The influence of control parameter on the morphology polyethersulfone/polyacrylonitrile (PES/PAN) fiber using electrospinning technique

The influence of control parameter on the morphology polyethersulfone/polyacrylonitrile (PES/PAN) fiber using electrospinning technique

M. Danny Pratama Lamura[1,3,4], Meuretta A Pulungan[1,3], Jaidan Jauhari[2,3], Ida Sriyanti[1,3*]

[1]Department of Physics Education, Universitas Sriwijaya, Palembang, Indonesia
[2]Faculty of Computer Science, Universitas Sriwijaya, Palembang, Indonesia
[3]Laboratory of Instrumentation and Material Applications, Faculty of Computer Science, Universitas Sriwijaya, Palembang, Indonesia
[4]Blue Sparkle NGO Scholarship, Palembang, Indonesia

*Corresponding author's e-mail: ida_sriyanti@unsri.ac.id

Abstract. Electrospinning is one of a method for fabricating nanometer to micrometre fibres. Some parameters that affect the formation of nanofibers in an electrospinning method such as solution, process, and environmental parameters. This research aims to synthesize and characterize polyethersulfone/polyacrylonitrile (PES/PAN) nanofibers and to analyze the effect of electrospinning parameters on PES/PAN nanofibers. PES/PAN fibres were prepared by dissolving PES with a concentration of 10% (w/w), 15% (w/w), 20% (w/w), and then added 0,5 gram of PAN. The results of fibre morphology with a variety of solutions showed the PPG1 fibre bead and the fibres for PPG2 and the fibre for PPG3, the morphological results of the PPG2 samples with variations in the tip collector distance indicated the fibre. The results of the diameter analysis showed that the effect of solution variation showed fibre for PPG1, PPG2, PPG3, namely 481 nm, 776 nm, 1339 nm, respectively while the diameter variation of the tip collector distance is 5 cm, 10 cm, 15 cm, namely 1266 nm, 860 nm, 401 nm, respectively and the voltage variation at 10 kV, 12 kV, 14 kV, namely 698 nm, 681 nm, 680 nm, respectively. The results of morphology and diameter show that the solution parameters and the electrospinning process affect the shape and diameter of the fibre. Fabricated fibres can be used as matrices in air filtration systems.
Keywords: Morphology, Polyethersulfone, Polyacrylonitrile, Fiber

1. Introduction

Electrospinning is a technique that has been utilized widely in recent years due to its simplicity and versatility. Electrospinning can be used to produce polymer fibres on a sub-micrometre scale, ranging from about 50 nanometers to several tens of micrometres [1]. This method involves the coulomb force obtained from an applied electric charge and the breaking of the polymers solution under the effects of exposure to an electric charge [2,3]. The electrospinning process can happen if there is a potential difference between the place where the solution is placed and the collector. The morphology, size, and surface of the fibre can be adjusted according to process parameters such as voltage, the distance between needle to the collector, needle shape, flow rate, and collector geometry: or by adjusting solution

parameters such as molecular weight, polymer concentration, conductivity ad viscocity[4–8]. Some of the parameters above can influence the formation of nanofibers. The result of nanofibers is small, has high porosity and high strength, so nanofibers are widely used for drug [9–11], supercapacitor [12,13], air filtration membrane [14–16], and water filtration membrane [17,18].

Some researchers have successfully synthesized nanofibers using various polymers for example polyvinylidenefluoride/collagen(PVDF/col) [19], Polyethersulfone/Polyvinylpyrrolidone/polyurethane (PES/PVP/PU)[20],Polyvinylidene fluoride/polyacrylonitrile (PVDF/PAN) [21,22], polyvinyl alcohol/polyacrylonitrile (PVA/PAN) [23], polyethersulfone/cellulose acetate (PES/CA) [24]. However, PES/PAN nanofibers synthesis is rare. PES is widely used in any sector such as gas purification, water purification, wastewater treatment, and biomedical application. PES has a harder benzene ring, softer ether bonds, and a conjugated structure [25]; moreover, PES has excellent performance such as good thermal, oxidative, and hydrolytic resistance [25]. However, if a single PES is synthesized without mixing with another polymer the result is chemical resistance decreased and has high hydrophobic properties [18]; therefore PAN is suitable to mix with PES because PAN can increase the chemical resistance of PES and reduce its hydrophobic to hydrophilic properties.

In this research, the PES/PAN polymer will synthesize. The fibre's morphology and diameter will be analyzed, and the influence of process parameters such as concentration, tip collector distance, and the voltage will be evaluated.

2. Experimental Methods

2.1. Materials

Polyethersulfone (PES) with the molecular weight of 98.000 g/mol was purchased from Sigma Aldrich, Singapore. Polyacrylonitrile (PAN) with the molecular weight of 150.000 g/mol was purchased from Sigma Aldrich, Singapore. NN-Dimethylformamide (DMF, assay 99.0% min) was purchased from Sigma Aldrich, Singapore.

2.2. Synthesis of Fiber

Polyethersulfone/Polyacrylonitrile (PES/PAN) were prepared with parameters shown in Table 1

Table 1. Solution Parameters

Sample	PES (w/w)	PAN (gr)	DMF
PPG1	10%	0.5	90%
PPG2	15%	0.5	85%
PPG3	20%	0.5	80%

PES dissolving with different concentration 10% (w/w), 15% (w/w), 20% (w/w) and then added 0,5 gram PAN. Then dissolved with DMF using hotplate- magnetic stirring (Theruma Sci, Japan) for 24 hours at room temperature 80^{o}C and rotational speed 300 rpm labelled PPG1, PPG2, PPG3. The solution was put into a syringe equipped (Terumo, Japan) and spun using electrospinning (Nanolab ES/DS 106, Malaysia). The process parameters used to produced PES/PAN fibres are: flow rate is 0.5 ml/h, high voltage is 12 kV, and the distance of the tip of the needle to the collector is 10 cm, fibre rotating is 220 rpm, and the temperature set at 35^{o}C.

The morphology of PPG 1, PPG 2, PPG 3 fibres was observed using a fluorescence microscope (MiF) (Optika B-380 Material Science MET, Italy). Analysis diameter size of the fibres using ImageJ 1.52a (National Institutes of Health, USA) and the data analysis in normal distribution using OriginPro 2018 (Origin Lab Corporation, USA).

3. Result and discussion

3.1. Morphology and Distribution of PES/PAN/rGO Fiber

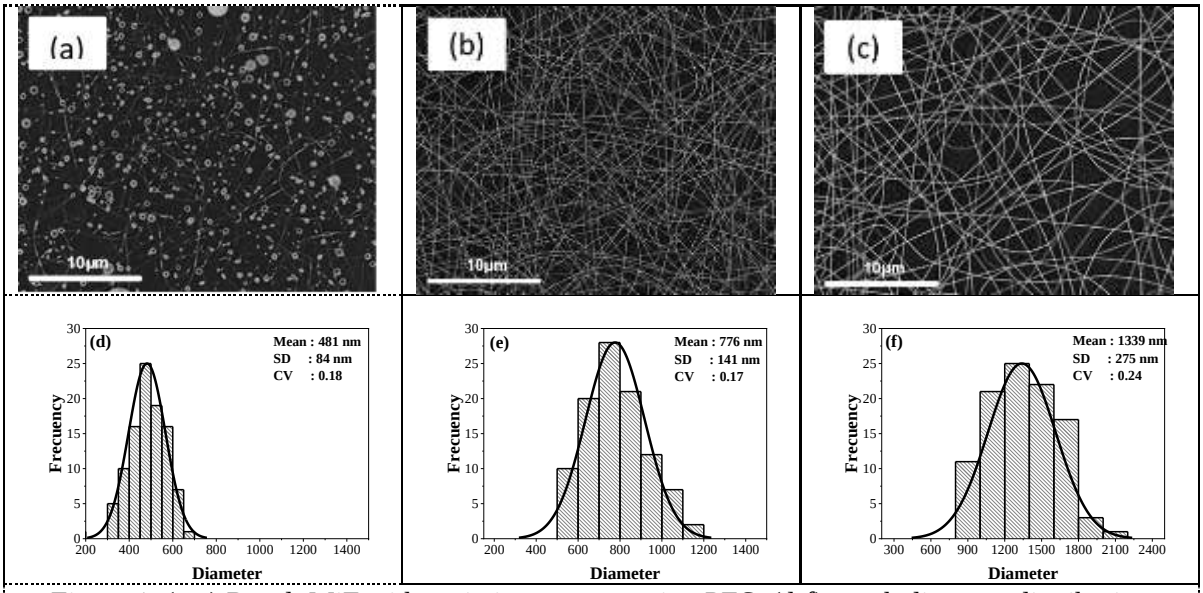
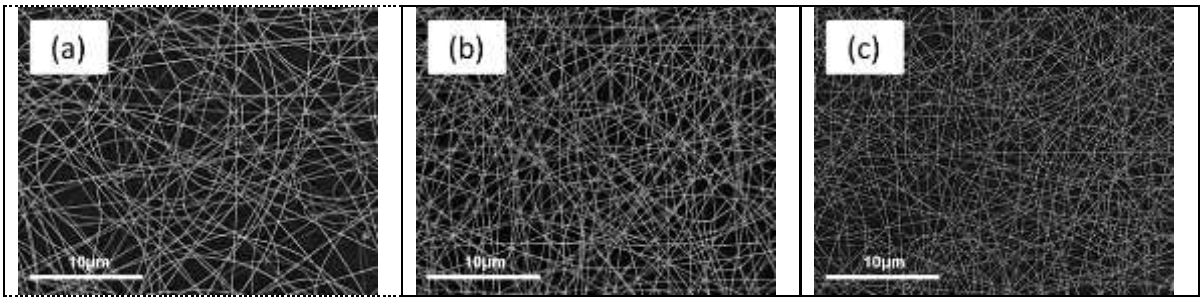


Figure 1. (a-c) Result MiF with variation concentration PES, (d-f) graph diameter distribution fibres with variation concentration PES

In figure 1(a-c) shows the fibre resulting using electrospinning with sample PPG1, PPG2, PPG3 with a digital microscope magnification (1000x). The result shows that the greater concentration of the solution, the fibres tend to have a larger diameter. The graph of fibre diameter distribution in Figure 1(d-f) shows that the average diameter is 481 nm;776 nm; 1339 nm. At a concentration, 10% of the fibre has a small diameter and bead. The optimal parameter at high voltage 12 kV and distance of the tip of the needle to the collector 10 cm is sample PPG2. Because at higher concentration, the more polymer chains are dispensed at the specified time to be spun [7,26].

Viscosity is a fluid ability to inhibit force or motion [4]. Viscosity is related to molecular mass and polymers concentration in the solution. Molecular mass is a molecular chain of polymers. Polymer with a high molecular mass has a greater viscosity because there is more molecular chain that binds [27].

Fibres are influenced by the concentration and viscosity of the polymer used. Low polymer viscosity will make intramolecular interaction not strong and caused the solution cannot forming fibres [28]. So, to form fibres, the concentration of the polymers must be increased to make intramolecular interaction sufficient to overcome the tensile force [29].



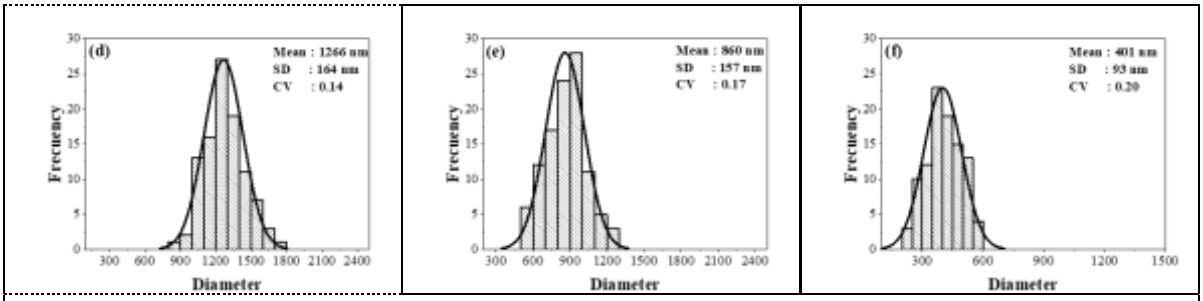


Figure 2. (a-c) Result MiF with variation tip collector distance (d-f)) graph diameter distribution fibers with variation tip collector distance

Figure 2 shows the result from PES/PAN with variation tip collector distance such as 5 cm, 10 cm, and 15 cm. The solution used was the PPG2 sample. The greater distance between the needle and collector, the fibre tends to have a smaller diameter [1]. This is confirmed with figure 2(d-f) fibre diameter distribution graph that shows with distance needle-collector is 10 cm produces an average fibre diameter of 1266 nm;860 nm; 401 nm. So, in sample PPG2 and high voltage 12 kV, the optimum distance was 10 cm.

Distance affects the time for jet before reaching the collector and evaporates the solvent so that when it reaches the collector, the fibre looks dry. At the close distance, the electric field that surrounds is more significant than caused time for the fibres to collect in the collector is smaller, this makes fibre look wet and stick together because of the evaporation process not perfect [4]. The distance between the needle-collector will cause the required voltage greater, and the result of fibre smaller [30].

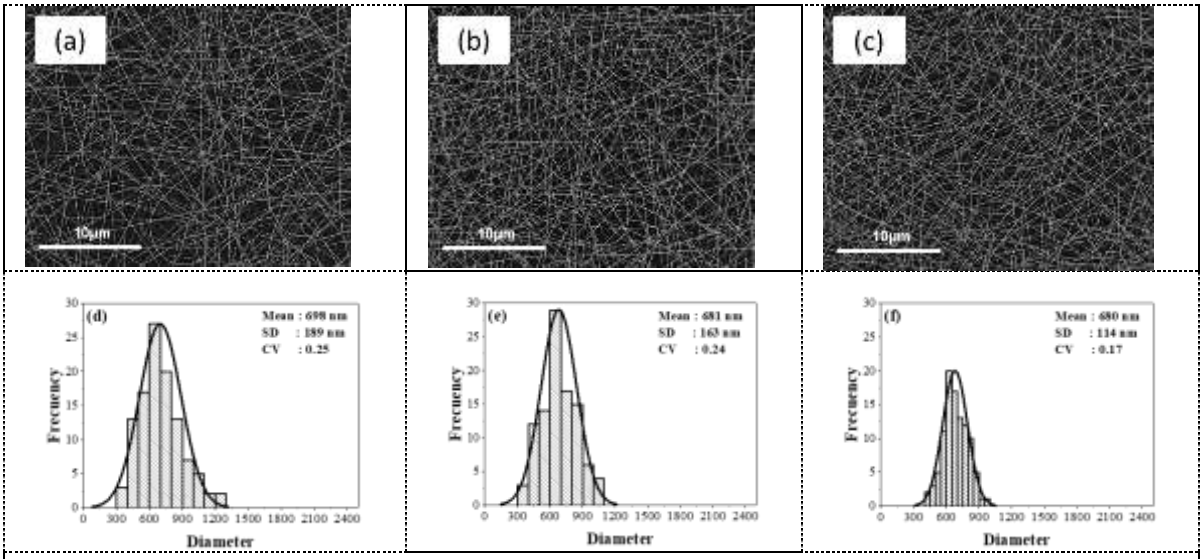


Figure 3. (a-c) Result with voltage variation (d-f) graph diameter distribution fibres with a voltage variation

Figure 3 shows the microscope image from PPG2 with variation voltage such as 10 kV, 12 kV, 14 kV. Solution concentration and distance needle-collector were set at 15% and 10 cm. The result of fibre diameter tends not to differ significantly. The average diameter is 698 nm;681 nm; 680 nm. So, the parameter for high voltage did not have any significant effect on the fibre morphology of PPG2 and distance between the needle-collector 10 cm. This is because fibre could elongate at long distance that causes the solvent in the solution vaporized before reach the collector [31,32].

4. Conclusion

PES/PAN morphology has been successfully produced using the electrospinning technique. Nanofiber was produced optimally with variation concentration of PES 10%, 15%, 20% (w/w) with addition of PAN 0,5 gr. The result of process parameters of electrospinning is sample PPG 1, PPG 2, PPG 3 with the average diameter is 481 nm;776 nm; 1339 nm shows that the greater concentration of the solution, the fibres tend to have a larger diameter. The optimal parameter at voltage 12 kV and distance needle-collector are sample PPG2. The result of sample PPG2 with variation tip collector distance such as 5 cm, 10 cm, and 15 cm and high voltage 12 kV the optimum tip collector distance was 10 cm. The result of sample PPG2 with variation voltage such as 10 kV, 12 kV, 14 kV does not have a critical impact on the shape of the fiber

References

[1] Castillo-Ortega M M, Nájera-Luna A, Rodríguez-Félix D E, Encinas J C, Rodríguez-Félix F, Romero J and Herrera-Franco P J 2011 Preparation, characterization and release of amoxicillin from cellulose acetate and poly(vinyl pyrrolidone) coaxial electrospun fibrous membranes *Mater. Sci. Eng. C* **31** 1772–8

[2]Risdian C, Nasir M, Rahma A and Rachmawati H 2015 The Influence of Formula and Process on Physical Properties and the Release Profile of PVA/BSA Nanofibers Formed by Electrospinning Technique *J. Nano Res.* **31** 103–16

[3]Sriyanti I, Edikresnha D, Rahma A, Munir M M, Rachmawati H and Khairurrijal K 2017 Correlation between Structures and Antioxidant Activities of Polyvinylpyrrolidone/ Garcinia mangostana L. Extract Composite Nanofiber Mats Prepared Using Electrospinnin *J. Nanomater.* **2017**

[4]Ramakrishna S, Fujihara K, Teo W E, Lim T C and Ma Z 2005 *An introduction to electrospinning and nanofibers*

[5]Ray S S, Chen S S, Li C W, Nguyen N C and Nguyen H T 2016 A comprehensive review: Electrospinning technique for fabrication and surface modification of membranes for water treatment application *RSC Adv.* **6** 85495–514

[6]Jauhari J, Wiranata S, Rahma A, Nawawi Z and Sriyanti I 2019 Polyvinylpyrrolidone/cellulose acetate nanofibers synthesized using electrospinning method and their characteristics *Mater. Res. Express* **6** 64002

[7]Sriyanti I, Edikresnha D, Rahma A, Munir M M, Rachmawati H and Khairurrijal K 2018 Mangosteen pericarp extract embedded in electrospun PVP nanofiber mats: Physicochemical properties and release mechanism of α-mangostin *Int. J. Nanomedicine* **13** 4927–41

[8]Sriyanti I, Marlina L and Jauhari J 2020 Optimization of The Electrospinning Process for Preparation of Nanofibers From Poly (Vinyl Alcohol) (PVA) and Chromolaena odorata L. Extrac (COE) *J. Pendidik. Fis. Indones.* **16** 47–56

[9]Tlili I and Alkanhal T A 2019 Nanotechnology for water purification: Electrospun nanofibrous membrane in water and wastewater treatment *J. Water Reuse Desalin.* **9** 232–47

[10]Sriyanti I, Edikresnha D, Munir M M, Rachmawati H and Khairurrijal 2017 Electrospun polyvinylpyrrolidone (PVP) nanofiber mats loaded by Garcinia mangostana L. Extracts *Mater. Sci. Forum* **880** 11–4

[11]Aruan N M, Sriyanti I, Edikresnha D, Suciati T, Munir M M and Khairurrijal K 2017 Polyvinyl Alcohol/Soursop Leaves Extract Composite Nanofibers Synthesized Using Electrospinning Technique and their Potential as Antibacterial Wound Dressing *Procedia Eng.* **170** 31–5

[12]Hendriansyah R, Prakoso T, Widiatmoko P, Nurdin I and Devianto H 2018 Manufacturing Carbon Material by Carbonization of Cellulosic Palm Oil Waste for Supercapacitor Material *MATEC Web Conf.* **156**

[13]Ariana L, Mohamed A, Christine H, Asia S, Genevieve D and Yury G 2018 Electrospun MXene/Carbon Nanofibers as Supercapacitor Electrodes *J. Mater. Chem. A* **7** 269–77

[14]Jauhari J, Suharli A J, Saputra R, Nawawi Z and Sriyanti I 2020 Polyvinylpyrollidone/Cellulose Acetate (PVA/CA) Fiber Size Prediction Using Scaling Law Model *J. Phys. Conf. Ser.* **1467**

[15]Li J, Zhang D, Yang T, Yang S, Yang X and Zhu H 2018 Nanofibrous membrane of graphene oxide-in-polyacrylonitrile composite with low filtration resistance for the effective capture of PM2.5 *J. Memb. Sci.* **551** 85–92
[16]Li P, Wang C, Zhang Y and Wei F 2014 Air filtration in the free molecular flow regime: A review of high-efficiency particulate air filters based on Carbon Nanotubes *Small* **10** 4543–61
[17]Kusumah F H, Sriyanti I, Edikresnha D, Munir M M and Khairurrijal 2017 Simply electrospun gelatin/cellulose acetate nanofibers and their physico-Chemical characteristics *Mater. Sci. Forum* **880** 95–8
[18]Abdel-Karim A, Leaper S, Alberto M, Vijayaraghavan A, Fan X, Holmes S M, Souaya E R, Badawy M I and Gorgojo P 2018 High flux and fouling resistant flat sheet polyethersulfone membranes incorporated with graphene oxide for ultrafiltration applications *Chem. Eng. J.* **334** 789–99
[19]Abazari M F, Soleimanifar F, Amini Faskhodi M, Mansour R N, Amini Mahabadi J, Sadeghi S, Hassannia H, Saburi E, Enderami S E, Khani M M and Zare Karizi S 2020 Improved osteogenic differentiation of human induced pluripotent stem cells cultured on polyvinylidene fluoride/collagen/platelet-rich plasma composite nanofibers *J. Cell. Physiol.* **235** 1155–64
[20]Agi A, Junin R, Alqatta A Y M, Gbadamosi A, Yahya A and Abbas A 2019 Ultrasonic assisted ultrafiltration process for emulsification of oil field produced water treatment *Ultrason. Sonochem.* **51** 214–22
[21]Ke G, Jin X and Hu H 2020 Electrospun polyvinylidene fluoride/polyacrylonitrile composite fibers: fabrication and characterization *Iran. Polym. J. (English Ed.* **29** 37–46
[22]Mokhtari-Shourijeh Z, Langari S, Montazerghaem L and Mahmoodi N M 2020 Synthesis of porous aminated PAN/PVDF composite nanofibers by electrospinning: Characterization and Direct Red 23 removal *J. Environ. Chem. Eng.* **8** 103876
[23]Kharaghani D, Gitigard P, Ohtani H, Kim K O, Ullah S, Saito Y, Khan M Q and Kim I S 2019 Design and characterization of dual drug delivery based on in-situ assembled PVA/PAN core-shell nanofibers for wound dressing application *Sci. Rep.* **9** 1–11
[24]Raharjo Y, Fahmi M Z, Wafiroh S, Widati A A, Amanda E R, Ismail A F, Othman M H D and Santoso D 2019 Incorporation of imprinted-zeolite to polyethersulfone/cellulose acetate membrane for creatinine removal in hemodialysis treatment *J. Teknol.* **81** 137–44
[25]Ran F, Li D and Niu X 2019 *Polyethersulfone fiber* (Elsevier Inc.)
[26]Sriyanti I, Edikresnha D, Rahma A, Munir M M, Rachmawati H and Khairurrijal K 2017 Correlation between Structures and Antioxidant Activities of Polyvinylpyrrolidone/ Garcinia mangostana L. Extract Composite Nanofiber Mats Prepared Using Electrospinnin *J. Nanomater.* 2017
[27]Andrady A L 2008 *Science and Technology of Polymer Nanofibers* (Canada: John Wiley & Sons, Inc., Hoboken, New Jersey)
[28]Yulina R, Winiati W, Bonadies I, Laurienzo P and Dal Poggetto G 2018 Optimasi Kondisi Larutan Dan Parameter Proses Pemintalan Elektrik Pada Sintesis Serat Nano Kitosan-Peo Optimization of Solution Condition and Electrospinning Process Parameters for Synthesis of Chitosan-Peo Nanofibers 1–10
[29]Stanger J, Tucker N and Staiger M 2005 Electrospinning **16**
[30]Sill T J and von Recum H A 2008 Electrospinning: Applications in drug delivery and tissue engineering *Biomaterials* **29** 1989–2006
[31]Yu D-G, Zhu L-M, White K and Branford-White C 2009 Electrospun nanofiber-based drug delivery systems *Health (Irvine. Calif).* **01** 67–75
[32]Pusporini P, Edikresnha D, Sriyanti I, Suciati T, Munir M M and Khairurrijal K 2018 Electrospun polyvinylpyrrolidone (PVP)/green tea extract composite nanofiber mats and their antioxidant activities *Mater. Res. Express* **5**

Acknowledgments
This Publication was supported by "Blue Sparkle for Sriwijaya Scholarship" in the year 2020.
This research was supported by Sriwijaya University, The Republic of Indonesia under the University's Excellence Research (PUPT) Grant in the fiscal year 2020.
This research was supported by BPDPKS, the Republic of Indonesia under the Research and Development of Palm Oil in the fiscal year 2020.