance, biocompatibility, non-toxic, environmentally friendly because it is easy to degrade, and also sustainable material (Putera, 2012).

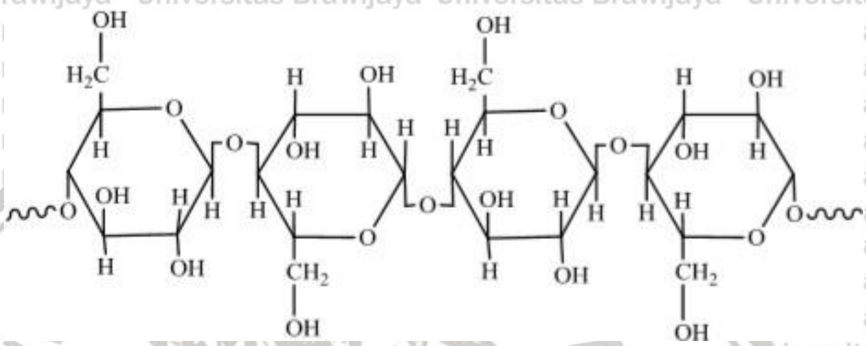


Figure 2.3 Chemical Structure of Cellulose

Source: Mulyadi (2019)

Natural cellulosic fibers have served to humans for primitive tools, construction, and good for everyday life. Regarding growing concern for environmental protection and counteracting global warming, the utilization of natural cellulosic fibers significantly increased due to as a renewable resource that possible to be used for the manufacture of recyclable products (Zimniewska, *et al.*, 2011). Yet, according to Mulyadi (2019), the existence of cellulose in nature had never existed in pure form but was still associated with hemicellulose and lignin. It was called the lignocellulose structure. In the structure of lignocellulose, the existence of lignin and cellulose were bound to each other, that was, lignin became the cellulose wrapper. Following by Suryaningrum and Reza (2018), the polymers of cellulose, hemicellulose, and lignin are tightly bonded by covalent and non-covalent bonds. Lignin binds to hemisellulose through covalent bonds, while the bond between cellulose and lignin is not clearly known. Each glucose unit within the cellulose chain is joined to another by a C – O – C covalent bond flanked by two hydrogen bonds. This geometry appears a few frames of participation between covalent and hydrogen bonds in the selulosa structure (Altaner, *et al*., 2014).

Furthermore, to break the cellulose chain bonds, the lignin content needs to be dissolved. The most common method for separating the structural chain between lignin, hemicellulose and cellulose in lignocellulose materials is called alkaline treatment. Moreover, alkaline treatment of cellulose fibers also aims to improve the cellulose fibers compatibility through hydrolysis of hydroxyl groups to increase the interface strength of the composites (Witono, *et al*., 2013). As reported by Fitriasari *et al.* (2019), alkaline treatment was used to break down the glycosidic bonds within the cellulose that seemed to alter the cellulose properties, thus, obtained the valuable cellulose derivatives.

The demand for cellulose fibers nowadays was increasing along with the increase in industry needs. Generally, cellulose was widely used as a raw material for paper, explosives, membranes, bioplastics, crafts material, and so on (Sumada, *et al*., 2011). Following by Fitriasari *et al.* (2019) the wider utilization and modification of cellulose fibers could be achieved through a good understanding of the structure and properties of cellulose fibers.

2.5. Sodium Hydroxide (NaOH)

Sodium Hydroxide (NaOH) is a compound that is commonly used in the alkaline treatment of pulping process from natural fibers for making composites or paper (Ahmadi and Sayed, 2019). The addition of NaOH will help the separation between cellulose fibers and non-cellulose fibers, thus it can increase the quality of fibers by increasing the cellulose content. This is called the delignification process (Ferreira, *et al*., 2021). The advantage of using NaOH as an alkaline treatment is that it is more efficient in time because NaOH reacts faster with lignin. It means that the time needed for the cooking process is quite shorter. Since lignin was a major inhibitor in the preparation of cellulose, the presence of high lignin was not expected in the pulping process, it preferred to have high cellulose in the pulp due to produce higher pulp yields and better strength (Fitriasari *et al.,* 2019).

On the other hand, NaOH was selected for alkaline treatment due to easier to obtain, as well as the price was relatively low (Ahmadi and Sayed, 2019). The increase in the cellulose content became a key factor to improved the properties and quality of natural fibers (Witono, *et al*., 2013), that related to the water absorption capability and the plasticity of fibers, thereby facilitate the moulding process, increasing the contact between the fibers and the improve the strength of the composite (Fitriasari *et al.,* 2019). According to Paskawati *et al.* (2010), in the pulping process (separating the fiber chain), the higher alpha-cellulose contained in the pulp was, the quality of the pulp produced would also be increasingly good.

NaOH is a chemical substance that is strongly alkaline and hygroscopic (absorbs water). In trade, it is better known as caustic soda in the form of a white solid or crystal. In the cooking process of cellulose fibers, NaOH also serves to remove unnecessary substances and the dirt attached to the fibers. The loss of unnecessary substances and impurities in the fiber will facilitate further processes and can inhibit the growth of fungi. However, because NaOH was corrosive which could damage materials such as, textiles, leather, or paper, then in its use it might be paid attention to the concentration used (Widihastuti, 2005). On the other hand, too much usage of NaOH as a cooking solution would cause degradation of the cellulose content in the fiber. In its use, NaOH concentration was limited to a maximum of 15% (Paskawati *et al*., 2010).

In the study of bagasse delignification using NaOH as a delignificator of 2%, 4%, 6%, the results showed a reduction in lignin levels of the highest in the 6% NaOH treatment. Lignin level fell by 32% from 17.65% to 11.9% (Gunam, *et al*., 2011). Another research was also carried out by Nasruddin (2012) and Dewi, *et al* (2019) respectively in the cellulose delignification process from OPEFB weighed 500 grams with NaOH solution of 2%, 4%, 6%, and 8%. The result showed that, at a concentration of 8% NaOH, lignin content decreased from 22.158% to 2.361%. Whereas the delignification of banana stems with NaOH concentrations of 1%, 2%, and 3%, showed a point yield optimum delignification at 3% NaOH to produce a final lignin level of 2.637% and cellulose by 80.713%. From the research above, it is known that NaOH solution was commonly used in the cellulose delignification process, but the optimum concentration of NaOH in cellulose delignification for OPEFB and banana stems is still unknown. Therefore, based on the best results from the literature above, it is used as a benchmark for the NaOH concentration used in this research.

2.6. Tapioca Starch Adhesive

Tapioca flour is starch from the extraction of cassava tubers (*Manihot utilissima Pohl*) that had been washed and dried. The main content of tapioca flour was starch (Bulkaini, *et al*., 2020). Starch content in tapioca flour was higher than cornstarch, rice flour, and glutinous rice flour (Ramona, *et al*., 2011 in Septianti, *et al*., 2016). Because of its high starch content, tapioca was widely used as an ingredient for thickeners, fillers, and binders in the food industry (Astawan, 2009).

In addition, tapioca flour had the potential to be used as a natural adhesive. The advantage of tapioca adhesive was that it had water absorption, good adhesive strength and it was easily obtained and not harmful to health (Jumiati, 2020). According to Rafi (2010), tapioca flour used as an adhesive needed to be converted into a colloidal gel through the process of warming up. Starch that turns into a gel was irreversible, where the starch molecules would stick together and form lumps resulting in increased viscosity value.

Lina`s research (2010), by making briquettes with 10% (m/v) tapioca adhesive, showed the optimum result and the increased briquette quality. While in the study of Akhir, *et al.* (2018) on the made of Environmentally Friendly Seedling Containers (WSRL) from newspaper raw materials using 8% and 12% (w/w) tapioca adhesive, it showed the best result on 8% tapioca adhesive. Therefore, based on the best results from the literature above, it is used as a benchmark for the tapioca adhesive concentration used in this research at 10% of concentration (m/v). The various types of natural adhesives can be seen in **Table 2.4.**

Table 2.4 The Types of Natural Adhesives

Types of Adhesive Material	Water (%)	Ash (%)	Fat (%)	Protein (%)	Crude Friber (%)	Carbon (%)
Tapioca flour	9.84	0.36	1.50	2.21	0.69	85.20
Corn flour	10.52	1.27	4.89	8.48	1.04	73.80
Rice flour	7.58	0.68	4.53	9.89	0.82	76.90
Wheat flour	10.70	0.86	2.00	11.50	0.64	74.20
Sago flour	14.10	0.67	1.03	1.12	0.37	82.70

Source: Jumiati (2020)

2.7. Previous Researches

Research on the utilization of oil palm solid waste has been done by many researchers. However, no research discusses the use of OPEFB as a raw material for biodegradable pots with a mixture material of banana stems. **Table 2.5** presents the utilization of oil palm solid waste that has been performed.

Table 2.5 Previous Researches

Researcher	Research Object and Steps	Method	Result
Jaya, *et al* (2019)	Palm oil fiber. The steps include preparation of raw materials, chopping fibers to 0.5 cm, adding natural adhesive, heating until viscous, and moulding process.	This research aims to analyzing the addition of natural adhesive on organic pots, as well as analyzing physical properties, moisture content, water absorption and level of liking to organic pots generated through the hedonic test, hedonic quality.	The result shows the moisture level of organic pots ranged between 10.11-10.6% with water absorption between 129.25-155.48%. And the hedonic test shows acceptance highest rate based on color and texture.
Effendi (2012)	OPEFB, MIidrib and stem of Palm oil. The steps include preparation of raw materials, washing process, chopping to 2-5 cm, first boiling phase for 2-3 hours, second boiling phase, pulping process, adding adhesive, moulding, and sunlight drying for 2 days.	To analyzing the influence of the different composition of constituents and dosage NaOH was used on the green polybags design in parameters pH, C/N ratio, mass, moisture content, and thickness.	The result shows there was a response on parameters pH value, C/N ratio, but it was not on mass, thickness, and moisture content of green polybag.
Silalahi (2017)	OPEFB, Midrib and stem of palm oil and newspapers. The steps include preparation of raw materials, chopping to 2-5 cm, first boiling phase for 1-2 hours, second boiling phase for 30 minutes, pulping, adding adhesive, moulding process, and sunlight drying for 2-3 days.	To analyzing the influence of different composition constituents and dosage of NaOH was used on the green polybags design in parameters pH, C/N ratio, mass, moisture content, and thickness.	The result shows the use of palm oil waste highly influence on parameters pH value, C/N ratio, moisture, and mass. While dosage NaOH only gave a response to moisture content and C/N ratio parameters.

CHAPTER III RESEARCH METHOD

3.1. Time and Location of Research

This research was conducted at the Processing and Process Technique of Food and Agricultural Products Laboratory, Department of Agricultural Engineering, Faculty of Agricultural Technology, Brawijaya University, Malang in March-May 2021.

3.2. Tools and Materials

3.2.1. Tools

1. Machete to chop OPEFB and Banana stems
2. A pot with a diameter of 22 cm as a container for boiling Ingredient materials
3. Starco brand digital scale to weigh the mass of ingredient materials
4. Measuring cup to measure the volume of boiling water
5. Blender with a volume of 1.5 liters to blend the ingredient materials
6. A stove that is used as a heater when boiling the ingredient materials
7. A bucket with a diameter of 30 cm as a container for washing ingredient materials
8. Biodegradable pots mould with dimensions of 5 x 8 x 9 cm and 4 x 7 x 8 cm
9. Oven to dry the biodegradable pots
10. Thermometer to measure water temperature during boiling
11. Glass stirrer for homogenization of NaOH solution
12. Beaker glass as a container for making NaOH solution
13. Plastic box of 13 cm height as a container in Biodegradition test
14. Soil as burying media in Biodegradation test
15. Aluminum foil for wrapping Biodegrable pots during drying process
16. PCE-FM 500 N mechine to measure the tensile strength

3.2.2. Materials

1. OPEFB as raw material for making biodegradable pots that were obtained from PT. Sawit Arum Madani, Blitar
2. Banana stems as a mixture material for making biodegradable pots that ware obtained from Gadang, Malang

3. Sodium Hydroxide (NaOH) crystal PA as an alkaline treatment to break down the fibers (pulping)
4. Tapioca flour as adhesive
5. Aquadest as a solvent
6. Water to boil ingredient materials

3.3. Research Method

This research used a factorial Completely Randomized Design (CRD) which consists of 2 factors and 3 replications. 1st Factor was the raw materials composition consisting of 5 levels, namely:

1. R_1 : 100% OPEFB
2. R_2 : 80% OPEFB + 20% Banana Stems
3. R_3 : 60% OPEFB + 40% Banana Stems
4. R_4 : 40% OPEFB+ 60% Banana Stems
5. R_5 : 100% Banana Stems

While 2nd Factor was the concentration of Sodium Hydroxide (NaOH) consisting of 3 levels, namely:

1. C_1 : 3% (m/v) NaOH
2. C_2 : 5% (m/v) NaOH
3. C_3 : 7% (m/v) NaOH

With this design, 15 treatment combinations will be obtained. The combination of the treatment can be seen in **Table 3.1.** SPSS packages were used for data analysis. Analysis of Variance (ANOVA) was applied to test for differences between various experimental factors then followed by DMRT (Duncan`s Multiple Range) to determine the effect of the independent variables (both of composition of the biodegradable raw materials and NaOH concentration) on the dependent variables which are the tested parameters (mass, moisture content, water uptake, tensile strength, and biodegradation test).

Table 3.1 Treatment Combinations

OPEFB+Banana Stems / NaOH	R_1	R_2	R_3	R_4	R_5
C_1	R_1C_1	R_2C_1	R_3C_1	R_4C_1	R_5C_1
C_2	R_1C_2	R_2C_2	R_3C_2	R_4C_2	R_5C_2
C_3	R_1C_3	R_2C_3	R_3C_3	R_4C_3	R_5C_3

3.4. Research Implementation

3.4.1 Making Biodegradable Pots

1. Preparation of Raw Materials and Tools

The raw materials used in this research were OPEFB and banana stem as a mixture material. The total amount of raw materials needed to make one biodegradable pot was 50 grams. 1.260 kg of OPEFB and banana stems as much as 0.990 kg were required to make 45 samples of biodegradable pots. NaOH used in the form of solid crystals PA (Pro Analysis) was further dissolved with distilled water according to the concentration used. While the tools needed were: blender, pot, machete, digital scale, stove, glass stirrer, thermometer, beaker glass, measuring cup, aluminum foil, and biodegradable pots mould.

2. Raw Materials Copping

Oil Palm Empty Fruit Bunches (OPEFB) and banana stems were chopped using a machete. The length of the OPEFB fibers and the banana stems fibers that had been chopped measured 1-2 cm.

3. Raw Materials Washing

Oil Palm Empty Fruit Bunches (OPEFB) and banana stems that had been chopped were washed to reduce the amount of dirt attached to the raw materials. Washing was done by soaking the raw materials in a bucket and manually rubbing on the surface then rinsed clean.

4. Drying

Oil Palm Empty Fruit Bunches (OPEFB) and banana stems that had been washed dried in the sunlight for 2 x 24 hours to reduce the moisture content in the materials, thus the raw materials could last for a long time storage before biodegradable pots making process.

5. First Phase Boiling

According to Jaya, *et al.* (2019) and Silalahi (2017), making biodegradable pots involves two phase of boiling process. In the first fhase of boiling, OPEFB fiber and banana stems fiber were boiled accordingly treatment composition. The first phase boiling aimed to soften raw materials and remove dirt that might still be attached to the materials. Comparison between raw materials and volume of water used during boiling was 50 grams: 1 liter, or until the materials submerged. Boiling was carried out for an hour at a temperature of 95^o - 105^o C. The temperature and boiling time were selected based on the results of the pre-research, because under these conditions, soft and clean OPEFB fiber and banana stems fiber have been obtained. The boiling water then was discarded and the materials were drained.

6. Second Phase Boiling

In making biodegradable pots, the second phase boiling aimed as an alkaline treatment. The second phase boiling was carried out at a temperature of 95^o - 105^o C for 30 minutes. The temperature and boiling time were selected based on the results of the pre-research, to avoid corrosion of the pan caused by adding NaOH solution during boiling process. Water needed to boil biodegradable pots composition material was 1 liter for every 50 grams of biodegradable pots (OPEFB and banana stems). Each composition of the constituent materials was poured into a pot that had been filled with water and boiled. NaOH solution was added according to the concentration of each treatment in making biodegradable pots, namely 3%, 5%, and 7%. And stirring was done occasionally during the boiling process. The addition of NaOH aimed to break the bonds between cellulose fibers with the lignin contained in the materials. After the boiling process, remove the water in the pot and drain materials to separated cellulose with lignin that had been degraded. Thus, the cellulose content in the material increased.

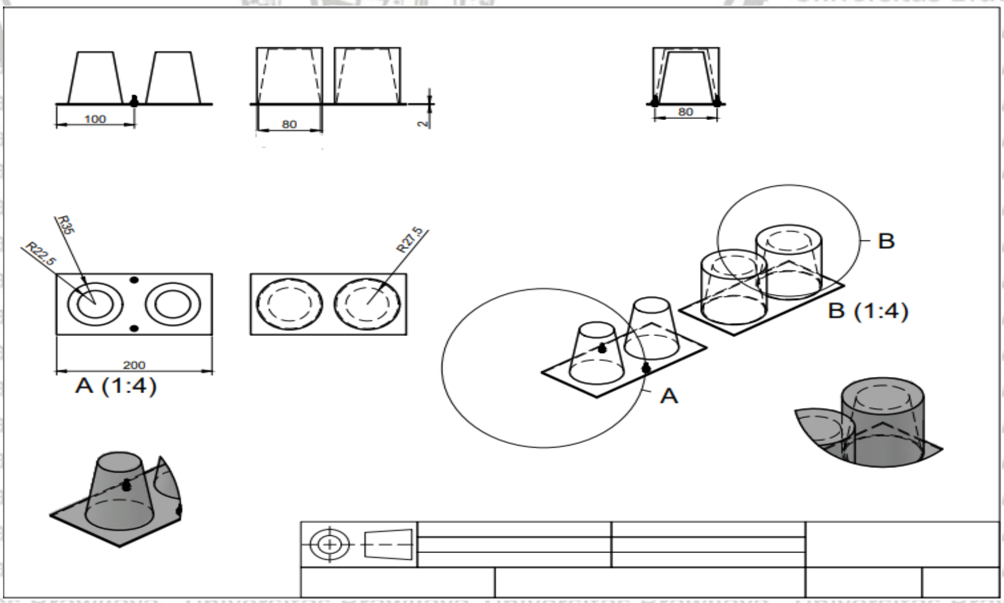
7. Pulping

OPEFB and banana stems were boiled and then mashed using a blender by adding 10% (m/v) tapioca adhesive in grams/milliliters unit. OPEFB and banana stems were then mashed until became pulp and mixed evenly. Addition of solution tapioca flour aimed as a natural adhesive to strengthen the bond between the fibers. After the blending process, the pulp materials were boiled again for 5 minutes or until viscous. The length of boiling time was selected based on the results of pre-research. And the results of the boiling process would produce a pulp.

8. Biodegradable Pots Moulding

After the pulping process, the pulp of biodegradable pot`s raw materials then went into the moulding process. The biodegradable Pots mould was made of an iron plate with a thickness of 2 mm, 20 cm long, and 10 cm wide which consists of 2 parts, namely the outer mould and inner mould (press) with holes at the bottom to facilitate the discharge of the remaining biodegradable pots pulp and water. The outer mould had a bottom diameter of 5 cm, top diameter of 8 cm, and a height of 9 cm, while the inner mould that was used as the press had a diameter of bottom 4 cm, top diameter of 7 cm, and height of 8 cm. So it was expected that wet biodegradable pots have a uniform section thickness of 5 mm side and bottom thickness of 1 cm, with the size of biodegradable pots moulded, was 5 x 8 x 9 cm, which was following the size of the organic pot on the global market.

Before the moulding process, the mould was coated with aluminum foil that had been smeared with cooking oil to facilitate the biodegradable pots moulding process. Biodegradable pots pulp was slowly poured into the outer mould according to the shape of the mould, then affixed the inner mould as a press and pressed retaining, thus the remaining pulp and the remaining water could exit through the hole in the mould. As the result, biodegradable pots were obtained in uniform thickness and dimensions.



Biodegradable Pots Mould Desain

Figure 3.1 Biodegradable Pots Mould

Source: Personal Documentation

9. Biodegradable Pots Drying

The biodegradable pots drying process was carried out by drying the biodegradable pots in sunlight for 2 x 7 hours until half-dry to reduce the amount of surface water on biodegradable pots, then oven-dried at temperature 105^o C for 24 hours to obtain a constant mass to determine the moisture content.

3.4.2 Testing Parameters

1. Biodegradable Pots Mass

The mass measurement of Biodegradable pots was carried out using a digital scale and expressed in grams. Measurement data of biodegradable pots mass will be processed by the ANOVA (Analysis of Variance) test.

2. Moisture Content Test

The moisture content test was carried out by ISO 287: 2017 Paper and board - Determination of moisture content of a lot – Oven drying method with weighed the wet biodegradable pots as the initial mass (m_i) and oven at 105^o C for 24 hours, then weighed until the mass was constant as the final mass (m_f). The calculation of the moisture content aimed to determine the level of ability of the material to withstand the quality of the attack microorganisms and fungi during storage. The higher the levels of water, microorganisms, or fungi have the potential to grow, thus it could cause the damage or decay of the biodegradable pots during the lifetime storage. The moisture content of the biodegradable pots was calculated using the equation as follows:

Moisture Content (%) = $\left[\frac{m_i - m_f}{m_i}\right] x\ 100\%$ ……………………………………… (1)

Note:

m_i : Initial mass of biodegradable pots before oven (grams)

m_f : Final mass of biodegradable pots after oven (grams)

3. Water Uptake Test

The water uptake test showed the ability of the material to absorb water to determine the level of water resistance indicated by the percentage addition of the sample mass from the swelling phenomena during the immersion process, carried out according to ASTM D570-98 Standard for water absorption by weighed dry mass of biodegradable pots sample (m_d), then the sample size 3 x 3 cm^2 soaked for 24 hours at a room temperature until became saturated and drained until there was no surface water left behind. The next step is to re-weighed the sample to found out the wet mass (m_w). The water uptake test indicated the level of mechanical resistance of the biodegradable pots when grown in wet soil. Therefore It is expected that biodegradable pots have good water resistance, by slightly absorbing water, thus it ought to has a low percentage of water uptake. To determine the percentage of water uptake can be known by using the following equation:

$$\text{Water uptake (\%)} = \left[\frac{m_d - m_w}{m_w}\right] x\ 100\% \quad \text{...} (2)$$

Note:

m_d : Dry mass of the sample before immersion (grams)

m_w : Wet mass of the sample after immersion (grams)

4. Biodegradation Test (Soil Burial Test)

The biodegradation test aimed to determine whether the biodegradable pots are well degraded in nature indicated by percentage loss of the sample mass during the soil burial test. Based on ASTM D5988 – Standard for determining aerobic biodegradation in soil, biodegradation test was carried out by burying the sample of biodegradable pots in the soil (soil burial test). The soil used was topsoil type at a maximum depth of 10 cm from the surface area, which has enough nutrient content. The soil was placed in the container plastic with small holes on the bottom and each side to improve air and water circulation. Sample size 3 x 3 cm^2 buried in the soil for 21 days at a soil depth of 10 cm from the surface and placed outdoors. Then the loss mass of sample was observed every week to find out the kinetics of loss mass. After testing, the samples were cleaned with distilled water, dried in an oven at

105° C for 2 hours, and weighed every 30 minutes until the mass of the sample was constant to determine the degradability of biodegradable pots and to compare the condition of the sample before and after buried. The degradation value was carried out based on the gravimetric method and expressed in percent units:

$$\text{Degradation Potential (\%)} = \left[\frac{m_i - m_f}{m_i}\right] x\ 100\% \ldots\ldots\ldots\ldots (3)$$

Note:

m_i : Initial mass of biodegradable pots sample before burying (grams)

m_f : Final mass of biodegradable pots sample after burying (grams)

5. Tensile Strength Test

Tensile strength testing of biodegradable pots was carried out at the Processing and Process Engineering of Food and Agricultural Products Laboratory used PCE-FM 500 N. Based on ASTM D3039 Standard Test Method for Tensile Properties of Polymers Matrix Composite Materials, tensile strength test performed on specimens with dimensions of 25 x 2.5 cm^2 and a thickness of 2.5 mm. The tensile strength test was carried out by clamping the specimen to the grips while given an ever-increasing graded axial load to a test sample up to the point of failure. The tensile test simulates natural pressure exerted by the environment against the biodegradation pots. The value of tensile strength is calculated using the equation:

$$\sigma = \frac{F}{A} \ldots\ldots\ldots\ldots (4)$$

Note:

σ : Tensile strength value (N/m^2)

F : Load when failure (N)

A : Cross-section area of the specimen (m^2)

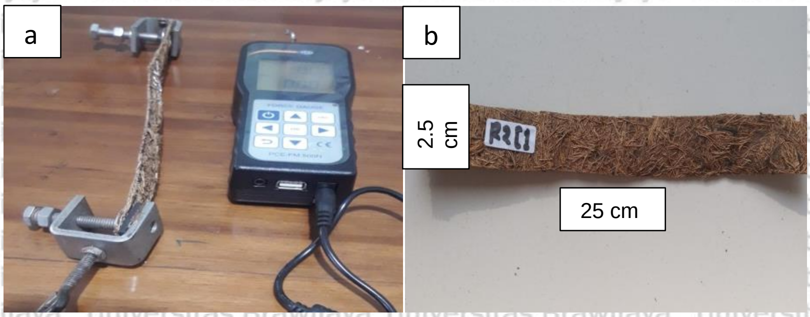


Figure 3.2 Tensile Strength Test Tools (a) PCE-FM 500 N (b) Specimen

Source: Personal Documentation

3.5. Research Flowcharts

3.5.1 Making Biodegradable Pots

The process of making biodegradable pots is shown in **Figure 3.3.**

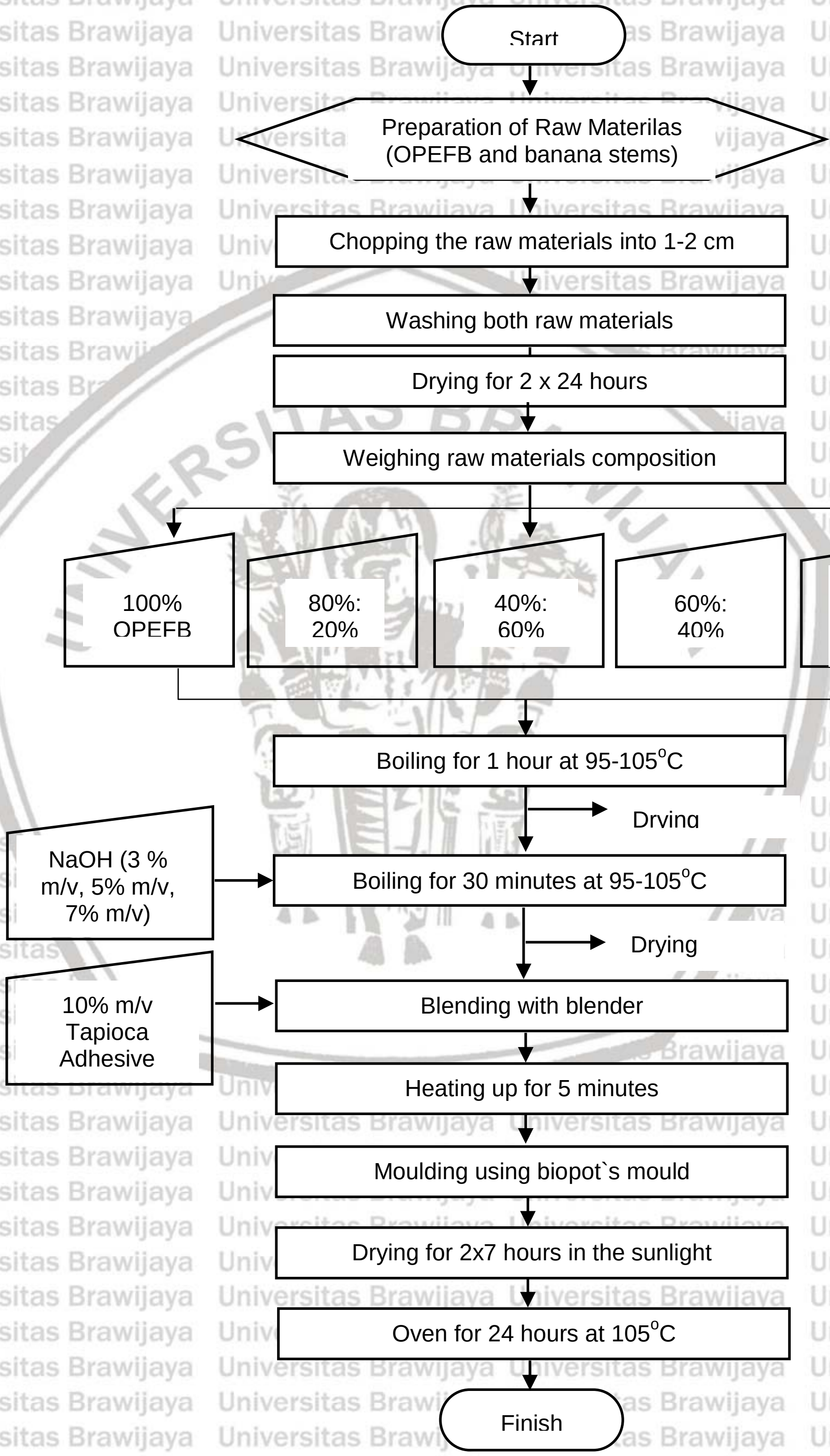


Figure 3.3 The Process of Making Biodegradable Pots

3.5.2 Observation of Biodegradable Pots

a. Mass Measurement

The mass measurement was done by measuring the mass of biodegradable pots after oven-drying process using digital scale with an accuracy of 0.01 grams.

b. Moisture Content Measurement

The procedure for measuring the moisture content of biodegradable pots is shown in **Figure 3.4.**

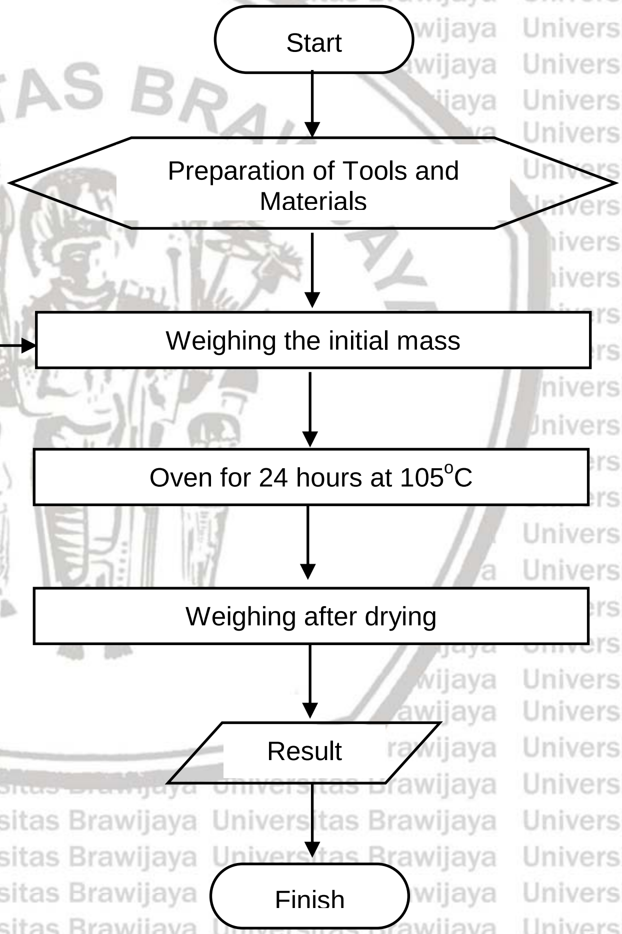


Figure 3.4 Moisture Content Measurement Procedure

c. Water Uptake Test

The procedure for analyzing the water upatake of biodegradable pots is shown in **Figure 3.5.**

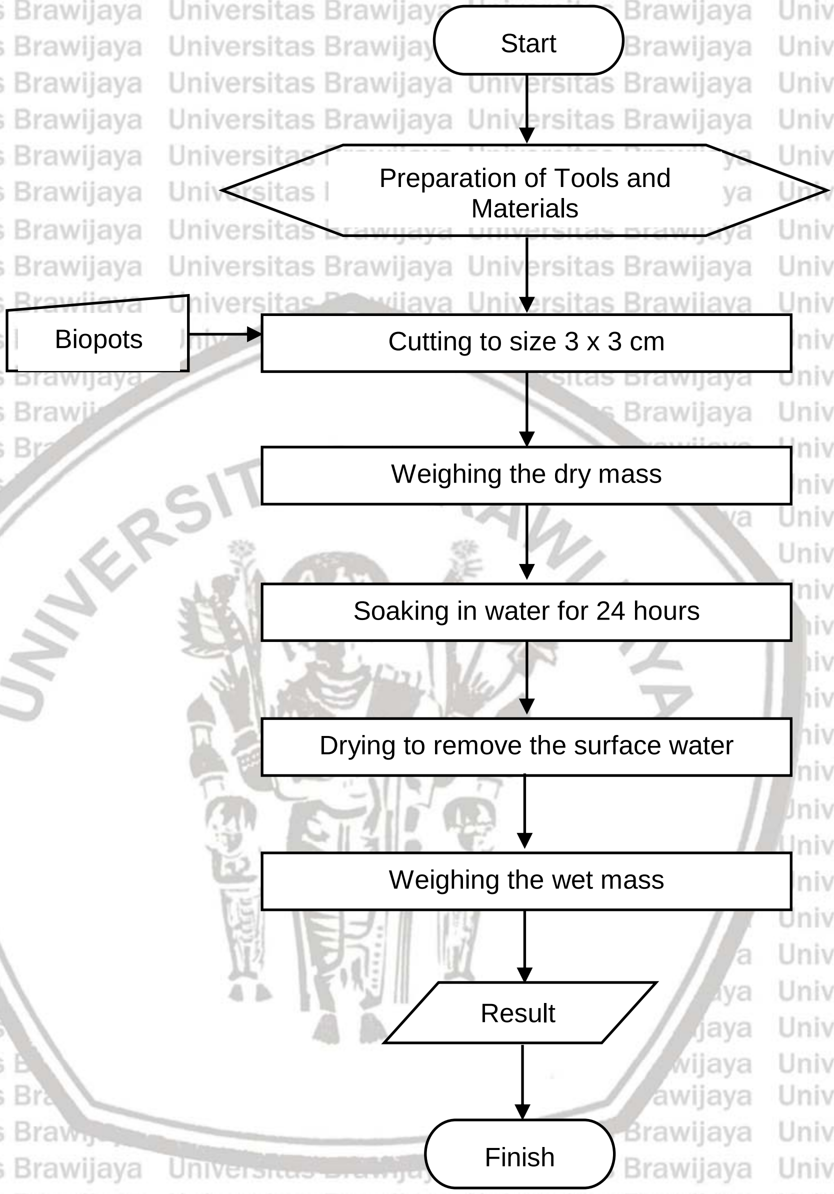


Figure 3.5 Water Uptake Analysis Procedure

d. Biodegradation Test

The procedure for biodegradation analysis of biodegrdable pots is shown in **Figure 3.6.**

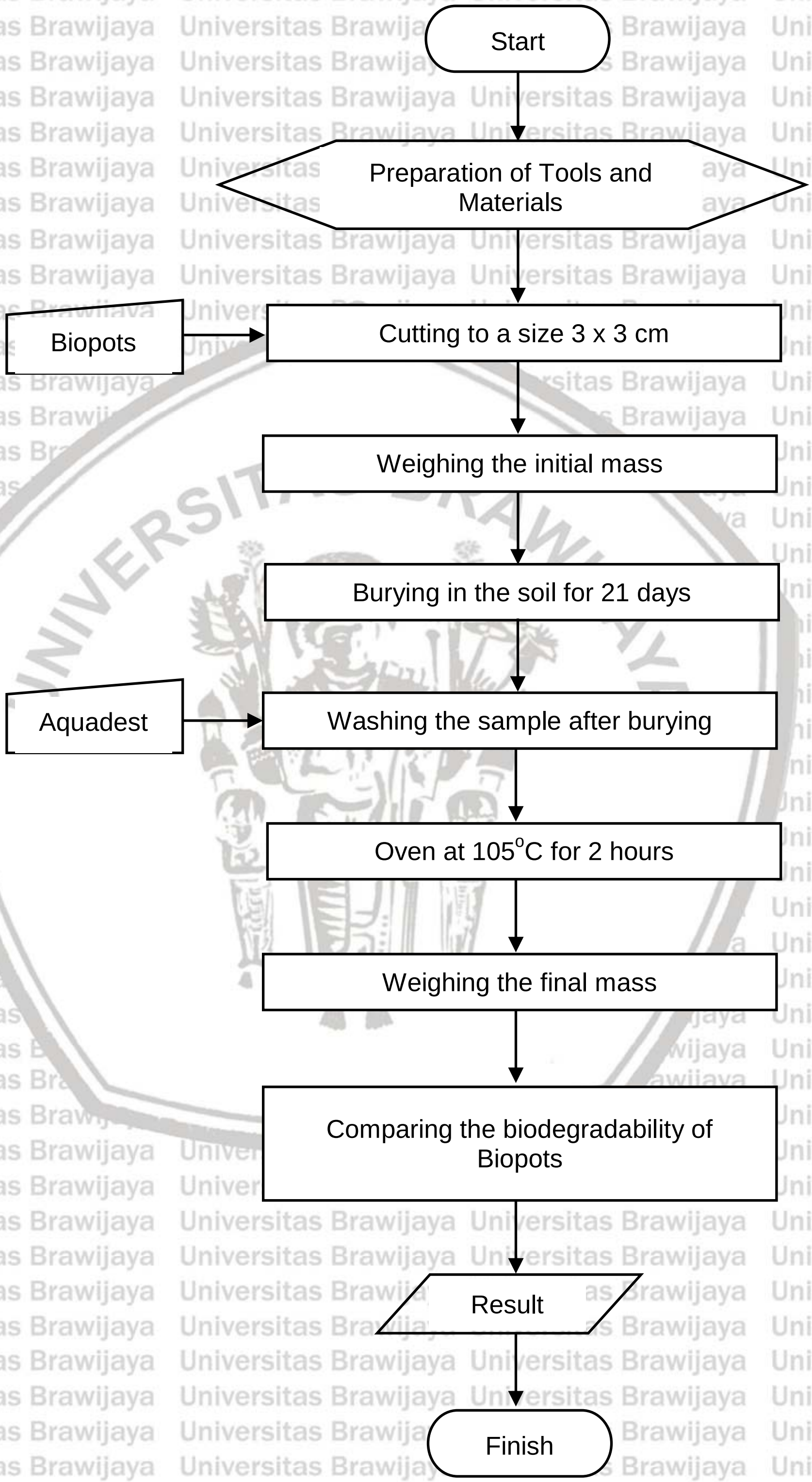


Figure 3.6 Biodegradation Analysis Procedure

e. Tensile Strength Test

The procedure for testing the tensile strength of biodegrdable pots is shown in **Figure 3.7.**

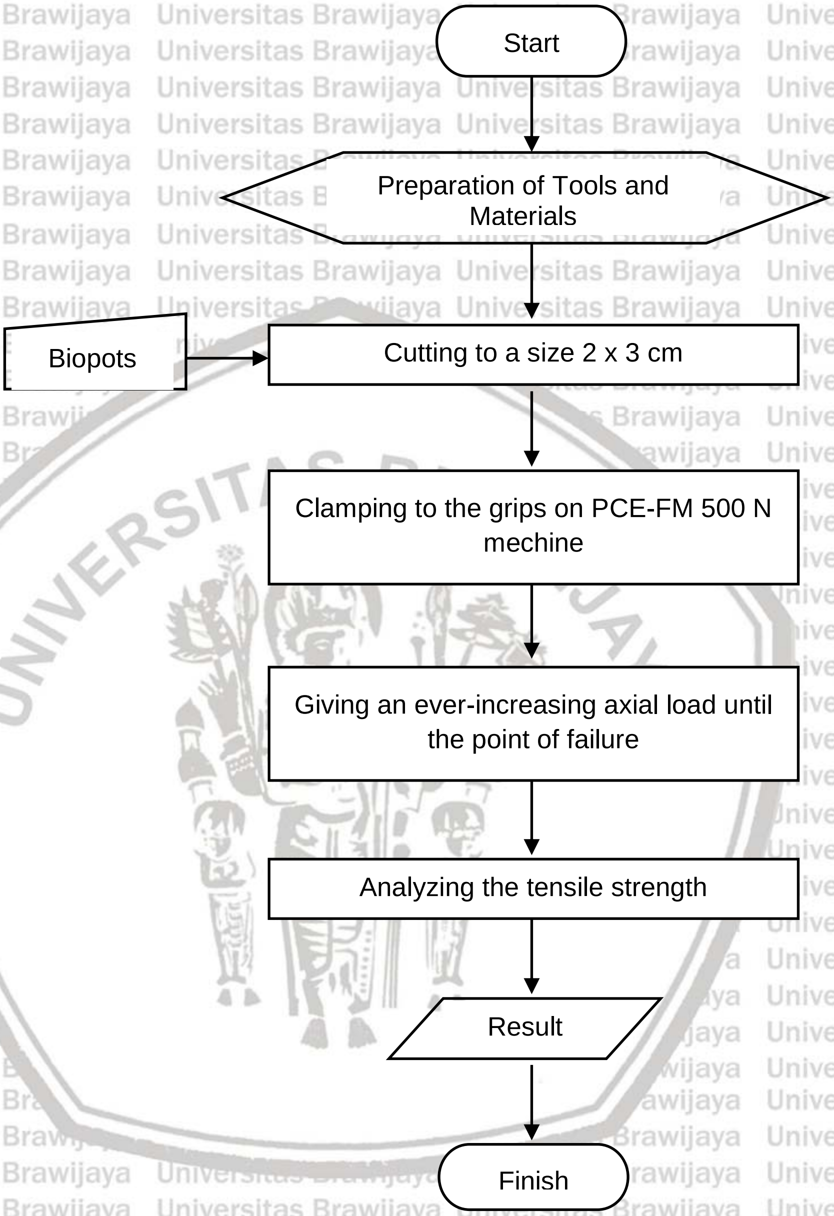


Figure 3.7 Tensile Strength Testing Procedure

CHAPTER IV RESULTS AND DISCUSSION

4.1. The Results of Making Biodegradable Pots

The results of making biodegradable pots made from oil palm empty fruit bunches and banana stems using variations of NaOH concentration can be seen in **Table 4.1**.

Table 4.1 The Results of Making Biopots

Treatment	Formulation	Results
R1C2	100% OPEFB	
R2C2	80% OPEFB : 20% Banana Stems	
R3C2	60% OPEFB : 40% Banana Stems	
R4C2	40% OPEFB : 60% Banana Stems	
R5C2	100% Banana Stems	

The quality of 15 variations of biodegradable pots was characterized by the actual size of height, top diameter and bottom diameter. Measurement results obtained biodegradable pots height of 9 cm (±0.3), the top diameter of 8 cm (±0.4), and the bottom diameter of 5 cm (±0.3) as seen in **Table 4.2**. The discrepancy between the actual size of biodegradable pots and the dimensions of the mould (5 x 8 x 9 cm) can be caused by the finishing process which aimed to improve the shape of biodegradable pots that was not tidy enough from the moulding process, as well as the addition of aluminum foil into the mould caused a reduction in the top diameter and bottom diameter of the biodegradable pots. However, the use of aluminum foil could effectively facilitate the moulding process due to the viscous pulp. Based on the **Table 4.1** it can be seen that the wall-surface of biodegradable pots with more composition of OPEFB fiber tended to be rougher compared to the biodegradable pots with more composition of banana stems fiber. It is caused by the difference in morphology of the size of the fibers between OPEFB fiber and banana stems fiber. Also according to Valasek, *et al.* (2021), the surface roughness of fiber was influenced by the alkaline effect. The roughness of natural fibers increased after alkaline treatment due to the disintegration of hemicellulose and lignin in lignocellulosic structure. In addition, if analyzed on the colour uniformity, biopots were brown and it tended to be whiter when the NaOH concentration in alkaline treatment was increased due to more lignin and impurities in the fiber that has been hydrolyzed, as can be seen in **Appendix 10.** After the process of making biopots, the physicomechanical properties will be analyzed based on the parameters of mass, moisture content, water uptake, biodegradable potential and tensile strength.

Table 4.2 The Data Quality of Biopots

Sample	Height (cm)	Top Diameter (cm)	Bottom Diameter (cm)
R1C1	9.2	7.8	4.7
R2C1	9	7.6	4.7
R3C1	8.9	7.7	4.7
R4C1	9	8	4.8
R5C1	9.1	7.8	4.9
R1C2	9.1	7.6	4.7
R2C2	9	7.7	4.7
R3C2	8.9	7.7	4.7
R4C2	9	7.8	4.7
R5C2	9	7.7	4.8
R1C3	8.9	7.6	4.7

Sample	Height (cm)	Top Diameter (cm)	Bottom Diameter (cm)
R2C3	8.8	7.7	4.7
R3C3	8.8	7.8	4.7
R4C3	9	7.9	4.8
R5C3	8.7	7.7	4.9

4.2. Mass of Biodegradable Pots

The results of the analysis of variance (ANOVA) showed a highly significant difference in the factor of raw materials composition, with a P-value of 5.225×10^{-9}, while both the factor of NaOH concentrations and the interaction between the two factors were not statistically significant difference with P-value of 0.950599 for the factor of NaOH concentrations and 0.957504 for the interaction between the two factors. Based on these results, it could be assumed that the factor of raw materials composition used in the making of biodegradable pots was significantly influential toward the mass of biodegradable pots produced due to had a high diversity of variance, as seen by the highly decreasing value from R1 of 18.48 grams to R5 of 9.58 grams. But no significant influence was found for the addition of NaOH concentrations and hence there was no interaction between the two factors evidenced by the absence of the influence of NaOH factor which depends on the level of raw materials composition factor to the mass of biodegradable pots. The results of the analysis of variance (ANOVA) on the mass of biodegradable pots have been presented in the **Appendix 1**. While the average value of biodegradable pot`s mass in each treatment can be seen in **Figure 4.1**.

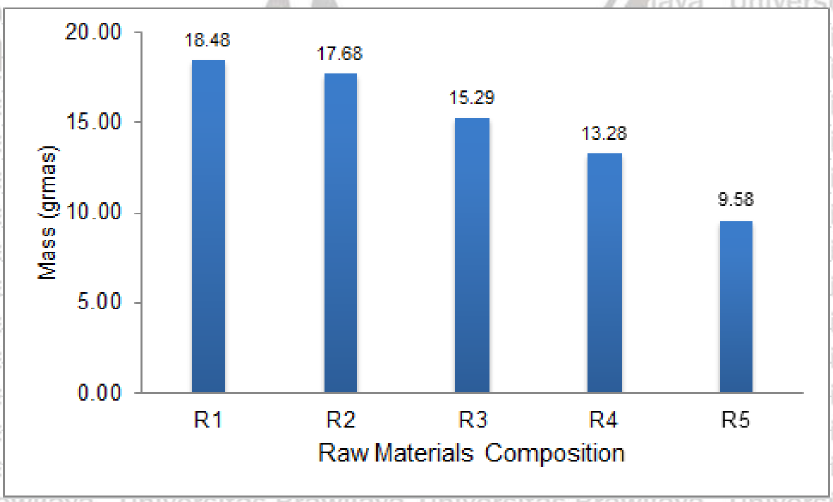


Figure 4.1 The Mass of Biodegradable Pots in Each Treatments

In **Figure 4.1** above, it can be seen that the average value of biodegradable pots mass in each treatment of raw materials composition factor showed different results, ranged from 9.58 grams to 18.48 grams. The lowest biodegradable pot`s mass is 9.58 grams was obtained from the treatment of R5 (100% Banana stems), and the highest mass of 18.48 grams was obtained from the treatment of R1 (100% OPEFB). In the treatment of raw materials composition factor, the mass of biodegradable pots tended to decrease. It can be seen that the treatment of R1 (100% OPEFB) had the highest value then continuously decreased to the treatment of R5 (100% Banana Stems). This trend might occur due to the differences in morphology of the fiber size between oil palm empty fruit bunches fiber and banana stems fiber, and also due to the physical properties of the fiber, namely its density. According to Rahmasita, *et al.* (2017), the density of OPEFB fiber reached to 1.55 g/cm^3, whereas according to Nopriantina and Astuti (2013), the density of banana stems fiber only 1.35 g/cm^3. The effect of differences in fiber size morphology on the biodegadable pots can be seen in **Figure 4.2**.

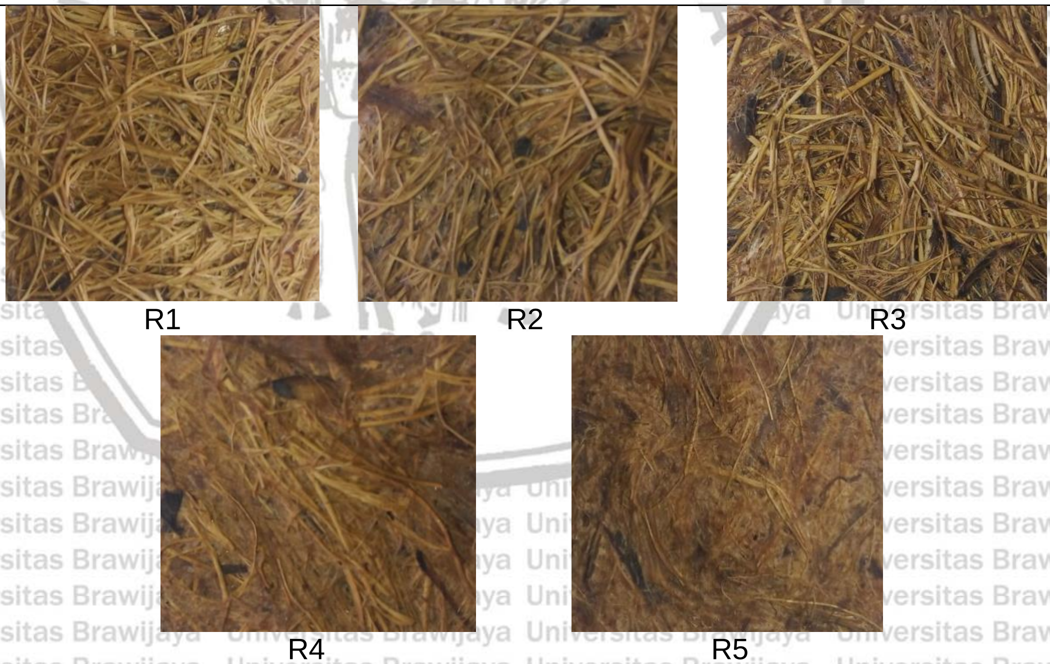


Figure 4.2 Fiber Size Morphological Appearances of Biopots

Based on **Figure 4.2** above, in can be seen the fiber size morphology between OPEFB fiber and banana stems fiber was very different. The morphology of OPEFB fiber which leaned to be coarser and larger than banana stems fiber will have an effect on the mass of the biodegradable pots when used in larger quantities, as seen in the treatment of R1 (100% OPEFB), the OPEFB fiber still looked very clear and had a large size compared to the treatments of R3 (60% OPEFB: 40% Banana Stems) and R5 (100% Banana Stems). Unlike the case in the treatment of K5, the fiber was almost invisible because of the small and smooth size of the fiber. According to Rahmasita, *et al.* (2017), the morphology of the oil palm empty fruit bunches fiber had a rough surface with large dimensions of 343 – 365 µm, while the large dimesions of banana stems fiber only reached to 5.8 µm (Nopriantina and Astuti, 2013). In this case, with large dimensions and higher density, the use of OPEFB fiber as raw materials can subsidize the mass of the biodegradable pot produced, which caused the higher the percentage of OPEFB used, the mass of the biodegradable pot will increase.

4.2.1. The Effect of Raw Materials Composition on Mass of Biopots

The results of the analysis of variance (ANOVA) test which showed a significant difference then continued with the DMRT (Duncan's Multiple Range) to figured out the difference between each level of raw materials composition in giving effect to the mass of biodegradable pots. Based on the results obtained, the DMRT test that was performed on the R factor (Raw Materials Composition) have been presented in the **Appendix 6**. The results of the DMRT test on the factor of raw material composition can be seen in **Table 4.3**.

Table 4.3 The Value of Biopots Mass Due to Raw Materials Composition Factor

Treatments	Average Value (grams)
R1	18.477c
R2	17.681c
R3	15.288b
R4	13.282b
R5	9.577a

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.2** above and the DMRT test in the **Appendix 6**, it can be seen that the levels of raw materials composition factor had a difference in giving effect to the mass of the biodegradable pots, indicated by different notation results. Treatment of R1 (100% OPEFB) had the highest average value, however not significantly different from the treatment of R2 (80% OPEFB: 20% Banana stems) in giving effect to the mass of biopots. Likewise, the treatment of R3 (60% OPEFB: 40% Banana stems) was no significantly different from the treatment of R4 (40% OPEFB: 60% Banana stems) in giving effect to the mass of biopots. While in the treatment of R5 (100% Banana Stems) had the lowest average value of biodegradable pot`s mass and significantly different from all treatment combinations. It seemed that the crosslinked biodegradable pots with the higher composition of banana stems fiber caused the decrease in the mass of biodegradable pots, while in the case of un-crosslinked biodegradable pots of OPEFB fiber-based to the un-crosslinked biodegradable pots of banana stems fiber-based had a high statistical significance in the mass of biodegradable pots, it was due to the difference in the morphology and the density of the fiber. The relationship between raw materials composition and the mass of biodegradable pots is presented in **Figure 4.3**.

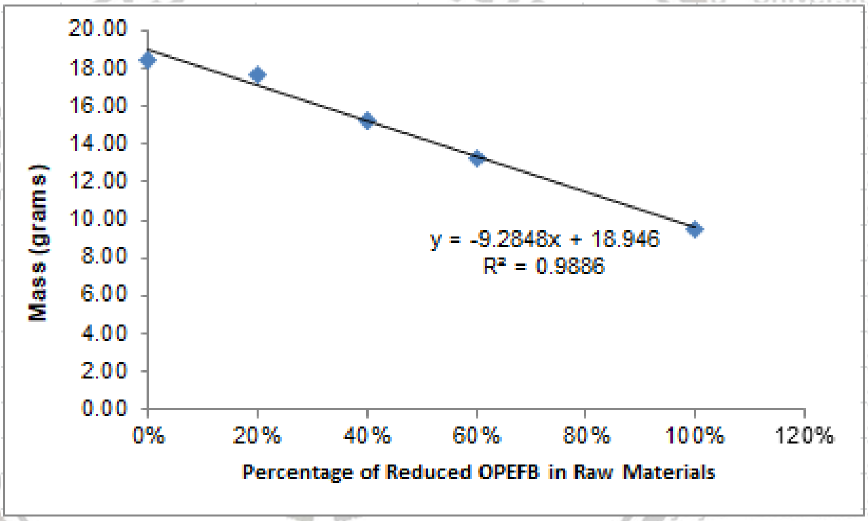


Figure 4.3 The Trend of Mass on Raw Materials Composition

The regression graph in **Figure 4.3** explained of the tendancy of the reduction of the percentage of OPEFB used in raw materials in each treatment to decrease the mass of biodegradable pot produced. The higher the percentage of banana stems used in raw materials, the lighter the mass of biodegradable pots obtained. These results were by research conducted by Randa and Alimin (2019), which stated that adding banana stems fiber could reduce the mass and density of a GRC (Glass-Fiber Reinforced Cement) composite material. Banana stems fiber is morphologically small, smooth, and light in size, thus the use of banana fibers in large quantities will make the mass of the biodegradable pot lighter. Analysis of the mass of the biodegradable pots was carried out to determine the durability level of biodegradable pots. The mass of biodegradable pots indicated the level of durability of biodegradable pots as nursery container media, which according to Evans, *et al*. (2010), the lighter the mass, the biodegradable pots tended to tear or break during greenhouse production, packaging, shipping, and retailing especially when wet condition. Therefore, in this research, the best result was obtained on the treatment combination of R1C1 (100% OPEFB; 3% NaOH) because had the heaviest mass.

4.3. Moisture Content

In the moisture content test, the results of the analysis of variance (ANOVA) test showed no significant difference in both of the factors of raw materials composition or concentration of NaOH, as well as the interaction between the two factors was no statistically significant difference. With each P-value of 0.8270 for raw materials composition factor, 0.11345 for NaOH concentrations factor, and 0.99645 for the interaction between the two factors. In other words, there was no significant effect on the moisture content of biopots that was given by either the factor of raw materials composition or NaOH concentrations factor, because the value of biopots moisture content had very low diversity of variance at each level of the factor. As seen for raw materials composition factor in R1 of 59.34 grams to R5 of 58.94 grams and for NaOH concentrations factor in C2 of 64.99 grams to C3 of 64.42 grams. Thus there was no interaction between the two factors that affected the value of the biopots moisture content, evidenced by the absence of the influence of the raw materials composition factor which depends on the level of NaOH concentrations factor, also vice versa. The results analysis of variance (ANOVA) on the Moisture content of biodegradable pots can be seen in the **Appendix 2**. While the average value of the Moisture content of the biodegradable pot in each treatment can be seen in **Figure 4.4**.

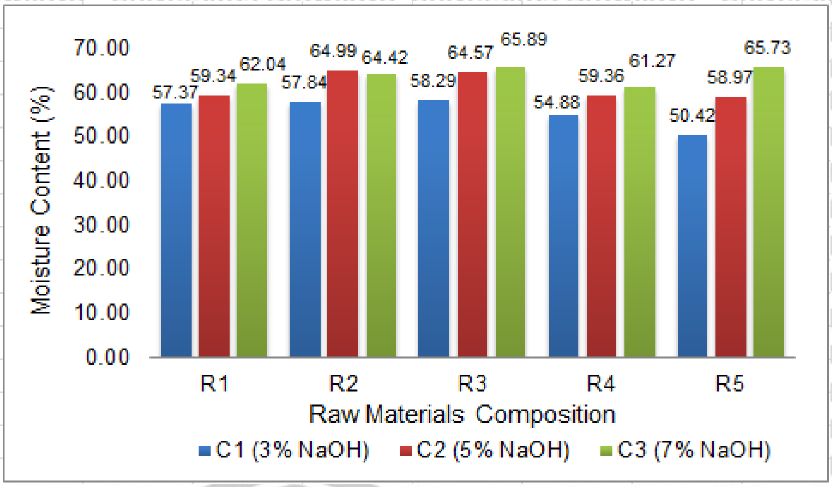


Figure 4.4 The Moisture Content of Biodegradable Pots in Each Treatments

Based on **Figure 4.4** above, it is known that the percentage of moisture content of biodegradable pots in each treatment showed different results, ranged from 50.42% to 65.89%. The lowest moisture content of 50.42% was obtained from the treatment combination of R5C1 (100% Banana stems; 3% NaOH), whereas the highest moisture content was 65.89% obtained from the treatment combination of R3C3 (60% OPEFB: 40% Banana stems; 7% NaOH). The graph above showed in treatment of raw materials composition had a percentage of moisture content that tended to fluctuate at each treatment. However, in the treatment of NaOH concentration, even though the ANOVA test showed no significant difference, the percentage of moisture content tended to increase with optimum point in the treatment of NaOH 7%. As seen that the treatment of C1 (3% NaOH) in each combination had the lowest percentage of moisture content and continued to increase until the treatment of C3 (7% NaOH), but in the treatment of C2 (5% NaOH) with a combination treatment of R2 (80% OPEFB: 20% Banana Stems) had a higher value of moisture content than the treatment of C3 (7% NaOH) on the same combination. According to Pudjiono, *et al*. (2012), an increase of NaOH levels in alkaline treatment could break the fiber bond more completely, thus could increase the porosity of biodegradable pots, and caused the moisture content stored in the biodegradable pots to be increased. Meanwhile, according to Wahyudi (2014) in Jaya, *et al*. (2019), the composition of the raw materials mixture for making biodegradable pots had no effect on the moisture content.

Nevertheless, in this research, it was found the opposite result for the NaOH concentration factor. This unusual outcome could be due to an uneven increased porosity of the biodegradable pot caused by irregular dispersion of the fibers in the biodegradable pot matrix during the moulding process. The appearance of fiber dispersion in the biodegradable pots can be seen in **Figure 4.5**.

Regular Dispersion | Irregular Dispersion

Figure 4.5 Fiber Dispersion Appearances of Biopots

Based on the **Figure 4.5** above, the regular fiber dispersion was indicated by completely bonded fibers. While the irregular fiber dispersion shows the breaking point, lead to discontinuity of the fibers bonds in the biodegradable pots. This irregular dispersion of fibers would cause decreasing the ablity of biopots to retain water, therefore the unevenness of the increase in porosity had an impact on an insignificant increase in moisture content, moreover, the moisture content decreased in R2 (5% NaOH) of 64.99% to R3 (7% NaOH) of 64.42%. Meanwhile, the results of this research was also in accordance with the results of research by Effendi (2012), in the making of green polybags from OPEFB and oil palm midribs, that either the material composition of green polybags or the NaOH concentration used, also the interaction between the two factors, did not significantly affect the moisture content of green polybags produced. The most plausible explanation for this difference in results may be due to the optimum concentration of NaOH used in the alkaline treatment, especially for crosslinked biocomposites. Because according to Valasek, *et al.* (2021), each type of nature fiber tends to have a different optimum of NaOH concentration. In addition the different amount of cellulose can be obtained from different NaOH concentration, it will also cause different changes in fiber dimensions after alkaline treatment, including fiber expansion, enlargement of the lumen diameter, and thinning of the cell wall as owing by dissolved lignin conten in fibers (Fitriasari *et al.,* 2019). Thus, allows for differences in physical properties, not only the composites but also individual fibers. Moreover, excessive use of NaOH caused the degradation of cellulose (Paskawati *et al*., 2010). It may result in the deterioration of the physical properties of biocomposites. Therefore the level of NaOH concentration used needs to be considered to get significant results on the moisture content value in crosslinked biocomposites more than one type of fiber.

Based on the results of the ANOVA test obtained, showed no significant difference, then no DMRT (Duncan's Multiple Range) test was needed to figure out the difference between each treatment in giving effect to the moisture content of biodegradable pots. The value of moisture content obtained in this research was also better than Jaya`s research on making Biodegradable pots from OPEFB and fiber with a moisture content of 70.93% (wet basis) and also in accordance with SNI (*Standart Nasional Indonesia*) 03-2105-2006 for composite, which the moisture content was less than 14% (dry basis) or 93% (wet basis).

The percentage of moisture content in the biodegradable pots also indicated the level of durability of biodegradable pots as nursery container media, according to Jaya, *et al*. (2019), high moisture content had caused damage to biodegradable pots due to the growth of unfavorable microorganisms. Therefore, it is expected that as a container media for seedling, biodegradable pots have a low moisture content to avoid spoilage and damage during storage and easier to apply in the nursery process, because this is related to the flexibility of using biodegradable pots both indoor and outdoor. Accordingly, in this research, the best result of moisture content was obtained in combination treatment of R5C1 (100% Banana stems; 3% NaOH).

4.4. Water Uptake

The results of the analysis of variance (ANOVA) test showed a highly significant difference in the factor of NaOH concentration with a P-value of 0.001713, while the factor of the raw materials composition and the interaction between the two factors showed a significant difference with a P-value of 0.015304 for the factor of raw materials composition and a P-value of 0.024443 for the interaction between the two factors. Based on these results, it can be seen that both at the factor of raw materials composition and NaOH concentrations affected differently to the percentage of water uptake of biodegradable pots produced due to had a high diversity of variance, as seen by the highly increasing value from R1 of 3.41% to R4 of 4.82%, and highly decreasing value from C1 of 4.22% to C3 of 2.27%. It indicates there was an interaction between the two factors evidenced by the influence of the raw materials composition factor which depends on the level of NaOH concentrations factor, also vice versa. The results of the analysis of variance (ANOVA) test on water uptake of biodegradable pots have been presented in the **Appendix 3**. Meanwhile, the average percentage of water uptake in each treatment can be seen in **Figure 4.6**.

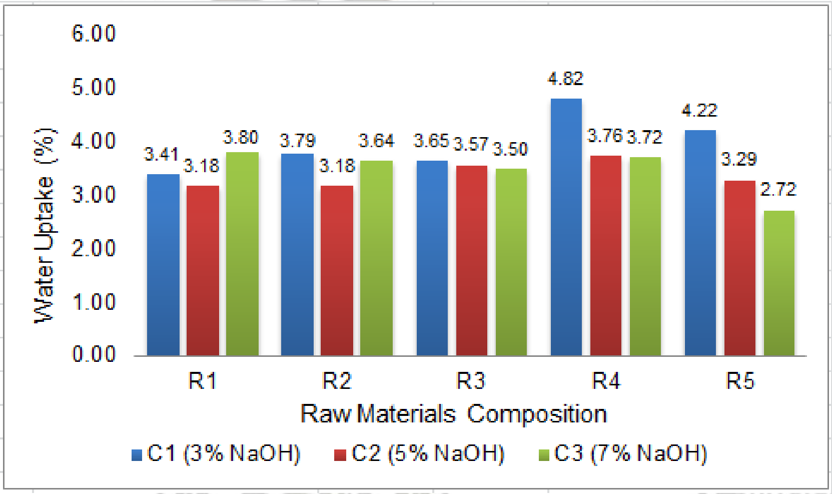


Figure 4.6 The Water Uptake of Biodegradable Pots in Each Treatments

In **Figure 4.6** above, it can be seen that the percentage of water uptake of biodegradable pots in each treatment showed different results, ranged from 2.72% to 4.82%. The lowest percentage of biodegradable pots water uptake of 2.72% was obtained from the treatment combination of R5C3 (100% Banana stems; 7% NaOH), and the highest percentage was 4.82% obtained from the treatment combination of R4C1 (40% OPEFB: 60% Banana stems; 3% NaOH). As seen in the graph above on the treatment of NaOH concentrations, the percentage of water uptake tended to fluctuate, then decreased on the treatment combination of R3, R4, and R5 in each treatment. Meanwhile, from the treatment of raw materials composition, the percentage of water uptake also tended to fluctuate, but increased on the treatment of R4, and decreased in value on the treatment of R5. According to Akhir, *et al*. (2018), it is known that the percentage of water uptake was influenced by fiber density. The more fiber density of the surface of biopots, the tendency of water to penetrate was inhibited. In this case, it can be proven by increased the thickness of the biocomposite during the swelling phenomena which cause an increase in free volume due to the availability of empty space in the biocomposite to bind water molecules. The more the thickness of the sample expanded, the higher the volume of water absorbed by the sample. The percentage of water uptake in organic growing media according to Sarka, *et al*. (2011) ranged from 3.86% - 9.44%.

4.4.1. The Effect of Raw Materials Composition on Water Uptake Biopots

The data results from the analysis of variance (ANOVA) test that indicated a significant difference then followed by the DMRT (Duncan's Multiple Range) test to figured out the difference between each level of factors in giving effect to the water uptake of the biodegradable pots. Based on the results obtained, the DMRT test that performed on the R factor (Raw Materials Composition), C factor (Concentration of NaOH), and the interaction between the two factors (R*C) have been presented in the **Appendix 7**. The results of the DMRT test on the each level of raw materials composition factor are presented in **Table 4.4**.

Table 4.4 The Value of Biopots Water Uptake Due to Raw Materials Composition Factor

Treatments	Average Value (%)
R1	3.460a
R2	3.536a
R3	3.573a
R4	4.097b
R5	3.411a

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.4** it can be seen that the treatment of raw materials composition had a difference in giving effect to the percentage of water uptake of biodegradable pots, indicated by different notation results. The treatment of R5 (100% Banana stems) had the lowest average value of water uptake, but not significantly different from the treatments of R1, R2, and R3. While in the treatment of R4 (40% OPEFB: 60% Banana Stems) produced the highest average value of biodegradable pot`s water uptake and significantly different for all treatment combinations. These results show an increase in the volume of pores and free space in the case of crosslinked biopots when banana stems fibers were added to the raw materials. The tendency for treatment of K4 to have the highes percentage of water uptake could be caused by the formation of more pores in the biopots. The pores formed in the materials would cause the materials to have permeability properties (Rahamsita, *et al*., 2017). It causes water could to pass through and be absorbed by the biopots. Moreover, the results show the water uptaking process increased in the crosslinked biodegradable pots if compared to un-crosslinked biodegradable pots. These results were also in agreement with the previous research on crosslinked biopots by Schettini, *et al*. (2013), crosslinked biopots able to increase the binding availability sites for water molecules by inducing the increasing of free volume. In addition, it also can be seen that the water uptaking process in the un-crosslinked biodegradable pots of banana stems fiber-based was lower than the un-crosslinked biodegradable pots of OPEFB fiber-based. The Trend of the percentage of water uptake biodegradable pots on raw materials composition can be seen in **Figure 4.7**.

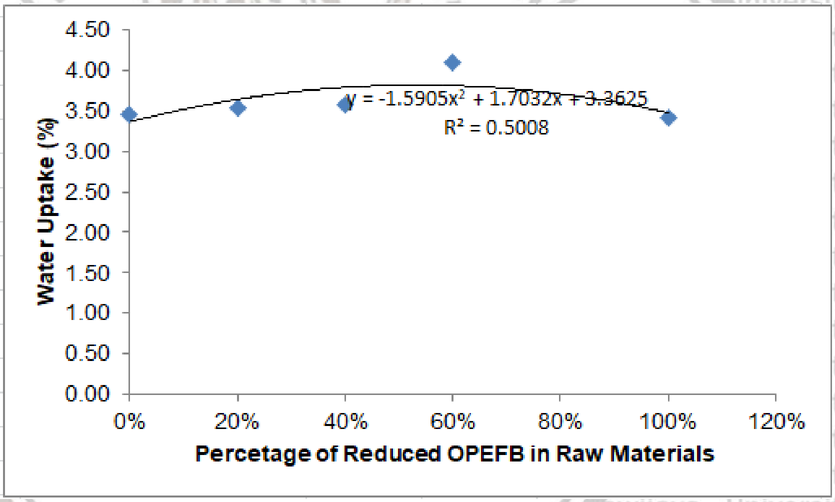


Figure 4.7 The Trend of Water Uptake on Raw Materials Composition

From the graph in **Figure 4.7**, it is known that there was a trend of influence of the reduction of OPEFB used in raw materials composition in each treatment on the percentage of water uptake of biodegradable pots produced. It showed in crosslinked biodegradable pots, the higher the percentage of banana stems used resulted in increased the percentage of water uptake of biodegradable pots, but then decreased in un-crosslinked biodegradable pots of banana stems fiber-based of R5 (100% Banana stems). In the crosslinked biopots, adding too much banana stems fiber can create more pores, thus cause the high porosity of the material and results in high water uptake of the material. This may be happened because banana stems fiber was hydrophilic, then it is facilitated the process of water absorption in the composite (Randa and Alimin, 2019). Meanwhile, according to Rahmasita, *et al*. (2017), the structure of Oil Palm Empty Fruit Bunches (OPEFB) fiber has a fairly large size dimension about 343 – 365 µm, and it is bigger than the size dimension of banana stems fiber which has a small dimension of 5.8 µm (Nopriantina and Astuti, 2013). This case allows for different pore characteristics of the fiber. Pore characteristics describe the total, size, distribution, and continuity of pores which play very important role in determining the movement of water (Masria, *et al.,* 2018). In addition according to research by Bhagat*, et al*. (2013), the rate of water uptake on composite increase along with increase in fiber dimensions. Hence. it may cause the water absorption of un-crosslinked biodegradable pots of OPEFB fiber-based is higher than un-crosslinked biodegradable pots of banana stems fiber-based.

4.4.2. The Effect of NaOH Concentrations on Water Uptake Biopots

The results of DMRT (Duncan's Multiple Range) test for the each level of NaOH concentrations factor can be seen in **Table 4.5**.

Table 4.5 The Value of Biopots Water Uptake Due to NaOH Concentrations Factor

Treatments	Averange Value (%)
C1	3.977b
C2	3.396a
C3	3.474a

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.5** above, it can be seen that the treatment on the factor of NaOH concentration used had a difference in giving effect to the percentage of water uptake of biodegradable pots, indicated by different notation results. The highest average value of water uptake was obtained in the treatment of C1 (3% NaOH). As for the lowest average value of water uptake obtained in the treatment of C2 (5% NaOH), but the results were not significantly different with the treatment of C3 (7% NaOH). The value of water uptake of biodegradable pots in this research showed a decrease along with the increase of NaOH concentration as a delignificator agent. These results is in agreement with research by

Ramadevi, *et al*. (2012) on water absorption of abaca fiber, indicated the ability of fiber to absorb water was reduced by alkaline treatment and decreased with an increase in alkaline concentration due to removal lignin content in the fiber. Hence, These results indicates the hydrolysis phenomena of higher lignin content in OPEFB fiber and Banana stems fiber from alkaline treatment of 3% NaOH concentration to 5% NaOH concentration. The NaOH treatment aims to ionize the hydroxyl groups on fiber lead to alkalization of cellulose. Thus, the fiber had a high water resistant (Zebua, 2015).

However, in this research, there was an indication of decreased cellulose content in alkaline treatment of 7% NaOH as indicated by increased the concentration of water uptake on biodegradable pots. The Trend of the percentage of water uptake biodegradable pots on NaOH concentrations can be seen in **Figure 4.8**.

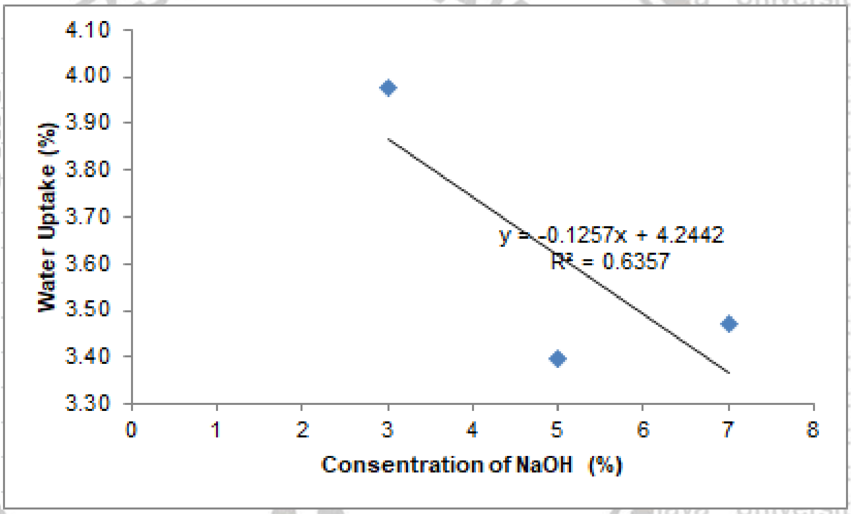


Figure 4.8 The Trend of Water Uptake on NaOH Concentrations

The regression graph in **Figure 4.8** above, explained the trend influence of the concentration of NaOH used in each treatment on the percentage of water uptake of biodegradable pots produced. The percentage of water uptake decreased along with the increase in the concentration of NaOH used. This is shown in the percentage of water uptake obtained in the treatment of C1 (3% NaOH) which decreased when the concentration of NaOH was added to the treatment of C2 (5% NaOH). However, at an increased concentration to the treatment of C3 (7% NaOH), the percentage of water uptake precisely increased. On alkaline treatment, cellulose fiber would react with alkaline and form alkaline cellulose indicated a broken lignocellulosic structure, with hydrolyzed the lignin content and resulted in the cellulose content increased. According to Zebua (2015), cellulose fibers that react with alkaline caused the permeability of the fiber to decrease, it made the water difficult to penetrate the surface of composite. Therefore, it concluded that the reduced level of permeability of the biodegradable pots directly affects the hygroscopicity of the biodegradable pots. And cause reduces the ability of the biodegradable pots to absorb water. This research showed that the delignification efficiency increased in line with the increase in the concentration of NaOH used. While the decrease in cellulose content that occurred in the alkaline treatment of 7% NaOH showed a tendency for the optimum NaOH concentration at 5% concentration for the crosslinked biodegradable pot of OPEFB fiber and Banana Stems fiber-based.

4.4.3. The Effect of Interaction between Raw Materials Composition and NaOH Concentration

The results of DMRT (Duncan's Multiple Range) test for the interaction between raw material composition factor and NaOH Concentration factor (R*C) can be seen in **Table 4.6**.

Table 4.6 The Value of Biopots Water Uptake Due to The Interaction between Raw Materials Composition and NaOH Concentrations

Treatments	Average Value (%)
R1C1	3.407a
R2C1	3.786b
R3C1	3.653a
R4C1	4.820d
R5C1	4.219c
R1C2	3.178a
R2C2	3.184a
R3C2	3.570a
R4C2	3.756b
R5C2	3.291a
R1C3	3.798b
R2C3	3.638a
R3C3	3.496a
R4C3	3.715b
R5C3	2.724a

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.6**, it can be seen that the interaction between the factor of raw materials composition and the factor of NaOH concentration used in the process of making biodegradable pots had a difference in giving effect on the percentage of water uptake of biodegradable pots produced, indicated by different notation results. The lowest average value of water uptake was obtained in the treatment combination of R5C3 (100% Banana stems; 7% NaOH) and was not significantly different with the treatment combination of R1C1, R3C1, R1C2, R2C2, R3C2, R5C2, R2C2, R3C3, proved by the notation "a". While the highest average of water uptake was obtained in the treatment combination of R4C1 (40% OPEFB: 60% Banana stems; 3% NaOH) and significantly different with all the treatment combinations. Following the hypothesis, the mass ratio of OPEFB fiber to banana stems fiber used in the composition of the raw materials, as well as the amount of NaOH concentration used in making biodegradable pots can affect the value of water uptake. The results in **Table 4.6**, show an increasing in certain porosity at the treatment of crosslinked samples when the concentration of banana stems fiber in raw materials increases, as seen in the treatment combination of R3C1 to R4C1, R2C2 to R4C2, and R2C3 to R4C3. In this case, indicates the crosslinked biodegradable pots with higher levels of banana stem fiber could absorb more water, compared to un-crosslinked biodegradable pots, either OPEFB fiber-based or banana stems-based. However, it was found a phenomenon of decreasing water uptake value in crosslinked biopots when the banana stems concentration was increased from treatment combination of R2C1 to R3C1 and R2C3 to R4C3 This is probably due to the irregular fiber dispersion that was shown in **Figure 4.5**, it leads to the presence of voids and discontinuity points on the biopots, thus higher un-wettable sample.

On the other hand, the value of water uptake will decrease along with an increase of NaOH concentration which indicates the increase of cellulose content in biopots, both in the crosslinked and uncrosslinked biopots of OPEFB fiber-based or banana stems fiber-based. Whereas, there was a tendency of a decrease in cellulose content due to optimum alkaline treatment at C2 (5% NaOH), which was shown in the increase of water uptake in treatment combination of R1C2 to R1C3 and R2C2 to R2C3. The trend of water uptake value on the interaction between raw material composition factor and NaOH concentration factor can be seen in **Figure 4.9**.

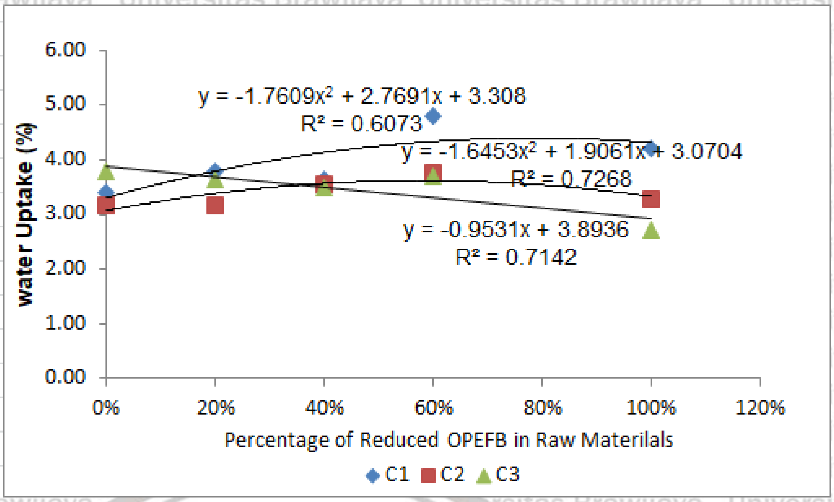


Figure 4.9 The Trend of Water Uptake on The Interaction of Raw Materials Composition and NaOH Concentrations

The regression graph in **Figure 4.9** above, explained the trend of water uptake value due to the interaction between the raw material composition factor and NaOH concentration factor used. The variations in the composition of raw material and concentration of NaOH used as an alkaline treatment gives variations in the percentage of water uptake of biodegradable pots. Schettini, *et al*. (2013), said that biocomposites consisted of several raw materials that would form crosslinked polymers caused differences in the volume of free space between biocomposites. Meanwhile, alkaline treatment could reduce the hydrophilic properties of the natural fiber. In alkaline treatment, hydrophilic hydroxyl groups reduce by reacting with NaOH which leads to prohibiting absorbed water of composite (Reddy, *et al.,* 2018). Hence, the interaction between raw materials factor and NaOH concentrations factor tends to influence the water uptake value of biodegradable pots. In addition, the use of an adhesive also facilitated the closure of the capillary cavity that connects the empty space of polymers, thereby reducing the water absorption ability of the material (Maharany and Ingrid, 2021).

In addition, based on the results of water uptake, there was an indication that value of water uptake was inversely proportional to the value of moisture content. It proved by the treatment combination of R5C1 with a moisture content of 50.42% had a water uptake of 4.22%, while the R5C3 with a moisture content of 65.73% had a water uptake of 2.72%. The trend of the relationship between water uptake and moisture content can be seen in **Figure 4.10**.

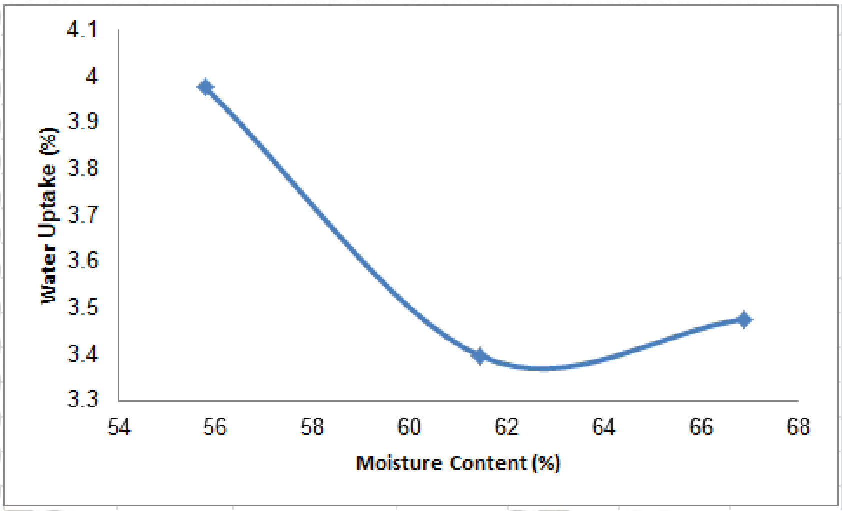


Figure 4.10 The Relationship Between Water Uptake and Moisture Content

This phenomenon in **Figure 4.10** has to do with the osmosis process, follow by Jaio, *et al*. (2015), since the osmosis process was driven by an osmotic pressure difference across solvent and solute, which is when the solvent had a higher concentration rather than the solute, lead to water molecules migrate into the solute until reaching the equilibrium state. Therefore, the higher osmotic pressure differences across water and biopots, the more water molecules tend to migrate into biopots, thus caused a higher percentage of water uptake. The percentage of water uptake of biodegradable pots indicated resilience biodegradable pots to water through the ability to absorb water. This is related to the level of durability of biodegradable pots as nursery media when applied in the field. The lower the percentage of biodegradable pot`s water uptake, then the quality of the biodegradable pots would be even better. Therefore, In this research, the best result was obtained from biopots with high water-resistant in the treatment combination of R5C3 (100% Banana stems; 7% NaOH).

4.5. Biodegradation Test

In the biodegradation test, the results of the analysis of variance (ANOVA) showed there was a significant difference in the factor of NaOH concentrations, with a P-value of 0.01556, while the factor of raw materials composition and the interaction between two factors showed highly significant difference with P-value respectively was 2.149×10^{-10} for the factor of raw materials composition and

0.006551 for the interaction between two factors. In other words, both factors of raw materials composition and the concentration of NaOH used in the making of biodegradable pots influence the biodegradability of biodegradable pots due to had a high diversity of variance, as seen by the highly increasing value from R1 of 76.39% to R4 of 51.14%, and highly increasing value from C1 of 76.39% to C3 of 68.85%. Hence, it indicates there was an interaction between the two factors evidenced by the influence of the raw materials composition factor which depends on the level of NaOH concentrations factor, also vice versa. The Results of the Analysis of variance (ANOVA) on the biodegradability of biodegradable pots can be seen in the **Appendix 4**. While the average value of the biodegradability of the biodegradable pots in each treatment is presented in **Figure 4.11**.

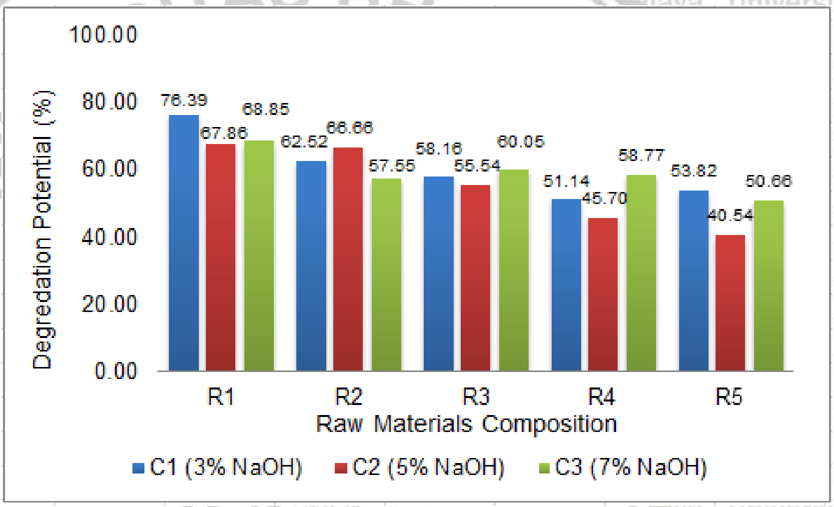


Figure 4.11 The Biodegradation Potential of Biodegradable Pots in Each Treatements

Based on **Figure 4.11**, it can be seen that the Biodegradation Potential of Biodegradable Pots in each treatment showed different results, ranged from 40.54% to 76.39%. The lowest value of biodegradation potential of 40.54% was obtained from the treatment combination of R5C2 (100% Banana stems; 5% NaOH), and the highest value of 76.39% was obtained from the treatment combination of R1C1 (100% OPEFB; 3% NaOH). As seen in the graph above, in the treatment of NaOH concentration, the biodegradation potential of biodegradable pots tended to undergo a reduction. While from the treatment of raw materials composition, the biodegradation potential of biodegradable pots also tended to decrease. Phenomena of the reduced potential of the biodegradable pot sample to be degraded during the burial period in the soil are related to the cellulose content in each treatment combination of the biodegradable pots. The hypothesis says the higher the cellulose content in the sample, the longer the biodegradable pots would take to degrade. According to Nambuthiri, *et al*. (2013), biodegradable pots as a good alternative media for seedlings at least capable of being degraded up to 60% in good natural conditions, including soil conditions and temperature. In this regard, the treatment combination between R1 (100% OPEFB) and R2 (80% OPEFB: 20% Banana stems) with each level of the NaOH concentrations factor (C1, C2, and C3) have reached that number. Mass loss in biodegradable pot samples during the biodegradation test within 21 days can be seen in **Figure 4.12**.

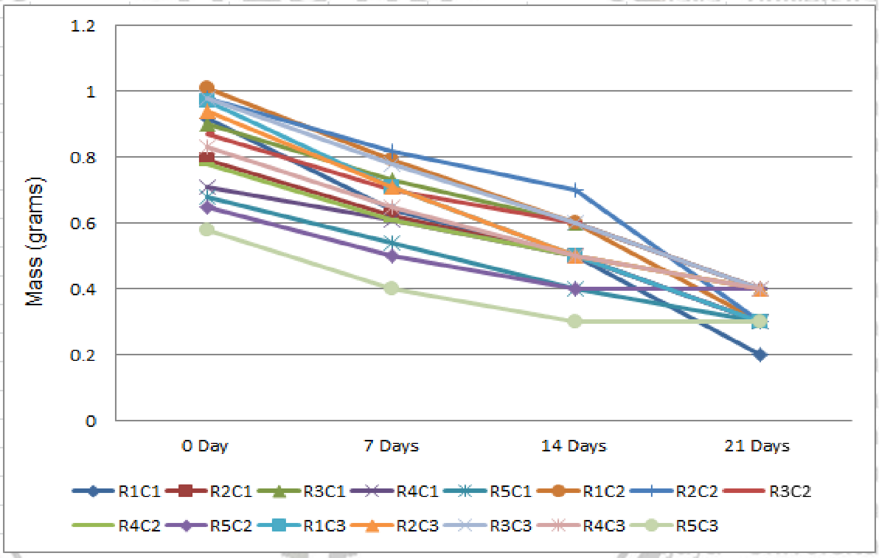


Figure 4.12 The Mass Loss During Biodegradations Test

Figure 4.12 showed the mass loss kinetics of biodegradable pot sample during the biodegradation testing period. As seen all treatment combinations experienced mass loss during the period of burial in the soil. This matter indicated an interaction between microorganisms and the sample of biodegradable pots that were buried during 21 days. Each treatment combination of biodegradable pots tends to have a different rate of degradation. This possibility indicates the ability of microorganisms in the soil to react with each sample, the difference occurs due to the different conditions of the biodegradable pots sample, especially because of the cellulose content in biopots. The process of the biodegradation mechanism occurs when microorganisms in the soil released enzymes and then adhesion of enzymes to surface and cleavage of polymer which caused the material will be damaged over time, this enzymatic process also produced final products in the form of water, carbon dioxide, and other metabolic products (Tomadoni, *et al.*, 2020).

4.5.1. The Effect of Raw Materials Compotion on Biodegradable Potential of Biodegradable Pots

The data results from the analysis of variance (ANOVA) test which indicated a significant difference then continued with the DMRT (Duncan's Multiple Range) test to figured out the difference between each treatment in giving effect to the biodegradation potential of the biodegradable pots. Based on the results obtained, the DMRT test that performed on the R factor (Raw Materials Composition), C factor (Concentration of NaOH), and the interaction between the two factors (R*C) have been present in the **Appendix 8**. The results of the DMRT test on the each level of raw materials concentration factor are presented in **Table 4.7**.

Table 4.7 The Value of Biopots Biodegradable Potential Due to Raw Materials Composition Factor

Treatments	Average Value (%)
R1	71.035c
R2	62.242b
R3	57.915b
R4	51.868a
R5	48.338a

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.7** above, it can be seen that the treatment of raw material composition factor had a difference in giving effect to the biodegradation potential of biodegradable pots, indicated by the different notation results. The treatment of R1 (100% OPEFB) had the highest average value of biodegradation potential, and significantly different for all treatment combinations. Likewise in treatment of R2 (80% OPEFB: 20% Banana stems) was not significantly different from the treatment of R3 (60% OPEFB: 40% banana stems). While in the treatment of R5 (100% Banana stems) produced the lowest average value of biodegradation potential of biodegradable pots, but not significantly different from the treatment of R4 (40% OPEFB: 60% banana stems). These phenomena explain that the addition of banana stem fiber to the crosslinked biodegradable pot would increase the cellulose content in the biodegradable pots, lead to the ability of the biodegradable pots to be degraded in nature decreased. Meanwhile, in un-crosslinked biodegradable pots, the highest biodegradable potential was owned by un-crosslinked biodegradable pots of OPEFB fiber-based since by means of contained less cellulose compared to un-crosslinked biodegradable pots of banana stems fiber-based, as can be seen in **Table 2.2**. The Trend of the percentage of biodegradation potential on raw materials composition is presented in **Figure 4.13.**

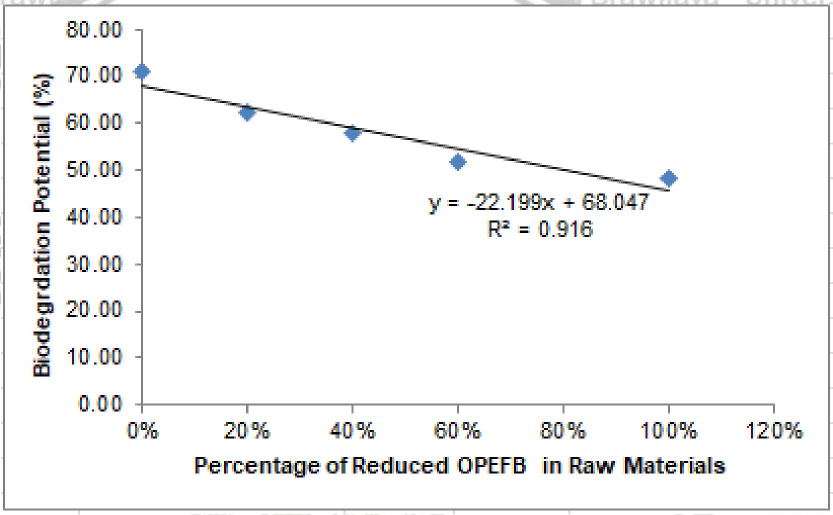


Figure 4.13 The Trend of Biodegradation Potential on Raw Materials Composition

The regression graph in **Figure 4.13** explained the trend of influence of the reduction of OPEFB used in raw materials composition in each treatment on the decreasing percentage of biodegradation potential of the biodegradable pot produced. The types of fiber greatly affect the ability of a biocomposite to degrade in nature, which the higher the percentage of banana stems in the raw materials used, the biodegradation potential of the biodegradable pots would be decreased. According to Schettini, *et al.* (2013), the high content of microcrystalline cellulose in fiber resulted in a low rate of biopolymer biodegradability, due to the chain hydrophilic macromolecules were not easily susceptible to attack by microorganisms. Cellulose fiber-based biocomposite had a chemical composition that was more structured, thus could inhibit and retarded microbial attack. On the other hand, the morphology of the oil palm empty fruit bunches fiber which was porous and contains silica (Rahmasita, *et al*., 2017), made the fiber easier to reacted by microorganisms in the soil during burying. Because following by Chinnathambi and Fuyuhiko (2020), silica was sensitive to enzymatic activities due to having a biodegradable organic group framework. On the other hand, the pores in the OPEFB fiber facilitated the enzymatic process in breaking down the molecular structure of the biopots caused the biodegradation process to take more quickly. These are sufficient enough to explain the trend of the regression graph in decrease the biodegradability of biopots due to the compostion of the raw materials. The cellulose content in the raw materials indicated to continue to increase from un-crosslinked biopots of OPEFB fiber-based to the crosslinked biopots, up to un-crosslinked biopots of Banana stems fiber-based. Nevertheless, the higher the proportion of banana stems added to the crosslinked biopots, the more difficult biopots to be degraded due to the high cellulose content. While in the un-crossllinked biopots of OPEFB fiber-based had the highest biodegradation potential because it was influenced by less cellulose content, also had silica content in the fiber, thus cause easily to attact by microorganisms during the burying test.

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4.5.2. The Effect of NaOH Concentrations on Biodegrdable Potential of Biodegrdable Pots

The results of DMRT (Duncan's Multiple Range) test for the each level of NaOH concentrations can be seen in **Table 4.8**.

Table 4.8 The Value of Biopots Biodegradable Potential Due to NaOH Concentration Factor

Treatments	Average Value (%)
C1	60.404b
C2	55.259a
C3	59.176b

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.8** above, it can be seen that the treatment on the factor of NaOH concentrations had a difference in giving effect to the biodegradation potential of biodegradable pots, indicated by the different notation results. The highest value of biodegradation potential of biodegradable pots was obtained in the treatment of C1 (3% NaOH) but not significantly different from the treatment of C3 (7% NaOH). While the lowest value of the biodegradation potential of biodegradable pots was obtained in the treatment of C2 (5% NaOH) and was significantly different from the two other treatments. The NaOH concentration in alkaline treatment plays a role in increasing the purity of the cellulose contained in the material by dissolving the lignin content. In this case, it can be seen that the C1 (3% NaOH) treatment released less lignin content than the C2 (5% NaOH) and C3 (7% NaOH) treatments. However, it was noted that there was an unusual degradation phenomenon as a result of the too high concentration of NaOH, namely in the treatment of C3 (7% NaOH), which was indicated by an increase in the biodegradation potential of the biodegradable pot when compared to the biodegradation potential in the treatment of C2 (5% NaOH). The Trend of the percentage of biodegradation potential on NaOH concentrations is presented in **Figure 4.14**.

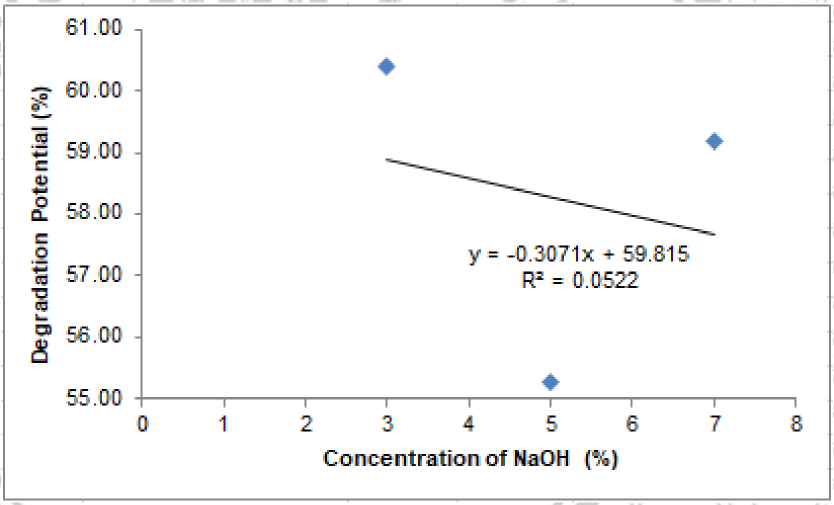

Figure 4.14 The Trend of Biodegradation Potential on NaOH Concentrations

The regression graph in **Figure 4.14** above, explained the trend influence of concentration of NaOH used in each treatment to decreased the biodegradation potential of the biodegradable pot produced. Gunam, *et al.* (2011), said that the higher the concentration of NaOH used as a delignification agent allowed hydrolysis of lignin in large quantities, thus caused the cellulose content to increases. In this research, there was a tendency of decreased the ability of biodegradable pots to degrade during the burial period, it showed an increased cellulose content in OPEFB fiber and banana stems as raw materials.

Somehow, there was also an unsual results that were in agreement with the analysis of the water uptake, that NaOH concentration tended to be optimum at 5% due to a phenomenon of a decrease cellulose content of biopots at 7% NaOH, that was indicated by increased the biodegradation potential. Cellulose is a simple polymer, but it formed insoluble, and crystalline microfibrils. The organization of individual microfibrils in crystalline cellulose is packed tightly enough to prevent penetration by enzymes (Lakhundi, *et al*., 2015). This may cause high resistance to enzymatic hydrolysis. Hence, the higher the cellulose content in the biocomposite, the more difficult biocomposite would be to degrade in nature due to poor enzymatic attack. Thus, the mechanism of cellulose hydrolysis could be achieved by the synergistic activity of two components, the first is swelling disrupt cellulose and the second having endoglucanase activity in order to get a faster cellulose degradation process (Dimarogona, *et al.,* 2021).

4.5.3. The Effect of Interaction between Raw Materials Composition and NaOH Concentration

The results of DMRT (Duncan's Multiple Range) test for the interaction between raw material composition factor and NaOH Concentration factor (R*C) can be seen in **Table 4.9**.

Table 4.9 The Value of Biopots Biodegradable Potential Due to The Interaction between Raw Materials Composition and NaOH Concentrations

Treatments	Average Value (%)
R1C1	76.390g
R2C1	62.519d
R3C1	58.156c
R4C1	51.137b
R5C1	53.818b
R1C2	67.863f
R2C2	66.658e
R3C2	55.538b
R4C2	45.697a
R5C2	40.539a
R1C3	68.851f
R2C3	57.551c
R3C3	60.050c
R4C3	58.770c
R5C3	50.658a

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.9**, it can be seen that the interaction between the factor of the composition of raw materials and the factor of NaOH concentration used in the process of making the biodegradable pots had a difference in giving the effect on the biodegradable potential of biodegradable pots, indicated by the different notation results. The lowest average value of biodegradation potential was obtained in the treatment combination of R5C2 (100% Banana stems; 5% NaOH) and not significantly different with treatment combinations of R4C2 and R5C3, as shown in **Table 4.9**. While the highest average value of biodegradation potential was obtained in the treatment combination of R1C1 (100% OPEFB; 3% NaOH) and significantly different with all treatment combinations. These results indicate that the un-crosslinked biodegradable pots of banana stems fiber-based were more difficult to degrade in nature when compared to the crosslinked biodegradable pots and to the un-crosslinked biodegradable pots of OPEFB fiber-based. Moreover, it does be even more difficult to be degraded when the concentration of NaOH during alkaline treatment was increased because of the having more cellulose content in the raw materials. However it also was found a phenomenon of increasing the biodegradation potential when the concentration of banana stems was increased from treatment ombination of R4C1 to R5C1 and from R2C3 to R3C3. This outcome could be due to the irregular dispersion of fiber inside the biopots that responsible for the voids rising and lead to facilitate the microorganisms to reach the bonding of the fibers on biopots, thus more easily cleavage of the polymer. Moreover, there was a tendency of a decrease in cellulose content because of excessive NaOH concentration at 7% NaOH, which was shown in the increase of biodegradation potential in the treatment combination of R1C3, R3C3, R4C3, and R5C3 respectively from 5% NaOH Concentration. Meanwhile, the trend of biodegradation potential value on the interaction between raw material composition factor and NaOH concentration factor can be seen in **Figure 4.15**.

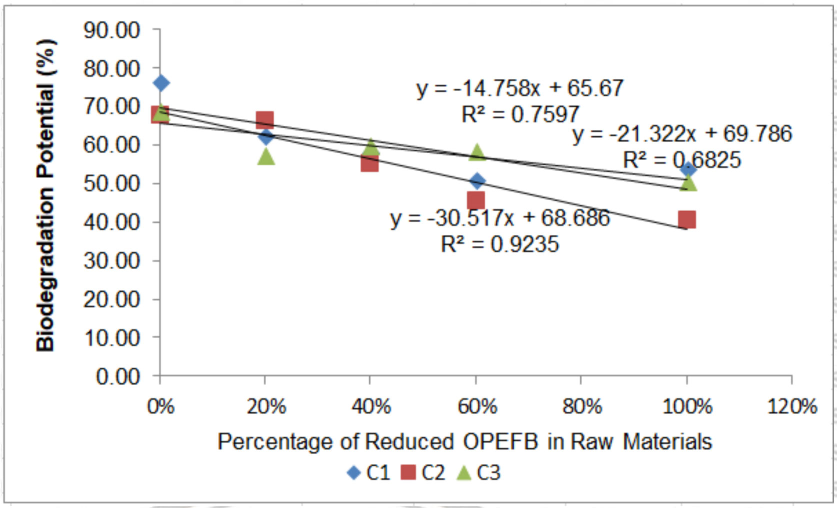

Figure 4.15 The Trend of Biodegradation Potential on The Interaction of Raw Materials composition and NaOH Concentrations

The regression graph in **Figure 4.15** above, explained the trend of biodegradation potential value due to the interaction between the raw material composition factor and NaOH concentrations factor used. The combination of treatments used in research provided different variations in the degradation rate. But it can be concluded that the percentage of the biodegradation potential of the biodegradable pots had decreased along with the increased concentration of banana stems fiber which added in raw materials because of the higher cellulose content in banana stems fiber rather than in OPEFB fiber, thus could enrich the cellulose content in raw materials, as shown in **Table 2.3**. Also, the addition of NaOH concentration in alkaline treatment has resulted in high cellulose content in the raw materials. Hence, the interaction between raw materials factor and NaOH concentrations factor tends to influence the percentage of biodegradation potential of biodegradable pots. As a result, compared to the crosslinked biopots and the un-crosslinked biopots of banana stems fiber-based, the un-crosslinked biopots of OPEFB fiber-based in all treatment combinations with the concentration of NaOH used were able to be degraded faster in nature due to contained less cellulose. The biodegradation process of biocomposite occurs when microorganisms firstly mineralized the polymetric matrix then following transform the fibers (Schettini, *et al.,* 2013). Therefore, the higher the cellulose content in the fibers, it would be slow down the process of biodegradation on the biodegradable pots.

The biodegradability test was also related to the lifespan of the biodegradable pot as an alternative nursery media that could be adapted to the cycle plant production. According to Nambuthiri, *et al.* (2013), mostly biodegradable pots would decompose in a few months depending on the conditions of the environment. In addition, extending the lifespan of biodegradable pots could be done by adding natural or synthetic adhesives, resins, waxes, or binder which then determines the level of biodegradability and compostability of the containers as nursery media. Regarding these results, in this research, the best result was obtained, which was the most easily to be degraded in nature in the treatment combination of R1C1 (100% OPEFB; 3% NaOH). Meanwhile, in the **Figure 4.16** below is showed the difference between biodegrdable pots sample after and before the degradation test.

Figure 4.16 The Sample of Biodegradation Test (a) Sample before Biodegradation Test (b) Sample after Biodegradation Test

4.6. Tensile Strength Test

The results of the analysis of variance (ANOVA) test showed a highly significant difference in the factor of NaOH concentrations, with a P-value of 3.75 x 10^{-7}, while the factor of raw materials composition and the interaction between two factors also showed highly significant difference with P-value respectively was 1.68 x 10^{-23} for the factor of raw materials composition and 9.98 x 10^{-14} for the interaction between two factors. In other words, both factors of raw materials composition and the concentration of NaOH used in the making of biodegradable pots influence the tensile strength of biodegradable pots due to had a high diversity of variance, as seen by the highly increasing value from R1 of 8798 Pa to R5 of 23418 Pa, and highly increasing value from C1 of 17320 Pa to C3 of 23418 Pa. Hence, it indicates there was an interaction between the two factors evidenced by the influence of the raw materials composition factor which depends on the level of NaOH concentrations factor, also vice versa. The results of the analysis of variance (ANOVA) on tensile strength of biodegradable pots have been presented in the **Appendix 5**. While the average value of tensile strength of biodegradable pots in each treatment can be seen in **Figure 4.17**.

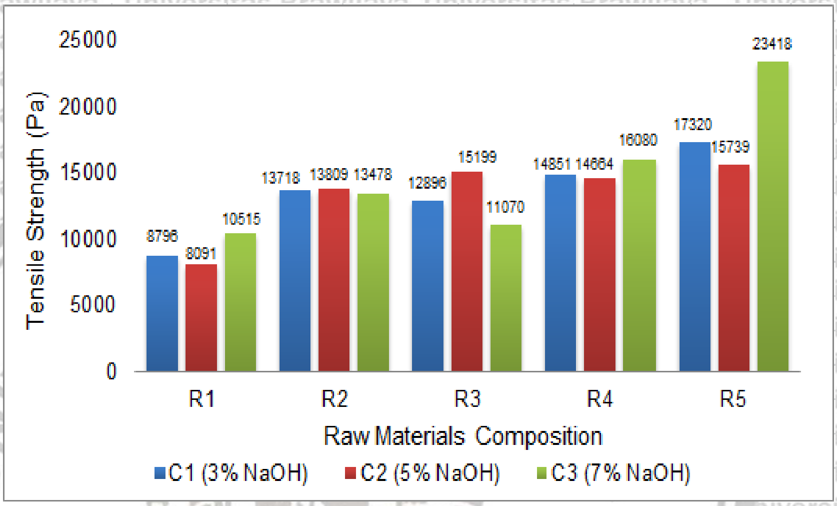

Figure 4.17 The Tensile Strength of Biodegradable Pots in Each Treatments

Based on **Figure 4.17**, it can be seen that the average value of biodegradable pots tensile strength in each treatment showed different results, ranged 8091 Pa to 23418 Pa. The lowest value of tensile strength of biodegradable pots of 8091 Pa was obtained from a treatment combination of R1C2 (100% OPEFB; 3% NaOH) and the highest value of 23418 Pa was obtained from the treatment combination of R5C3 (100% Banana stems; 7% NaOH). In the treatment of raw materials compositions and NaOH concentrations, the tensile strength of the biodegradable pot tended to increase with optimum point in the treatment of C3 (7% NaOH) and the treatment of K5 (100% Banana Stems). In the study of Schettini, *et al.* (2013), the making process of biodegradable pots from tomato and hemp fibers, the tensile strength resulted ranged from 460000 – 1200000 Pa, and the value of the tensile strength was influence by the fiber dispersion during the making process. To date, research and studies on the mechanical properties of biodegradable pots from OPEFB fibers were still limited. If compared to the result by Schettini, *et al.*

(2013), the tensile strength of the biodegradable pots produced in this research tended to be smaller. It probably due to discontinuity of fibers on biodegradable pots, as a result by irregular fiber dispersion during the moulding process of biodegradable pots. Following by Schettini, *et al*. (2013), if the voids were produced due to irregular dispersion of fiber in the composite, it would significantly weaken the load transfer capability, thus the tensile strength would decrease. Furthermore, the biodegradable pots have a stiffness composite structures by utilizing natural fibers, thus the mechanichal permorfance of the composites of natural fibers-based was poorer if compared to the composites of synthetic fibers-based.

4.6.1. The Effect of Raw Materials Composition on Tensile Strength of Biopots

The data results from the analysis of variance (ANOVA) test which indicated a significant difference then continued with the DMRT (Duncan's Multiple Range) test to figured out the difference between each treatment in giving effect to the biodegradation potential of the biodegradable pots. Based on the results obtained, the DMRT test that performed on the R factor (Raw Materials Composition), C factor (Concentration of NaOH), and the interaction between the two factors (R*C) have been present in the **Appendix 9**. The results of the DMRT test on the each level of raw materials concentration factor are presented in **Table 4.10**

Table 4.10 The Value of Biopots Tensile Strength Due to Raw Materials Composition Factor

Treatments	Average Value (Pa)
R1	9134a
R2	13668c
R3	13034b
R4	15199d
R5	18826e

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.10** above, it can be seen that each level in treatment of raw material composition factor had a difference in giving effect to the tensile strength of biodegradable pots, indicated by the different notation results. The treatment of R1 (100% OPEFB) had the lowest average value of tensile strength, and significantly different for all treatment combinations. Meanwhile, in the treatment of R5 (100% Banana stems) showed the highest average value of tensile strength of biodegradable pots, also significantly different from all treatment combinatrion. Moreover, in the uncrosslinked biopots from R2 (80% OPEFB: 20% Banana stems) up to R4 (40% OPEFB: 60% Banana stems) the tensile strength showed an increase in value, yet from treatment of R2 to R3 (60% OPEFB: 40% Banana stems) the tensile strength was decreased, this unsual outcome probably due to irregular dispersion of fiber on biopots as seen in the **Figure 4.6**. According to Indrawan, *et al*. (2018) the decreased of tensile test on composite could be caused by the formation of voids that lead to an inhomogeneity between the fibers and matrix. These phenomena explain that the uncrosslinked biopots with OPEFB fiber-based had a lowest tensile strength, compored to the both crosslinked or the uncrosslinked biopots with banana stems fiber-based. However, there was a tendency of increasing tensile strength due to an addition of banana stem fiber in the raw materials. Following by Rao and Rao (2005) in Purnama, *et al.,* (2013), said that the banana fibers is one of natural fibers with highest average of tensile strength reached to 600 MPa due to high cellulose content, while the palm fibers only had value of 377 MPa. Thus, could be assumed that the addition of banana stems fiber to the raw material can support the increased on tensile strength of biodegradable pots produced, by that also answed the tendency of uncrosslinked biopots R1 (100% OPEFB) to have the lowest tensile strength. The Trend of the tensile strength of biodegradable pots on raw materials composition is presented in **Figure 4.18.**

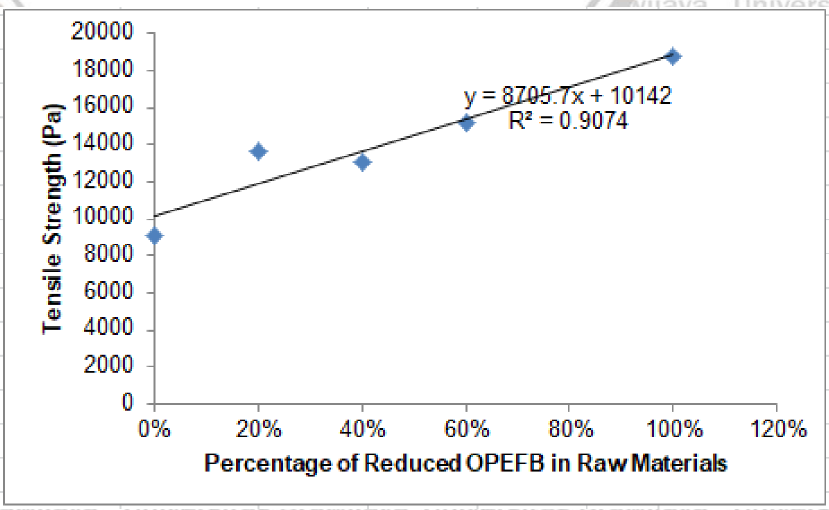

Figure 4.18 The Trend of Tensile Strength on Raw Materials Composition

The regression graph in **Figure 4.18** explained the trend of influence of the reduction of OPEFB used in raw materials composition in each treatment on the increasing tensile strength of the biodegradable pot produced. The types of fiber greatly affect to the mechanical properties, especially the tensile strength of biodegradable pots, which the higher the percentage of banana stems in the raw materials used, the tensile strength of the biodegradable pots would be increased due to more cellulose content in raw materials. This result is in a greement with Karimah, *et al.* (2021), reported that the presence of cellulose of natural fiber affected to the tensile strength of biocomposites when used as a mixture or raw materilas. Cellulose correlated positively with tensile strength and Young's modulus, which means the higher the cellulose content in the raw materials used, the higher the tensile strength of biocomposite will be. Following this hypothesis, it can be known that the cellulose content in the raw materials indicated to continue to increase from un-crosslinked biopots of OPEFB fiber-based (R1) to the crosslinked biopots (R2, R3, and R4) up to un-crosslinked biopots of Banana stems fiber-based (R5). Thus, the higher the proportion of banana stems added to the crosslinked biopots could support a stronger tensile strength of biopots due more cellulose content, supported by Nair, *et al*. (2016), the addition of banana fiber in composites material composition could strengthen composited and showed higher tensile. Whereas, in the un-crossllinked biopots of OPEFB fiber-based had the lowest tensile strength because it was influenced by less cellulose content and had more lignin content compared to banana stems fiber as can be seen in **Table 2.2**, which lignin content had negative impact and correlation to the mechanical properties of natural fiber, especially the tensile strength. Moreover, the un-crossllinked biopots of banana stems fiber-based had the highest tensile strength influenced by the highest the cellulose content in the fibers as can be seen in **Table 2.3**.

4.6.2. The Effect of NaOH Concentrations on Tensile Strength of Biopots

The results of DMRT (Duncan's Multiple Range) test for the each level of NaOH concentrations can be seen in **Table 4.11**

Table 4.11 The Value of Biopots Tensile Strength Due to NaOH Concentration Factor

Treatments	Average Value (Pa)
C1	13515a
C2	13500a
C3	14900b

Note: the average value followed by the same letter does not significantly difference based on the DMRT test analyzed in SPPS packages

Based on **Table 4.10** above, it can be seen that the treatment on NaOH concentration factor had a difference in giving effect to the tensile strength of biodegradable pots, indicated by different notation results. The highest value of tensile strength was obtained in the treatment of C3 (7% NaOH), and significantly different for all treatment combinations. And the lowest value of tensile strength was obtained in the treatment of C2 (3% NaOH), but not significantly different from the treatment of C1 (5% NaOH). Tensile strength analysis showed that the increase in NaOH concentration would increase the tensile strength of the biodegradable pots due to the high cellulose content obtained by hydrolyzed the lignin content in fibers. Based on Bahtiar, *et al*. (2016), lignin is a component that covers cellulose and hemicellulose in the fibers and could provide stiffness to the fibers. Thus far, the hydrolysis of lignin in fiber among alkaline treatment was able to increase the mechanical properties of the fibers due to reduced stiffness in fibers.

However, the results in tensile test of biopots were slightly different from the results of the water uptake and biodegradation test, which showed the optimum delignification point at 5% NaOH concentration. In the tensile strength test, the concentration of 5% NaOH and 3% NaOH showed not significantly different in giving effect on tensile strength, also the tendency of tensile strength continued to increase up to 7% of NaOH concentration indicated the highest cellulose content obtained, both in the un-crosslinked biodegradable pots and crosslinked biodegradable pots treatment. The difference at the optimum point of NaOH concentration may be influenced by the irregular fiber dispersion that leads to produce the voids on biopots. The presence of these voids could affect the fiber density of biopots. According to Herma P, *et al*. (2019), the fiber density of the composite will weaken when voids were more formed inside the composite. Furthermore, as reported by Darni, *et al*. (2018), fiber density is one of the physical properties of polymer that influence the mechanical properties. The higher the fiber density of the materials will increase the mechanical properties. Due to this hypothesis, it can be assumed that the mechanical properties of the biopots are not necessarily affected by the high content of cellulose in the fibers. The phenomenon of irregular fiber dispersion on the biopots probably indicates a poor uniformity of the fiber density of the biopots and it is responsible for the poor ability of biopots to transfer the load during tensile test. The Trend of the tensile strength of biodegradable pots on NaOH concentrations can be seen in **Figure 4.19**

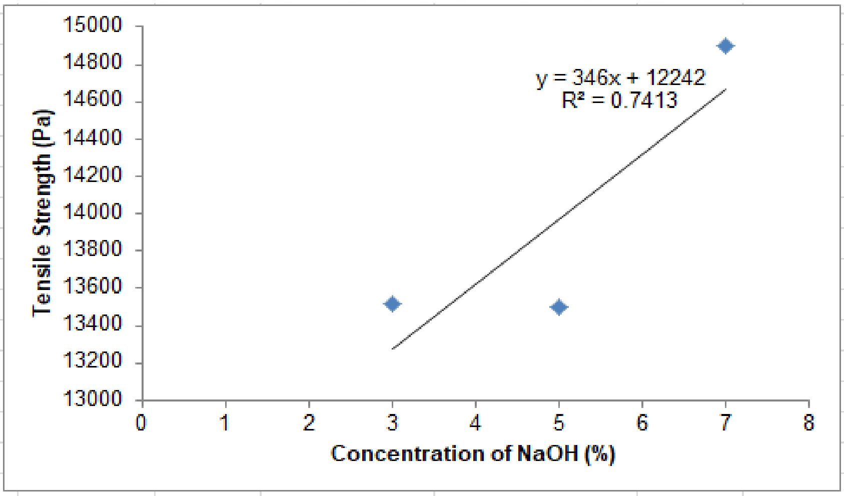

Figure 4.19 The Trend of Tensile Strength on NaOH Concentrations

The regression graph in **Figure 4.19** explained the trend influence of concentration of NaOH used in each treatment to increased the value of tensile strength of the biodegradable pots, which was the higher concentration of NaOH used, the tensile strength of the biodegradable pots would also increase. This is related to the number of cellulose content obtained after the alkaline treatment process. According to Rachman (2010), said that the increase in cellulose content caused increased hardness of the material, which was directly related to increases in the tensile and compressive strength of the composites. This corresponds to research conducted by Schettini, *et al.* (2013), that the biocomposite composed of natural fibers which were mostly cellulose structures increased in tensile strength. Therefore, the tensile strength of biodgradable pots, both the un-crosslinked biodegradable pots with OPEFB fiber-based and un-crosslinked biodegradable pots with banana stems fiber-based, as well as the crosslinked biodegradable pots (R2, R3, and R4) tended to increased along with an increase of NaOH concentration due to more lignin content that were be hydrolyzed, and lead to the higher cellulose content in the fiber after alkaline treatment. This is directly related to the increasing of the tensile strength in fiber individual also in the biodegradable pots produced.

4.6.3. The Effect of Interaction between Raw Materials Composition and NaOH Concentration

The results of DMRT (Duncan's Multiple Range) test for the interaction between raw material composition factor and NaOH Concentration factor (R*C) can be seen in **Table 4.12**.

Table 4.12 The Value of Biopots Tensile Strength Due to The Interaction between Raw Materials Composition and NaOH Concentrations

Treatments	Average Value (Pa)
R1C1	8796a
R2C1	13718c
R3C1	12896c
R4C1	14851d
R5C1	17320e
R1C2	8091a
R2C2	13809c
R3C2	15199d
R4C2	14664d
R5C2	15739d
R1C3	10515b
R2C3	13478c
R3C3	11010b
R4C3	16080e
R5C3	23418f

Note: the average value followed by the same letter does not significantly different based on the DMRT test analyzed in SPPS packages

Based on **Table 4.12**, it can be seen that the interaction between the factor of the composition of raw materials and the factor of NaOH concentration used in the process of making the biodegradable pots had a difference in giving the effect on the tensile strength of biodegradable pots, indicated by the different notation results. The lowest average value of tensile strength was obtained in the treatment combination of R1C2 (100% OPEFB; 5% NaOH) and not significantly different with treatment combinations of R1C1 (100% OPEFB; 3% NaOH). Whereas, the highest average value of tensile strength was obtained in the treatment combination of R3C5 (100% Banana stems; 7% NaOH) and significantly different with all treatment combinations. These results indicate that the un-crosslinked biodegradable pots of banana stems fiber-based had astronger of tensile strength compared to the crosslinked biodegradable pots and to the un-crosslinked biodegradable pots of OPEFB fiber-based. Futhermore, the tensile strength even higher when the concentration of NaOH during alkaline treatment was increased due to more cellulose content was obatained in the raw materials. However it also was found a phenomenon of decreasing the tensile strength when the concentration of banana stems was increased from treatment ombination of R2C1 to R3C1, R3C2 to R4C2 and from R2C3 to R3C3. This un unusual outcome could be due to the irregular dispersion of fiber inside the biopots that lead to voids rising, thus caused inefficient load transfer between fibers and matrix of biodegradable pots. Moreover, there was also unusual outcome by decreasing value of tensile strength when the NaOH concentration increased in treatment combination of R1C1 to R1C2, and from R3C2 to R3C3. Meanwhile, the trend of tensile strength on the interaction between raw material composition factor and NaOH concentration factor can be seen in **Figure 4.15**.

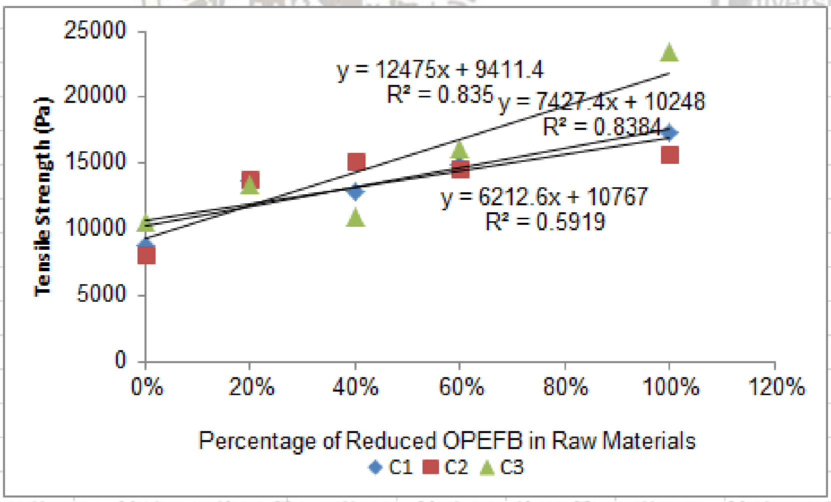

Figure 4.19 The Trend of Tensile Strength on The Interaction of Raw Materials composition and NaOH Concentrations

The regression graph in **Figure 4.19** above, explained the trend of tesile strength value due to the interaction between the raw material composition factor and NaOH concentrations factor used. The combination of treatments used in research provided different variations of tensile strength. But it can be assumed that the value of biopots tensile strength of the had increased along with the increased concentration of banana stems fiber which added in raw materials because of the higher cellulose content in banana thus support the higher presence of cellulose content in raw materials. As well as, the addition of NaOH concentration in alkaline treatment and an increase in concentration has resulted in high tensile strength due to rich of cellulose content in the raw materials. Hence, the interaction between raw materials factor and NaOH concentrations factor affect the tensile strength of biodegradable pots. If compared to the crosslinked biopots and the un-crosslinked biopots of OPEFB-based, the un-crosslinked biopots of banana stems fiber-based in all treatment combinations with the concentration of NaOH used had a stronger tensile strength.

Following the results of tensile strength, the fiber density of biodegradable pots, both crosslinked and un-crosslinked, needs to be considered. The Irregular dispersion of the fibers inside the polymeric matrix that provided voids in the biocomposites, both in the matrix or between the fiber and matrix would cause uneven load distribution on biodegradable pots due to discontinuity of fibers bonding. Moreover, the tensile strength is affected by the efficiency of load transfer from the matrix to the fiber (Schettini, *et al., 2013)* Thus, increasing the fibers density of biodegradable pots are needed to build a good bonding between the fiber and the constituent matrix, to get a good tensile strength. The tensile strength of biodegradable pots also indicated the level of durability of biodegradable pots as nursery container media. Tensile strength account for handling capacity of biodegradable pots, which refers to the tensile forces are exerted on the container walls during plant growth and manually transporting the container (Juanga, *et al*., 2021). Hence, in this regard, the best result based on the highest value of tensile strength was obtained in the treatment combination of R5C3 (100% Banana Stems; 7% NaOH).

4.7. The Best Treatment Formulation

According to Juanga, *et al*. (2021), the development of bio-containers has been continuously focused on utilizing the appropriate biodegradable waste materials, improving the strength of the container and also increasing its biodegradability. Thus, the best treatment formulation in this study was obtained from treatment combinataion of R2C2 (80% OPEFB: 20% banana stems; 5% NaOH) due to higher OPEFB in raw materilas could support the faster biodegradability of biopots by the avalaibility of silica content. Following by Tomadoni, *et al.* (2020) the main thing to consider is that it is fundamental to offer fast biodegradation of planting biopots within the soil to avoid their accumulation and root circling while increasing biopots water use efficiency when rising plants. Thus far, adding banana stems fiber in the raw materials could support the better strength of biopots, both in the tensile strength and water resistance. Because reported by Nechita (2019), the main drawbacks of the biodegradable pots are its strength, especially wet strength. However, adding too much banana stems fiber is necessary to avoid due to more pores that caused the low water resistance of biopots and related to the durability of biopots that plays an important role during the plant's nursery process before the plants are ready to be transferred to the cultivation land. Thus, biodegradable container or biopots become a sustainable containers that could easily adjust to both horticulture and floriculture production.

Also, based on physicomechanical testing that was carried out to the biodegradable pots indicated an irregular dispersion of the fiber during the moulding process, thus cause the presence of discontinuity of fibers affected the fiber density of biodegradable pots, resulting in a weakening of the biodegradable pots matrix which directly related to the quality of biodegradable pots. Hence, the fibers density of biodegradable pots needed some improvement in future research. The poor fibers density might be by means of the size dimensions of the OPEFB fibers still quite rough during the pulping process, that lead to inhomogeneity fibers size when mixed with banana stems fiber. The physicomechanical results of the quality of biodegradable pots are presented in the **Table 4.13**.

Table 4.13 Physicomechanical Results of The Quality of Biodegradable

Parameters	Results
Mass	The mass of biodegradable pots was influenced by raw materials composition. The value ranged from 9.58-18.48 grams, a significant difference in the morphology of the fiber size and the density between OPEFB and banana stems greatly affected the mass the biodegradable pots.
Moisture Content	The factors of raw materials composition and NaOH concentrations, also the interaction had no effect. The value ranged from 50.42%-65.89%, the phenomenon of irregular dispersion of fibers slightly affected the porosity qualityof biodegradable pots. However, the moisture content obtained in this study was better than the previous study and was in accordance with SNI.

Parameters	Results
Water Uptake	The factors of raw materials composition and NaOH concentrations, also the interaction affected on water uptake. The value ranged from 2.72%-4.82%, an increase of banana stems in raw materials was able to increase the permeability of biodegradable pots due to the formation of more pores in biodegradable pots, therefore crosslinked biodegradable pots absorb water more easly rather than uncrosslinked biodegradable pots. While an increase in NaOH concentration affected the reduction number of hydroxyl groups that were ionized and form alkaline cellulose in the fiber, thus will increase the water resistance of the biodegradable pots.
Biodegradation Potential	The factors of raw materials composition and NaOH concentrations, also the interaction affected on biodegradation potential. The value ranged from 76.39%- 40.54%, the addition of banana stems fiber in the raw materials composition and the increase in the concentration of NaOH had an impact on increasing the cellulose content in biodegradable pots. Thus, able to inhibit the enzymatic activities of microorganism, and thereby reducing the potential for biodegradable pots to be degraded in nature.
Tensile Strength	The factors of raw materials composition and NaOH concentrations, also the interaction affected on tensile strength. The value ranged from 8091 Pa-23418 Pa, the increase in NaOH concentration as well as the proportion of babana stems fibers used in raw materials lead to more cellulose obtained, which was able to increase the hardness of the biodegradable pots, thus the tensile strength increased. However, the irregular dispersion of fibers phenomenon found in the biodegradable pots was able to weaken the bonding between the matrix and fibers, thereby reducing the effiency of load transfer which results in a weakening of the biodegradable pots tensile strength.

CHAPTER V CONCLUSION AND RECOMMENDATION

5.1. Conclusions

Based on the results of research and discussion, it can be concluded that:

1. OPEFB have the potential to be utilized, especially in the making of biodegradable pots as an alternative nursery container. Also adding banana stems in the raw materials, as well as increasing the concentration of NaOH, can strengthen the physicomechanical properties of the biodegradable pots, due to the increasing cellulose content in the fibers.
2. The raw materials composition factor affects the mass of biodegradable pots, the interaction between two factors influences the value of water uptake, biodegradation potential, and tensile strength, yet it does not show any effect on the moisture content of biodegradable pots.
3. The quality results show biodegradable pots have the height of 9 cm (±0.3), the top diameter of 8 cm (±0.4), and the bottom diameter of 5 cm (±0.3).
4. The physicomechanical results show biodegradable pots have a mass range from 9.58-18.48 grams, moisture content of 50.42%-65.89%, water uptake of 2.72%-4.82%, biodegradation potential of 40.54%-76.39%, and tensile strength of 8091 Pa-23418 Pa.
5. Treatment combination of R2C2 (80% OPEFB: 20% banana stems; 5% NaOH) is the best treatment formulation due to having faster biodegradability also can support the durability of biodegradable pots through high tensile strength and water resistance. However, the fiber density of biodegradable pots needs some improvement caused by the irregular fiber dispersion.

5.2. Recommendations

1. In future research, it is recommended to do a Scanning Electron Micrograph (SEM) on the sample to determine the image of the bonding between fibers and matrix in biodegradable pots produced.
2. It is recommended to use a smaller size of OPEFB fiber to increase the fiber density of biopots, also facilitate the moulding proses.
3. To get a whiter and cleaner color of cellulose fiber a bleaching process is required using a Hydrogen Peroxide solution (H_2O_2).

4. Research on the effect of the types of the banana plants used on the banana stems fiber as raw material for making biodegradable pots deemed necessary to do so.
5. The study in particular focus on the customer acceptance of biodegradable pots is recommended to do so, to knowing the appeal and the aesthetic value of biodegradable pots through the hedonic test.
6. The application test of biodegradable pots in the nursery process is needed to knowing the effectiveness of using biopots compared to polybags.

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APPENDIX

Appendix 1. The Data and Anova Test for The Mass of Biopots

NO	CODE	MASS (GRAMS) 1	2	3	TOTAL
1	**R1C1**	18.32	17.67	23.07	59.06
2	**R2C1**	16.53	17.51	19.39	53.43
3	**R3C1**	14.85	14.27	16.60	45.72
4	**R4C1**	11.39	11.67	14.00	37.06
5	**R5C1**	9.70	8.54	10.20	28.44
6	**R1C2**	14.46	17.79	20.89	53.14
7	**R2C2**	12.66	19.31	19.15	51.12
8	**R3C2**	12.02	13.73	18.44	44.19
9	**R4C2**	10.81	13.97	14.40	39.18
10	**R5C2**	7.56	8.36	10.71	26.63
11	**R1C3**	14.92	21.64	17.53	54.09
12	**R2C3**	18.53	18.14	17.91	54.58
13	**R3C3**	14.88	16.05	16.75	47.68
14	**R4C3**	13.09	15.17	15.04	43.3
15	**R5C3**	11.49	10.06	9.57	31.12
TOTAL		**201.21**	**223.88**	**243.65**	**668.74**

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Raw Materials Composition	464.624364	4	116.156	24.1364	5.22E-09	2.68963
NaOH Concentrations	9.14947111	2	4.57474	0.9506	0.39785	3.31583
Interaction	11.8135956	8	1.4767	0.30685	0.9575	2.26616
Galat	144.374333	30	4.81248			
Total	629.961764	44				

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	485.587[a]	14	34.685	7.207	.000
Intercept	9938.071	1	9938.071	2065.063	.000
R	464.624	4	116.156	24.136	.000
C	9.149	2	4.575	.951	.398
R*C	11.814	8	1.477	.307	.958
Error	144.374	30	4.812		
Total	10568.033	45			
Corrected Total	629.962	44			

a. R Squared = .771 (Adjusted R Squared = .664)

Appendix 2. The Data and Anova Test for The Moisture Content of Biopots

NO	CODE	MOISTURE CONTENT (%) 1	2	3	TOTAL
1	**R1C1**	52.147	59.334	60.615	172.096
2	**R2C1**	52.957	60.980	59.593	173.530
3	**R3C1**	55.493	60.159	59.222	174.874
4	**R4C1**	55.143	49.983	59.510	164.636
5	**R5C1**	47.518	45.714	58.022	151.255
6	**R1C2**	63.957	55.424	58.633	178.015
7	**R2C2**	71.239	62.931	60.804	194.974
8	**R3C2**	71.365	55.185	67.173	193.723
9	**R4C2**	74.898	38.450	64.744	178.092
10	**R5C2**	76.309	43.657	56.951	176.917
11	**R1C3**	64.786	60.128	61.202	186.116
12	**R2C3**	68.993	55.621	68.633	193.247
13	**R3C3**	69.336	61.429	66.899	197.663
14	**R4C3**	72.742	40.314	70.742	183.798
15	**R5C3**	80.063	42.922	74.214	197.198
TOTAL		**976.947**	**792.230**	**946.957**	**2716.134**

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Raw Materials Composition	168.939	4	42.2348	0.38058	0.8207	2.68963
NaOH Concentrations	519.853	2	259.927	2.34224	0.11345	3.31583
Interaction	124.645	8	15.5807	0.1404	0.99654	2.26616
Within	3329.21	30	110.974			
Total	4142.64	44				

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	813.469[a]	14	58.105	.524	.900
Intercept	163941.865	1	163941.865	1477.315	.000
R	168.946	4	42.236	.381	.821
C	519.867	2	259.934	2.342	.113
R*C	124.656	8	15.582	.140	.997
Error	3329.186	30	110.973		
Total	168084.520	45			
Corrected Total	4142.656	44			

a. R Squared = .196 (Adjusted R Squared = -.179)

Appendix 3. The Data and Anova Test for The Water Uptake of Biopots

NO	CODE	WATER UPTAKE (%) 1	2	3
1	**R1C1**	3.365	2.742	4.113
2	**R2C1**	3.590	4.048	3.721
3	**R3C1**	3.590	3.480	3.889
4	**R4C1**	5.446	4.711	4.303
5	**R5C1**	4.323	4.440	3.893
6	**R1C2**	2.960	3.090	3.484
7	**R2C2**	2.897	3.050	3.606
8	**R3C2**	3.115	3.853	3.742
9	**R4C2**	4.000	3.303	3.964
10	**R5C2**	3.269	3.104	3.500
11	**R1C3**	3.563	3.727	4.103
12	**R2C3**	2.840	3.913	4.159
13	**R3C3**	3.025	3.793	3.670
14	**R4C3**	4.228	2.900	4.018
15	**R5C3**	2.643	2.657	2.871
TOTAL		**52.853**	**52.813**	**57.038**

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Raw Materials Composition	27499.185	4	6874.8	3.65697	0.0153	2.68963
NaOH Concentrations	29834.756	2	14917.4	7.93512	0.00171	3.31583
Interaction	40063.034	8	5007.88	2.66388	0.02444	2.26616
Within	56397.516	30	1879.92			
Total	153794.49	44				

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	9.739[a]	14	.696	3.700	.001
Intercept	588.258	1	588.258	3128.599	.000
R	2.751	4	.688	3.658	.015
C	2.984	2	1.492	7.935	.002
R*C	4.004	8	.501	2.662	.025
Error	5.641	30	.188		
Total	603.638	45			
Corrected Total	15.380	44			

a. R Squared = .633 (Adjusted R Squared = .462)

Appendix 4. The Data and Anova Test for The Biodegradation Potential of Biopots

NO	CODE	DEGRADATION POTENTIAL (%)			TOTAL
		1	2	3	
1	**R1C1**	78.261	71.963	78.947	229.171
2	**R2C1**	62.025	57.447	68.085	187.557
3	**R3C1**	55.556	63.855	55.056	174.467
4	**R4C1**	57.746	51.220	44.444	153.410
5	**R5C1**	55.882	58.904	46.667	161.453
6	**R1C2**	70.297	67.480	65.812	203.589
7	**R2C2**	69.388	68.085	62.500	199.973
8	**R3C2**	54.023	60.784	51.807	166.615
9	**R4C2**	48.718	48.980	39.394	137.091
10	**R5C2**	38.462	40.299	42.857	121.617
11	**R1C3**	69.072	71.963	65.517	206.552
12	**R2C3**	57.447	62.264	52.941	172.652
13	**R3C3**	59.184	55.056	65.909	180.149
14	**R4C3**	51.807	61.538	62.963	176.309
15	**R5C3**	48.276	54.545	49.153	151.974
TOTAL		**876.144**	**894.383**	**852.053**	**2622.579**

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Raws Materials Composition	2866.22	4	716.556	31.7768	2.15E-10	2.68963
NaOH Concentrations	216.598	2	108.299	4.80269	0.01551	3.31583
Interaction	616.914	8	77.1142	3.41975	0.00655	2.26616
Within	676.49	30	22.5497			
Total	4376.23	44				

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	3699.714[a]	14	264.265	11.720	.000
Intercept	152842.680	1	152842.680	6778.278	.000
R	2866.225	4	716.556	31.778	.000
C	216.586	2	108.293	4.803	.016
R*C	616.903	8	77.113	3.420	.007
Error	676.467	30	22.549		
Total	157218.861	45			
Corrected Total	4376.180	44			

a. R Squared = .845 (Adjusted R Squared = .773)

Appendix 5. The Data and Anova Test for The Tensile Strength of Biopots

NO	CODE	TENSILE STRENGTH (Pa) 1	2	3
1	**R1C1**	8833.830	8825.985	8727.919
2	**R2C1**	13792.073	13729.310	13631.244
3	**R3C1**	12897.706	12846.712	12944.780
4	**R4C1**	14937.489	14906.108	14709.980
5	**R5C1**	17636.279	17651.970	16671.310
6	**R1C2**	8190.514	7845.320	8237.586
7	**R2C2**	13870.526	13827.376	13729.310
8	**R3C2**	15000.252	15004.174	15592.574
9	**R4C2**	14670.748	14709.980	14611.908
10	**R5C2**	15737.712	15690.640	15788.707
11	**R1C3**	10952.067	10787.320	9806.650
12	**R2C3**	13368.425	13337.004	13729.310
13	**R3C3**	11454.167	11767.980	9806.650
14	**R4C3**	15878.928	16671.310	15690.640
15	**R5C3**	22437.615	25555.300	22261.095
	TOTAL	**209658.332**	**213156.489**	**205939.663**

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Raws Materials Composition	444935864.2	4	1.11E+08	289.6267	1.68079E-23	2.689627574
NaOH Concentrations	19377465.87	2	9688733	25.227	3.7461E-07	3.315829501
Interaction	118744808	8	14843101	38.647	9.98294E-14	2.266163274
Within	11521791.99	30	384059.7			
Total	594579930.1	44				

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	583058131.353[a]	14	41647009.382	108.439	.000
Intercept	8785159997.613	1	8785159997.613	22874.463	.000
R	444935854.964	4	111233963.741	289.627	.000
C	19377465.817	2	9688732.908	25.227	.000
R * C	118744810.572	8	14843101.321	38.648	.000
Error	11521792.022	30	384059.734		
Total	9379739920.988	45			
Corrected Total	594579923.374	44			

a. R Squared = .981 (Adjusted R Squared = .972)

Appendix 6. The DMRT Test for The Mass of Biopots

Factor R (Raw Materials Composition)

Mass

	Factor R	N	Subset		
			1	2	3
Duncan[a,b]	R5	9	9.5767		
	R4	9		13.2822	
	R3	9		15.2878	
	R2	9			17.6811
	R1	9			18.4767
	Sig.		1.000	.062	.448

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 4.812.
a. Uses Harmonic Mean Sample Size = 9.000.
b. Alpha = .05.

Factor C (NaOH Concentrations)

Mass

	Factor C	N	Subset
			1
Duncan[a,b]	C2	15	14.2840
	C1	15	14.9140
	C3	15	15.3847
	Sig.		.204

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 4.812.
a. Uses Harmonic Mean Sample Size = 15.000.
b. Alpha = .05.

Appendix 7. The DMRT Test for The Moisture Content of Biopots

Factor R (Raw Materials Composition)

Moisture Content

	Factor R	N	Subset
			1
Duncan[a,b]	R5	9	58.3744
	R4	9	58.5029
	R1	9	59.5807
	R2	9	62.4168
	R3	9	62.9179
	Sig.		.423

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 110.973.
a. Uses Harmonic Mean Sample Size = 9.000.
b. Alpha = .05.

Factor C (NaOH Concentrations)

Moisture Content

	Factor C	N	Subset
			1
Duncan[a,b]	C1	15	55.7593
	C2	15	61.4480
	C3	15	63.8683
	Sig.		.054

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 110.973.
a. Uses Harmonic Mean Sample Size = 15.000.
b. Alpha = .05.

Appendix 8. The DMRT Test for The Water Uptake of Biopots

Factor R (Raw Materials Composition)

Water Uptake

	Factor R	N	Subset	
			1	2
Duncan[a,b]	R5	9	3.4111	
	R1	9	3.4608	
	R2	9	3.5360	
	R3	9	3.5730	
	R4	9		4.0970
	Sig.		.478	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .188.
a. Uses Harmonic Mean Sample Size = 9.000.
b. Alpha = .05.

Factor C (NaOH Concentrations)

Water Uptake

	Factor C	N	Subset	
			1	2
Duncan[a,b]	C2	15	3.3958	
	C3	15	3.4740	
	C1	15		3.9769
	Sig.		.625	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .188.
a. Uses Harmonic Mean Sample Size = 15.000.
b. Alpha = .05.

Factor R*C DMRT Test

Water Uptake

	Factor R*C	Subset			
		1	2	3	4
Duncan[a,b]	R5C3	2.724			
	R1C2	3.178			
	R2C2	3.184			
	R5C2	3.291			
	R1C1	4.407			
	R3C3	3.496			
	R3C2	3.570			
	R2C3	3.638			
	R3C1	3.653			
	R4C3		3.715		
	R4C2		3.756		
	R2C1		3.786		
	R1C3		3.798		
	R5C1			4.219	
	R4C1				4.820

Appendix 9. The DMRT Test for The Biodegradable Potential of Biopots

Factor R (Raw Materials Composition)

Biodegradation Potential

	Factor R	N	Subset		
			1	2	3
Duncan[a,b]	R5	9	48.3383		
	R4	9	51.8678		
	R3	9		57.9144	
	R2	9		62.2424	
	R1	9			71.0347
	Sig.		.125	.063	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 22.549.
a. Uses Harmonic Mean Sample Size = 9.000.
b. Alpha = .05.

Factor C (NaOH Concentrations)

Biodegradation Potential

	Factor C	N	Subset	
			1	2
Duncan[a,b]	C2	15	55.2591	
	C3	15		59.1757
	C1	15		60.4039
	Sig.		1.000	.484

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 22.549.
a. Uses Harmonic Mean Sample Size = 15.000.
b. Alpha = .05.

Factor R*C DMRT Test

	Factor R*C	Biodegradation Potential						
		Subset						
		1	2	3	4	5	6	7
Duncan[a,b]	R5C2	40.539						
	R4C2	45.697						
	R5C3	50.658						
	R4C1		51.137					
	R5C1		53.818					
	R3C2		55.538					
	R2C3			57.551				
	R3C1			58.156				
	R4C3			58.770				
	R3C3			60.050				
	R2C1				62.519			
	R2C2					66.658		
	R1C2						67.863	
	R1C3						68.851	
	R1C1							76.390

Appendix 10. The DMRT Test for The Tensile Strength of Biopots

Factor R (Raw Materials Composition)

Tensile Strength

	Factor R	N	Subset 1	2	3	4	5
Duncan[a,b]	R1	9	9134.1				
	R3	9		13034.9			
	R2	9			13668.2		
	R4	9				15198.5	
	R5	9					18825.6
	Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 384059.734.
a. Uses Harmonic Mean Sample Size = 9.000.
b. Alpha = .05.

Factor C (NaOH Concentrations)

Tensile Strength

	Factor C	N	Subset 1	2
Duncan[a,b]	C2	15	13500.4885	
	C1	15	13516.1797	
	C3	15		14900.2974
	Sig.		.945	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 384059.734.
a. Uses Harmonic Mean Sample Size = 15.000.
b. Alpha = .05.

Factor R*C DMRT Test

Biodegradation Potential

	Factor R*C	Subset					
		1	2	3	4	5	6
Duncan[a,b]	R1C2	8091					
	R1C1	8796					
	R1C3		10515				
	R3C3		11010				
	R3C1			12896			
	R2C3			13478			
	R2C1			13718			
	R2C2			13809			
	R4C2				14664		
	R4C1				14851		
	R3C2				15199		
	R5C2				15739		
	R4C3					16080	
	R5C1					17320	
	R5C3						23418

Appendix 11. The Documentations

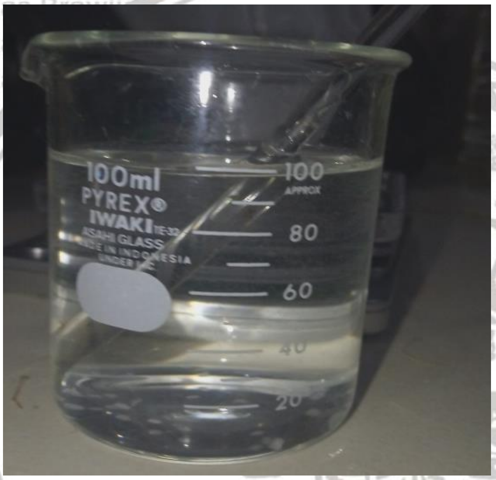
a. The Making Process of Biopots

The Process of Chopping the OPEFB and Banana Stems

OPEFB and Banana Stem Fibers

1st Phase Boiling Process

2^{nd} Phase Boiling Process



The NaoH Solution

The Tapioca Solution

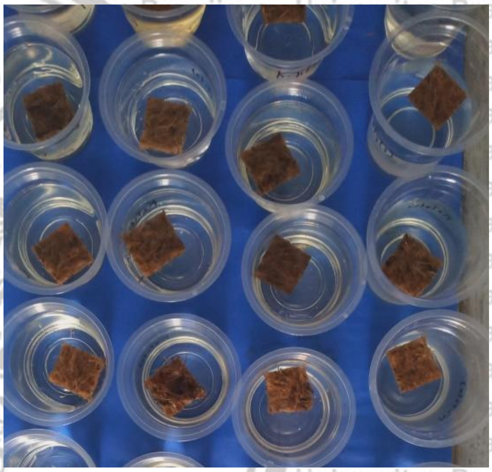
The Pulping Process

The Moulding Process

Wet Biopots

The Driying Process

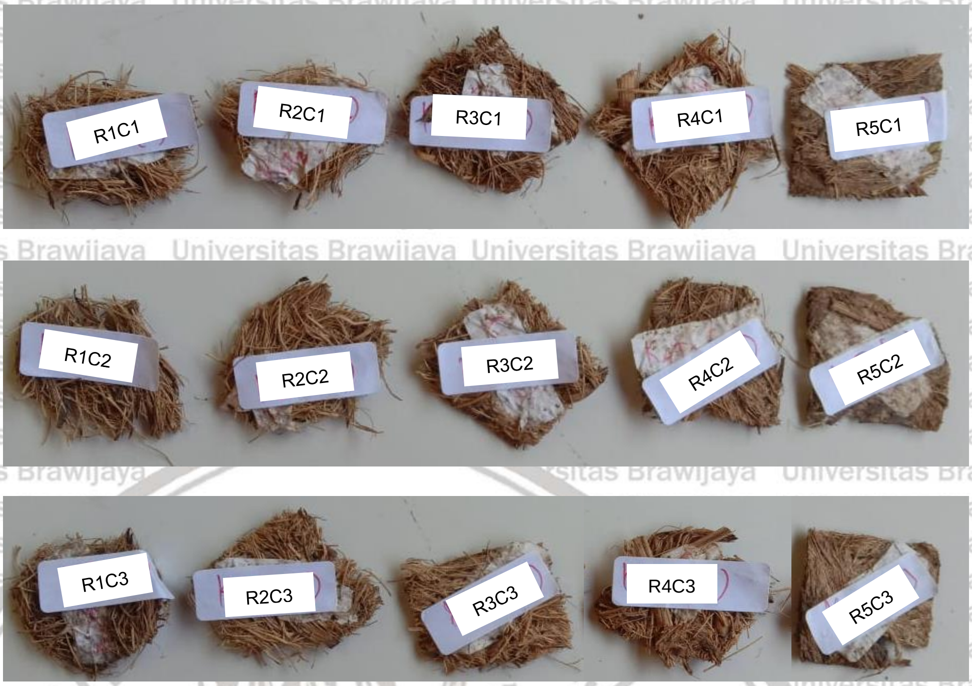
Biodegradation Test



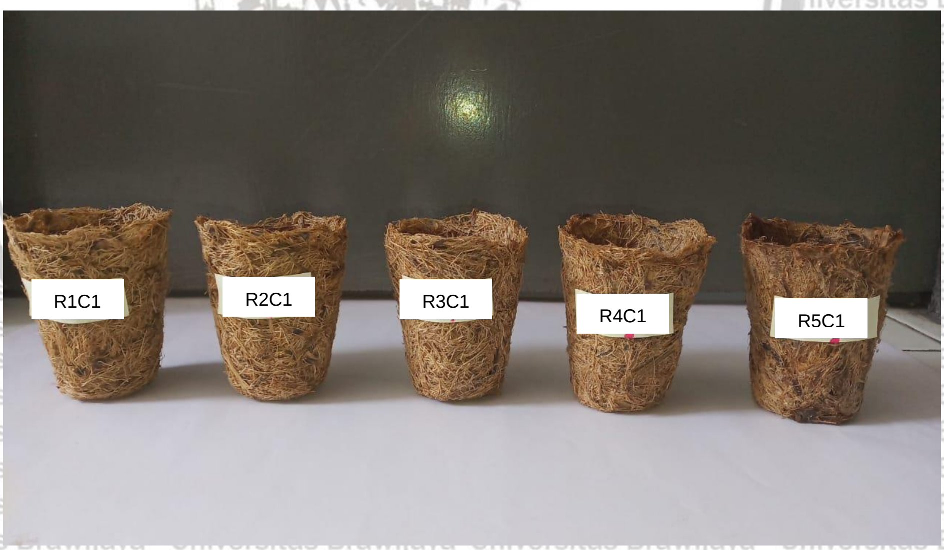
Water Uptake Test

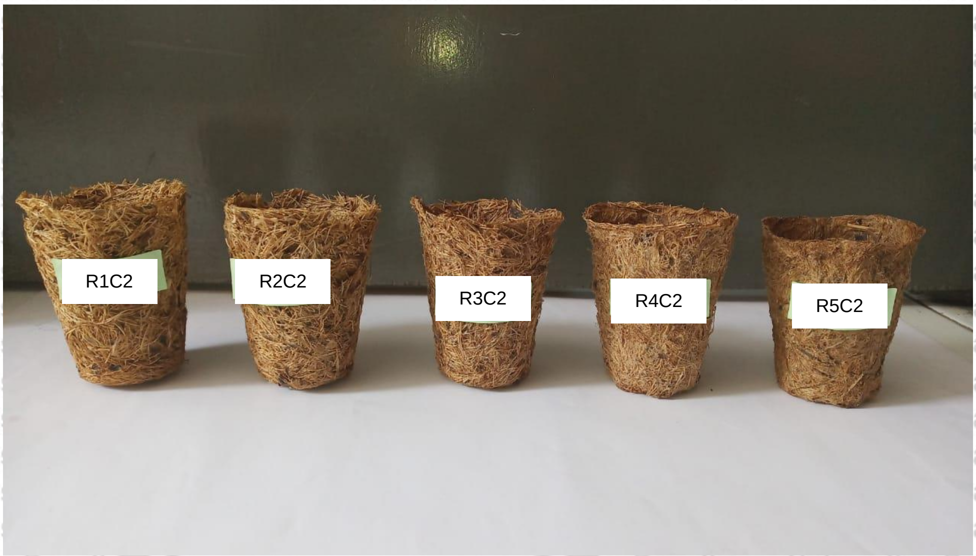
The Drying Process After Biodegradation Test

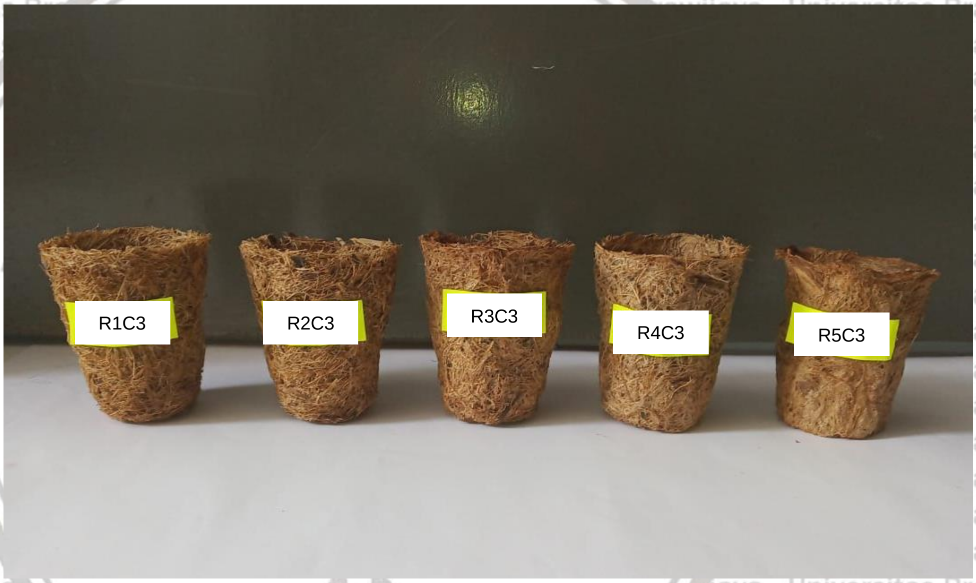
b. The Sample Of Biodegradation Test After 21 Days of Burying



c. The Biodegradable Pots Produced




R1C2
R2C2
R3C2
R4C2
R5C2


R1C3
R2C3
R3C3
R4C3
R5C3