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# LAMPIRAN

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**Balai Besar Industri Agro**
**Departemen Perindustrian Republik Indonesia**
**Jalan Ir. H. Juanda No. 11 Bogor**

**KARAKTERISASI PATI SAGU *(Metroxylon SP)* DALAM MENGEMBANGKAN MATERIAL BIOPLASTIK**

**CHARACTERIZATION OF SAGO (Metroxylon SP) STARCH IN DEVELOPING BIOPLASTIC MATERIALS**

**BUDIAWAN SULAEMAN**
**D043181001**

**PROGRAM STUDI DOKTOR ILMU TEKNIK MESIN**
**DEPARTEMEN TEKNIK MESIN**
**FAKULTAS TEKNIK**
**UNIVERSITAS HASANUDDIN**
**GOWA**
**2023**

Kementerian Perindustrian
REPUBLIK INDONESIA

BADAN STANDARDISASI DAN KEBIJAKAN JASA INDUSTRI
**BALAI BESAR INDUSTRI AGRO**
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*To* Budiawan Sulaeman
Mahasiswa Pascasarjana Univ. Hasanudin
Jl. Pulau Bangka No. 7 A Kota Palopo

# LAPORAN HASIL UJI
*REPORT OF ANALYSIS*

**Nomor Seri** *Serial Number* : 2345/BSKJI/BBIA/LHU.1/VI/2022

**Nomor Analisis** *Analysis Number* : 3030

**Tanggal Penerbitan** *Date of Issue* : 17 Juni 2022

**Halaman** *Page* : 1 dari *of* 2

**IDENTITAS CONTOH**
*Sample Indentity*

**Nama Contoh** *Sample Name* : Tepung Sagu
Kode Contoh : STA

**Merek** *Brand* :

**Keterangan Contoh** *Description of sample* : Dikemas dalam plastik tidak berlabel

**Nomor BAPC** *Sampling Report Number* :

**Tanggal Pengambilan Contoh** *Date of Sampling* :

**TANGGAL PENERIMAAN** *Date of Sample* : 03 Juni 2022

**TANG... N** *Date o...* : 07 Juni 2022 - 16 Juni 2022

**JENIS** *Type o...* : Kimia

**HASIL** *Result* : Terlampir

# HASIL PENGUJIAN

*Result of Analysis*

**Nomor** : 2345/BSKJI/BBIA/LHU.1/VI/2022
*Number*

**Nomor Analisis** : 3030
*Analysis Number*



| Parameter | Satuan | Hasil | Metode Uji / Teknik |
|---|---|---|---|
| Amilosa | % | 36,49 | MU/AKBB/3 (Spektrofotometri) |
| Amilopektin | % | 46,33 | IK 7.2.3 (Cara Perhitungan) |

**Deputi Manajer Teknis Pengujian II**
***Deputy Manager of Testing Laboratories II***

Ditandatangani secara elektronik menggunakan Sertifikat Elektronik yang diterbitkan BSrE
*Electronically signed using Electronic Certificate issued by BSrE*

**Agustina Malinda, S.Si**
**NIP. 198008302002122004**

Kepada :
*To*

Budiawan Sulaeman
Mahasiswa Pascasarjana Univ. Hasanudin
Jl. Pulau Bangka No. 7 A Kota Palopo

# LAPORAN HASIL UJI
*REPORT OF ANALYSIS*

**Nomor Seri** *Serial Number* : 2346/BSKJI/BBIA/LHU.1/VI/2022

**Nomor Analisis** *Analysis Number* : 3031

**Tanggal Penerbitan** *Date of Issue* : 17 Juni 2022

**Halaman** *Page* : 1 dari *of* 2

**IDENTITAS CONTOH**
*Sample Indentity*

**Nama Contoh** *Sample Name* : Tepung Sagu
Kode Contoh : STB

**Merek** *Brand* :

**Keterangan Contoh** *Description of sample* : Dikemas dalam plastik tidak berlabel

**Nomor BAPC** *Sampling Report Number* :

**Tanggal Pengambilan Contoh** *Date of Sampling* :

**TANGGAL PENERIMAAN** *Date of Sample* : 03 Juni 2022

**TANG N** *Date o* : 07 Juni 2022 - 16 Juni 2022

**JENIS** *Type o* : Kimia

**HASI** *Result* : Terlampir

# HASIL PENGUJIAN
*Result of Analysis*

**Nomor** : 2346/BSKJI/BBIA/LHU.1/VI/2022
*Number*
**Nomor Analisis** : 3031
*Analysis Number*


| Parameter | Satuan | Hasil | Metode Uji / Teknik |
|---|---|---|---|
| Amilosa | % | 36,42 | MU/AKBB/3 (Spektrofotometri) |
| Amilopektin | % | 47,01 | IK 7.2.3 (Cara Perhitungan) |

**Deputi Manajer Teknis Pengujian II**
***Deputy Manager of Testing Laboratories II***

Ditandatangani secara elektronik menggunakan Sertifikat Elektronik yang diterbitkan BSrE
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**Agustina Malinda, S.Si**
**NIP. 198008302002120 04**

# LAMPIRAN

## PENGUJIAN XRD

**Laboratorium Penelitian dan Pengembangan Sains**
**Fakultas Matematika dan Ilmu Pengetahuan Alam**
**UNIVERSITAS HASANUDDIN**

**KARAKTERISASI PATI SAGU *(Metroxylon SP)* DALAM MENGEMBANGKAN MATERIAL BIOPLASTIK**

**CHARACTERIZATION OF SAGO (Metroxylon SP) STARCH IN DEVELOPING BIOPLASTIC MATERIALS**

**BUDIAWAN SULAEMAN**
**D043181001**

**PROGRAM STUDI DOKTOR ILMU TEKNIK MESIN**
**DEPARTEMEN TEKNIK MESIN**
**FAKULTAS TEKNIK**
**UNIVERSITAS HASANUDDIN**
**GOWA**
**2023**

KEMENTERIAN RISET, TEKNOLOGI DAN PENDIDIKAN TINGGI
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Nomor : 13298/UN4.7.1/PT.01.04/2023 20 Juni 2023
Lamp. : -
Hal : Permohonan izin Pengujian Material

Yth : Kepala Laboratorium Penelitian dan Pengembangan Sains
Fakultas MIPA Universitas Hasanuddin
di
Tempat

Dengan hormat, berdasarkan surat Ketua Program Studi S3 Teknik Mesin Fakultas Teknik Universitas Hasanuddin Nomor: 13223/UN4.7.8/PT.01.04/2023 tanggal 20 Juni 2023 tentang permohonan pengantar izin Pengujian Material Mahasiswa Program Doktor (S3) Teknik Mesin Fakultas Teknik Universitas Hasanuddin tersebut dibawah ini:

| | |
|---|---|
| Nama | : Budiawan Sulaeman |
| Nomor Pokok | : D043181001 |
| Program Pendidikan | : Doktor (S3) |
| Program Studi | : Teknik Mesin |

bermaksud melakukan Pengujian Material dalam rangka penyelesaian disertasinya.

Sehubungan dengan hal tersebut kami mohon kebijaksanaan bapak/ibu kiranya berkenan memberi izin kepada yang bersangkutan.

Atas perkenan dan kerjasamanya disampaikan terima kasih.

a.n. Dekan
Wakil Dekan Bidang Akademik dan Kemahasiswaan,

**Dr. Amil Ahmad Ilham, S.T., M.IT**
NIP 19731010 199802 1 001

Tembusan :
1. Dekan FT-Unhas;
2. Ketua Departemen Teknik Mesin;
3. Ketua Program Studi S3 Teknik Mesin;

ang bersangkutan.

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# LAPORAN HASIL PENGUJIAN

*CERTIFICATE OF ANALYSIS*

**Nomor Pekerjaan** : **LPPS.XJ-2305-9/4**
*Job Number*

**Dipersembahkan Kepada**
*Presented To*

| | | | |
|---|---|---|---|
| **Kepada Yth** *Attention* | : **Budiawan Sulaeman** | **Jabatan** *Job Title* | : **Peneliti** |
| **Nama Pelanggan** *Customer Name* | : **Budiawan Sulaeman** | **Tujuan Pengujian** *Purpose of analysis* | : **Analisis Unsur** |
| **Alamat/Universitas** *Address/University* | : **Universitas Hasanuddin** | **No. Faks/** *Fax No.* | : - |
| | | **No. Telp./** *Phone No.* | : **081242625598** |
| **Tanggal Sampel Diterima** *Date of Sample Receipt* | : **9 Mei 2023** | **Tanggal Sampel Dianalisis** *Date of Sample Analysed* | :**17 - 23 Mei 2023** |
| **Email** *Email* | : **budiawan.sulaeman77@gmail.com** | **Total Halaman** | : **3** |
| **Nama Pengujian** *Name of analysis* | : **Analisis Sampel Serbuk dan Film menggunakan XRD dan XRF** | | |

Hasil hanya berhubungan dengan contoh yang diuji dan laporan ini tidak boleh digandakan kecuali seluruhnya.
*The result relate only to the samples tested and this report shall not be reproduced except in full*

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# LAPORAN HASIL PENGUJIAN
*CERTIFICATE OF ANALYSIS*

**Nomor Pekerjaan : LPPS.XJ-2305-9/4**

**I. Pelanggan / *Principal***

| | |
|---|---|
| 1.1 Nama / *Name* | : Budiawan Sulaeman |
| 1.2 Alamat / *Address* | : Universitas Hasanuddin |
| 1.3 Telepon / *Phone* | : 081242625598 |
| 1.4 Personil Penghubung / *Contact Person* | : - |
| 1.5 Email / *Email* | : budiawan.sulaeman77@gmail.com |

**II. Contoh Uji / *Sample***

| | |
|---|---|
| 2.1 Kode Sampel / *Sampel Code* | : LPPS.X-2305-9/4a -4d |
| 2.2 Kemasan / *Packaging* | : Plastik |
| 2.3 Nama Sampel / *Sample Name* | : Serbuk dan Film |
| 2.4 Jumlah Sampel / *Number of Sample* | : 4 |
| 2.5 Tanggal Sampling / *Date of Sampling* | : - |
| 2.6 Diterima / *Date of Received* | : 9 Mei 2023 |
| 2.7 Tanggal Uji / *Date of Analysis* | : 17 – 23 Mei 2023 |
| 2.8 Jenis Uji / *Type of Analysis* | : XRD dan XRF |

**III. Hasil Uji / *Result***

3.1 XRF

a. Kode Sampel : LPPS.X-2305-9/4a

| Parameter | Satuan | Hasil |
|---|---|---|
| Si | m/m% | 38.57 |
| Px | m/m% | 29.47 |
| Ca | m/m% | 12.91 |
| Cl | m/m% | 7.70 |
| K | m/m% | 7.09 |
| Nb | m/m% | 1.22 |
| Mo | m/m% | 0.941 |
| In | m/m% | 0.573 |
| Sn | m/m% | 0.459 |
| Ru | m/m% | 0.43 |
| Sb | m/m% | 0.35 |
| Rh | m/m% | 0.285 |

Nama Sampel : MAT STA

| Parameter | Satuan | Hasil |
|---|---|---|
| SiO2 | m/m% | 52.45 |
| P2O5 | m/m% | 31.09 |
| CaO | m/m% | 7.16 |
| K2O | m/m% | 3.60 |
| Cl | m/m% | 3.51 |
| Nb2O5 | m/m% | 0.665 |
| MoO3 | m/m% | 0.539 |
| In2O3 | m/m% | 0.262 |
| SnO2 | m/m% | 0.221 |
| RuO4 | m/m% | 0.212 |
| Sb2O3 | m/m% | 0.158 |
| Rh2O3 | m/m% | 0.130 |

b. Kode Sampel : LPPS.X-2305-9/4b

| Parameter | Satuan | Hasil |
|---|---|---|
| Mg | m/m% | 37.32 |
| Si | m/m% | 35.89 |
| Px | m/m% | 11.90 |
| K | m/m% | 9.07 |
| [illegible] | m/m% | 4.44 |
| [illegible] | m/m% | 0.41 |
| [illegible] | m/m% | 0.30 |
| [illegible] | m/m% | 0.172 |
| [illegible] | m/m% | 0.159 |
| [illegible] | m/m% | 0.130 |
| [illegible] | m/m% | 0.122 |

Nama Sampel : MAT STB

| Parameter | Satuan | Hasil |
|---|---|---|
| SiO2 | m/m% | 45.29 |
| MgO | m/m% | 36.61 |
| P2O5 | m/m% | 12.85 |
| K2O | m/m% | 3.24 |
| CaO | m/m% | 1.52 |
| Nb2O5 | m/m% | 0.159 |
| MoO3 | m/m% | 0.123 |
| In2O3 | m/m% | 0.056 |
| SnO2 | m/m% | 0.055 |
| RuO4 | m/m% | 0.045 |

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# Strongest 3 peaks

3.2 XRD

a. Kode Sampel : LPPS.X-2305-9/4a Nama Sampel : MAT STA

| No. | Peak No. | 2Theta (deg) | d (A) | I/I1 | FWHM (deg) | Intensity (Counts) | Integrated Int (Counts) |
|---|---|---|---|---|---|---|---|
| 1. | 2 | 17.1600 | 5.16321 | 100 | 0.92800 | 131 | 4924 |
| 2. | 3 | 17.9200 | 4.94591 | 89 | 1.49000 | 116 | 7286 |
| 3. | 34 | 64.4068 | 1.44542 | 79 | 0.56360 | 103 | 2875 |

b. Kode Sampel : LPPS.X-2305-9/4b Nama Sampel : MAT STB

| No. | Peak No. | 2Theta (deg) | d (A) | I/I1 | FWHM (deg) | Intensity (Counts) | Integrated Int (Counts) |
|---|---|---|---|---|---|---|---|
| 1. | 2 | 17.1200 | 5.17518 | 100 | 1.07000 | 171 | 7624 |
| 2. | 3 | 17.9200 | 4.94591 | 92 | 1.18000 | 157 | 8006 |
| 3. | 7 | 23.2625 | 3.82070 | 84 | 1.86500 | 144 | 13098 |

c. Kode Sampel : LPPS.X-2305-9/4c Nama Sampel : Specimen A (A9)

| No. | Peak No. | 2Theta (deg) | d (A) | I/I1 | FWHM (deg) | Intensity (Counts) | Integrated Int (Counts) |
|---|---|---|---|---|---|---|---|
| 1. | 11 | 44.0632 | 2.05349 | 100 | 0.17310 | 814 | 7496 |
| 2. | 12 | 64.4212 | 1.44513 | 86 | 0.18910 | 697 | 7424 |
| 3. | 9 | 37.8189 | 2.37693 | 15 | 0.17260 | 125 | 1345 |

d. Kode Sampel : LPPS.X-2305-9/4d Nama Sampel : Specimen D (D8)

| No. | Peak No. | 2Theta (deg) | d (A) | I/I1 | FWHM (deg) | Intensity (Counts) | Integrated Int (Counts) |
|---|---|---|---|---|---|---|---|
| 1. | 16 | 44.0867 | 2.05245 | 100 | 0.15990 | 716 | 6038 |
| 2. | 18 | 64.4502 | 1.44455 | 76 | 0.18630 | 546 | 5818 |
| 3. | 14 | 37.8264 | 2.37648 | 17 | 0.15800 | 125 | 1193 |

Makassar, 25 Mei 2023
Wakil Penanggung Jawab Teknis

Mahdalia, S.Si, M.Si
NIP. 197508261996012001

Catatan:

- Hasil Uji hanya berlaku untuk contoh tersebut di atas
- Dilarang mengutip/menyalin sebagian isi hasil uji ini

# LAMPIRAN

## Pengujian Uji FTIR
## *(Fourier Trasform infra-Red)*

**Laboratorium Microstruktur Kimia**
**Fakultas Matematika dan Ilmu Pengetahuan Alam**
**UNIVERSITAS HASANUDDIN**

**KARAKTERISASI PATI SAGU *(Metroxylon SP)* DALAM MENGEMBANGKAN MATERIAL BIOPLASTIK**

**CHARACTERIZATION OF SAGO (Metroxylon SP) STARCH IN DEVELOPING BIOPLASTIC MATERIALS**

**BUDIAWAN SULAEMAN**
**D043181001**

**PROGRAM STUDI DOKTOR ILMU TEKNIK MESIN**
**DEPARTEMEN TEKNIK MESIN**
**FAKULTAS TEKNIK**
**UNIVERSITAS HASANUDDIN**
**GOWA**
**2023**

KEMENTERIAN RISET, TEKNOLOGI DAN PENDIDIKAN TINGGI
**UNIVERSITAS HASANUDDIN**
**FAKULTAS TEKNIK**
Jalan Poros Malino, Km.6 Gowa, 92171, Sulawesi Selatan
☎ (0411) 586015, 586262 Fax (0411) 586015.
http://eng.unhas.ac.id. E-mail:teknik@unhas.ac.id

Nomor : 13298/UN4.7.1/PT.01.04/2023 20 Juni 2023
Lamp. : -
Hal : Permohonan izin Pengujian Material

Yth : Kepala Laboratorium Microstruktur Jurusan Kimia
Fakultas MIPA Universitas Hasanuddin
di
Tempat

Dengan hormat, berdasarkan surat Ketua Program Studi S3 Teknik Mesin Fakultas Teknik Universitas Hasanuddin Nomor: 13223/UN4.7.8/PT.01.04/2023 tanggal 20 Juni 2023 tentang permohonan pengantar izin Pengujian Material Mahasiswa Program Doktor (S3) Teknik Mesin Fakultas Teknik Universitas Hasanuddin tersebut dibawah ini:

| | |
|---|---|
| Nama | : Budiawan Sulaeman |
| Nomor Pokok | : D043181001 |
| Program Pendidikan | : Doktor (S3) |
| Program Studi | : Teknik Mesin |

bermaksud melakukan Pengujian Material dalam rangka penyelesaian disertasinya.

Sehubungan dengan hal tersebut kami mohon kebijaksanaan bapak/ibu kiranya berkenan memberi izin kepada yang bersangkutan.

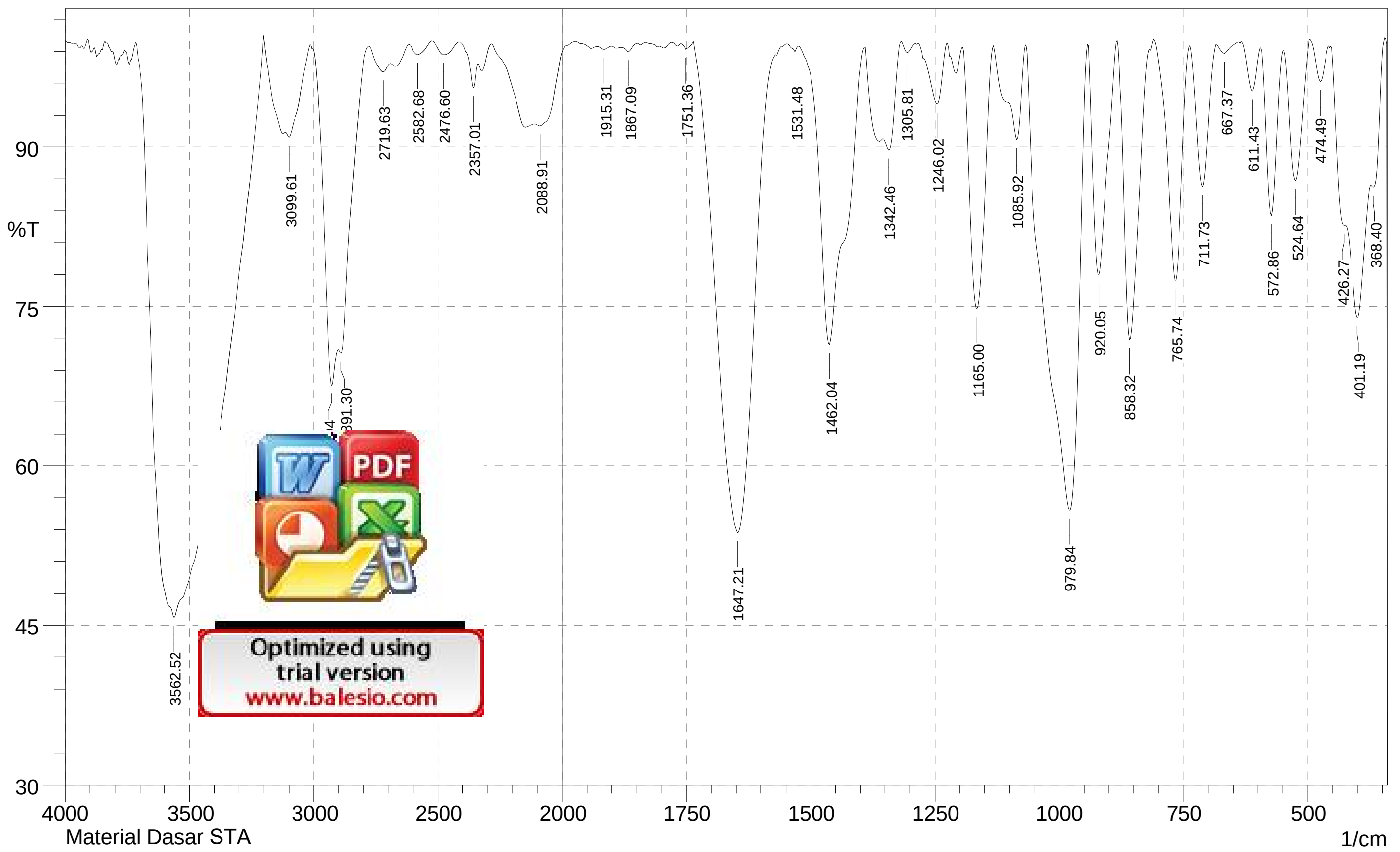
Atas perkenan dan kerjasamanya disampaikan terima kasih.

a.n. Dekan
Wakil Dekan Bidang Akademik dan Kemahasiswaan,

**Dr. Amil Ahmad Ilham, S.T., M.IT**
NIP 19731010 199802 1 001

Tembusan :
1. Dekan FT-Unhas;
2. Ketua Departemen Teknik Mesin;
3. Ketua Program Studi S3 Teknik Mesin;
4. ang bersangkutan.

SHIMADZU






| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 368.4 | 86.236 | 2.138 | 372.26 | 345.26 | 0.988 | 0.235 |
| 2 | 401.19 | 73.992 | 10.29 | 422.41 | 374.19 | 4.85 | 1.339 |
| 3 | 426.27 | 82.629 | 1.137 | 453.27 | 424.34 | 1.469 | 0.24 |
| 4 | 474.49 | 96.147 | 3.655 | 495.71 | 457.13 | 0.336 | 0.308 |
| 5 | 524.64 | 86.833 | 12.73 | 547.78 | 497.63 | 1.66 | 1.577 |
| 6 | 572.86 | 83.552 | 15.661 | 594.08 | 549.71 | 1.791 | 1.636 |
| 7 | 611.43 | 95.265 | 4.336 | 634.58 | 594.08 | 0.448 | 0.385 |
| 8 | 667.37 | 98.83 | 0.914 | 684.73 | 640.37 | 0.128 | 0.084 |
| 9 | 711.73 | 86.291 | 13.312 | 736.81 | 684.73 | 1.686 | 1.597 |
| 10 | 765.74 | 77.462 | 22.203 | 808.17 | 738.74 | 3.368 | 3.285 |
| 11 | 858.32 | 71.86 | 27.828 | 883.4 | 819.75 | 4.456 | 4.338 |
| 12 | 920.05 | 77.989 | 21.696 | 941.26 | 885.33 | 3.256 | 3.19 |
| 13 | 979.84 | 55.845 | 43.77 | 1066.64 | 943.19 | 17.484 | 17.26 |
| 14 | 1085.92 | 90.696 | 8.911 | 1132.21 | 1068.56 | 1.509 | 1.395 |
| 15 | 1165 | 74.777 | 24.567 | 1193.94 | 1134.14 | 4.063 | 3.892 |
| 16 | 1246.02 | 94.038 | 5.136 | 1273.02 | 1226.73 | 0.748 | 0.558 |
| 17 | 1305.81 | 98.919 | 0.971 | 1317.38 | 1288.45 | 0.08 | 0.063 |
| 18 | 1342.46 | 89.713 | 4.068 | 1354.03 | 1319.31 | 1.079 | 0.377 |
| 19 | 1462.04 | 71.423 | 28.033 | 1523.76 | 1392.61 | 8.302 | 7.989 |
| 20 | 1531.48 | 98.964 | 0.616 | 1546.91 | 1523.76 | 0.063 | 0.025 |
| 21 | 1647.21 | 53.703 | 45.535 | 1735.93 | 1571.99 | 20.666 | 20.153 |
| 22 | 1751.36 | 99.217 | 0.598 | 1761.01 | 1735.93 | 0.052 | 0.034 |
| 23 | 1867.09 | 98.98 | 0.573 | 1880.6 | 1849.73 | 0.09 | 0.033 |
| 24 | 1915.31 | 99.196 | 0.301 | 1928.82 | 1899.88 | 0.081 | 0.018 |
| 25 | 2088.91 | 92.013 | 1.521 | 2110.12 | 1994.4 | 2.996 | 0.866 |
| 26 | 2357.01 | 95.555 | 2.8 | 2412.95 | 2337.72 | 0.646 | 0.27 |
| 27 | 2476.6 | 98.686 | 1.273 | 2524.82 | 2412.95 | 0.368 | 0.345 |
| 28 | 2582.68 | 98.694 | 1.079 | 2613.55 | 2524.82 | 0.31 | 0.243 |
| 29 | 2719.63 | 97.068 | 1.319 | 2779.42 | 2690.7 | 0.808 | 0.293 |
| 30 | 2891.3 | 70.6 | 2.594 | 2900.94 | 2779.42 | 8.065 | 0.367 |
| 31 | 2927.94 | 67.582 | 10.43 | 3003.17 | 2902.87 | 9.539 | 2.052 |
| 32 | 3099.61 | 90.908 | 1.584 | 3113.11 | 3014.74 | 2.478 | 0.503 |
| 33 | 3562.52 | 45.749 | 54.3 | 3716.83 | 3201.83 | 98.145 | 98.539 |

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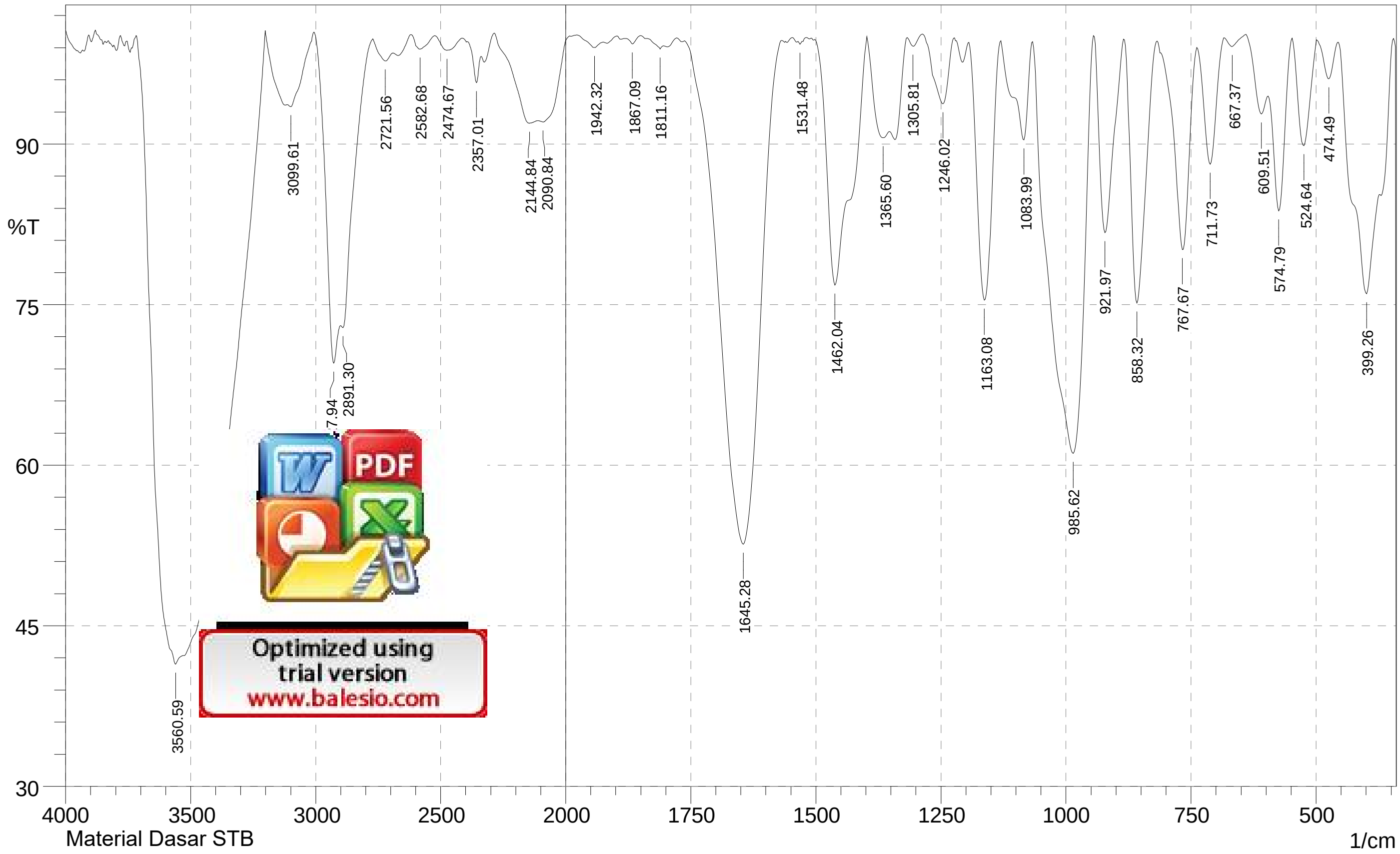




| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 399.26 | 76.032 | 13.651 | 455.2 | 374.19 | 6.095 | 3.143 |
| 2 | 474.49 | 96.088 | 3.518 | 499.56 | 457.13 | 0.387 | 0.318 |
| 3 | 524.64 | 89.862 | 9.967 | 547.78 | 499.56 | 1.213 | 1.176 |
| 4 | 574.79 | 83.765 | 13.096 | 596 | 549.71 | 2.007 | 1.426 |
| 5 | 609.51 | 92.809 | 3.427 | 640.37 | 596 | 0.844 | 0.321 |
| 6 | 667.37 | 99.107 | 0.947 | 684.73 | 640.37 | 0.069 | 0.086 |
| 7 | 711.73 | 88.118 | 11.274 | 736.81 | 684.73 | 1.469 | 1.339 |
| 8 | 767.67 | 80.143 | 19.063 | 815.89 | 738.74 | 3.171 | 2.923 |
| 9 | 858.32 | 75.138 | 24.558 | 883.4 | 817.82 | 3.875 | 3.784 |
| 10 | 921.97 | 81.717 | 18.242 | 943.19 | 885.33 | 2.63 | 2.611 |
| 11 | 985.62 | 61.103 | 38.838 | 1066.64 | 945.12 | 15.221 | 15.142 |
| 12 | 1083.99 | 90.396 | 9.121 | 1130.29 | 1068.56 | 1.494 | 1.376 |
| 13 | 1163.08 | 75.432 | 24.092 | 1193.94 | 1132.21 | 3.869 | 3.741 |
| 14 | 1246.02 | 93.763 | 6.294 | 1286.52 | 1222.87 | 0.883 | 0.912 |
| 15 | 1305.81 | 99.139 | 0.933 | 1317.38 | 1286.52 | 0.047 | 0.062 |
| 16 | 1365.6 | 90.587 | 2.871 | 1396.46 | 1354.03 | 1.398 | 0.469 |
| 17 | 1462.04 | 76.838 | 23.001 | 1500.62 | 1398.39 | 6.023 | 5.971 |
| 18 | 1531.48 | 99.323 | 0.345 | 1535.34 | 1517.98 | 0.026 | 0.009 |
| 19 | 1645.28 | 52.619 | 47.021 | 1761.01 | 1570.06 | 22.84 | 22.535 |
| 20 | 1811.16 | 98.882 | 0.454 | 1838.16 | 1803.44 | 0.094 | 0.022 |
| 21 | 1867.09 | 99.364 | 0.623 | 1880.6 | 1849.73 | 0.034 | 0.035 |
| 22 | 1942.32 | 99.016 | 0.723 | 1978.97 | 1924.96 | 0.109 | 0.075 |
| 23 | 2090.84 | 92.065 | 1.308 | 2108.2 | 1992.47 | 2.779 | 0.799 |
| 24 | 2144.84 | 91.956 | 1.863 | 2283.72 | 2110.12 | 3.605 | 0.635 |
| 25 | 2357.01 | 95.734 | 2.931 | 2393.66 | 2337.72 | 0.552 | 0.277 |
| 26 | 2474.67 | 98.77 | 1.257 | 2522.89 | 2412.95 | 0.336 | 0.342 |
| 27 | 2582.68 | 98.869 | 1.319 | 2619.33 | 2522.89 | 0.229 | 0.303 |
| 28 | 2721.56 | 97.763 | 1.243 | 2771.71 | 2690.7 | 0.568 | 0.271 |
| 29 | 2891.3 | 72.858 | 2.21 | 2900.94 | 2773.64 | 7.424 | 0.272 |
| 30 | 2927.94 | 69.544 | 10.08 | 3007.02 | 2902.87 | 8.772 | 1.965 |
| 31 | 3099.61 | 93.488 | 1.071 | 3113.11 | 3008.95 | 1.696 | 0.345 |
| 32 | 3560.59 | 41.429 | 9.831 | 3716.83 | 3531.66 | 44.866 | 10.424 |

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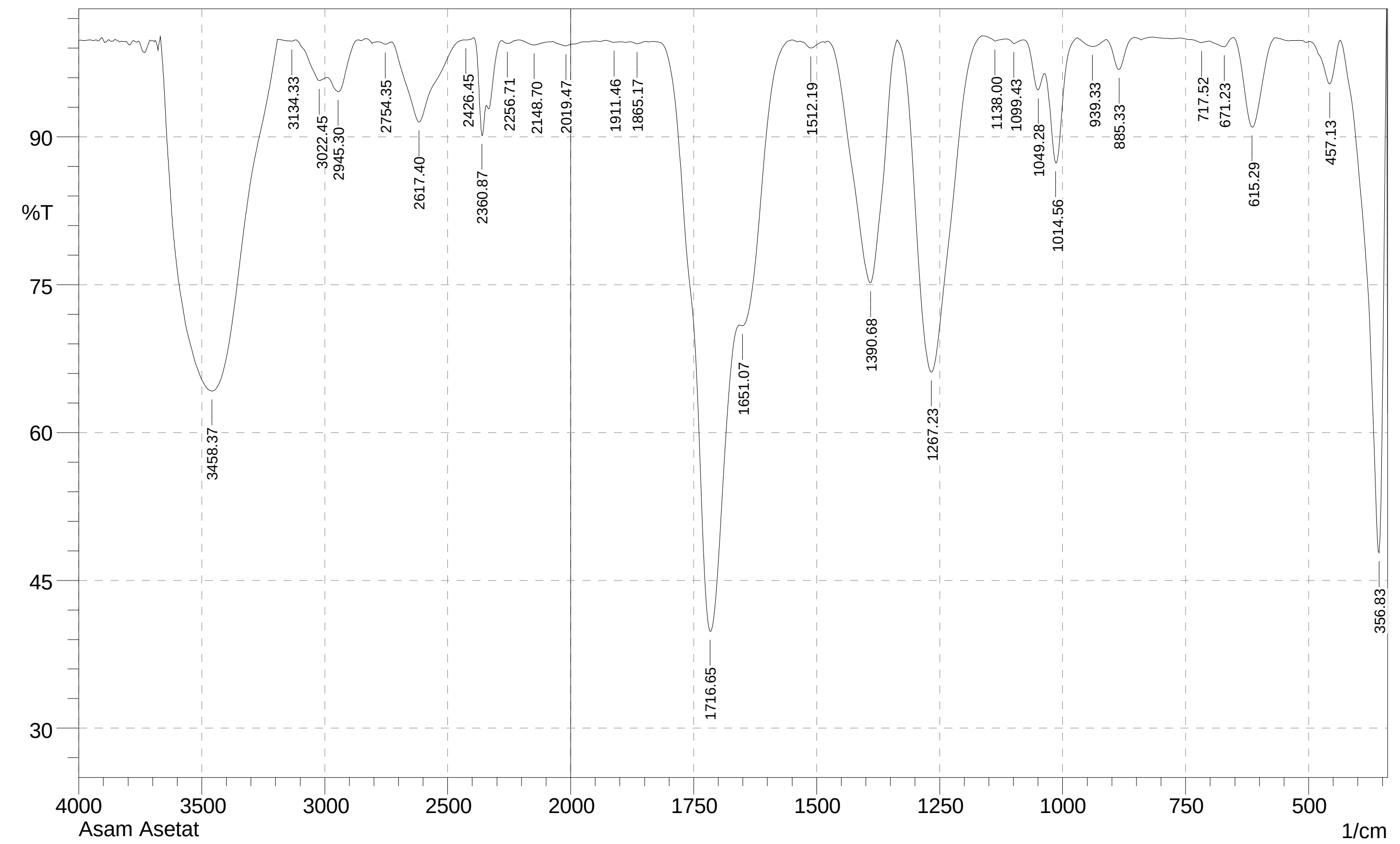


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| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 356.83 | 47.809 | 48.286 | 433.98 | 343.33 | 10.364 | 9.375 |
| 2 | 457.13 | 95.365 | 4.396 | 497.63 | 435.91 | 0.602 | 0.532 |
| 3 | 615.29 | 90.986 | 9.074 | 651.94 | 569 | 1.584 | 1.606 |
| 4 | 671.23 | 99.151 | 0.789 | 702.09 | 653.87 | 0.107 | 0.084 |
| 5 | 717.52 | 99.557 | 0.243 | 761.88 | 702.09 | 0.055 | 0.024 |
| 6 | 885.33 | 96.829 | 3.133 | 910.4 | 854.47 | 0.342 | 0.335 |
| 7 | 939.33 | 99.166 | 0.801 | 970.19 | 910.4 | 0.129 | 0.121 |
| 8 | 1014.56 | 87.359 | 10.246 | 1035.77 | 970.19 | 1.656 | 1.167 |
| 9 | 1049.28 | 94.761 | 2.596 | 1080.14 | 1037.7 | 0.534 | 0.183 |
| 10 | 1099.43 | 99.451 | 0.444 | 1114.86 | 1080.14 | 0.042 | 0.026 |
| 11 | 1138 | 99.705 | 0.394 | 1161.15 | 1114.86 | 0.01 | 0.03 |
| 12 | 1267.23 | 66.117 | 33.818 | 1334.74 | 1163.08 | 12.887 | 12.881 |
| 13 | 1390.68 | 75.195 | 24.591 | 1477.47 | 1336.67 | 8.048 | 7.907 |
| 14 | 1512.19 | 99.011 | 0.668 | 1533.41 | 1487.12 | 0.127 | 0.062 |
| 15 | 1651.07 | 70.844 | 1.122 | 1654.92 | 1550.77 | 6.415 | 0.335 |
| 16 | 1716.65 | 39.822 | 40.992 | 1830.45 | 1656.85 | 28.533 | 15.855 |
| 17 | 1865.17 | 99.441 | 0.225 | 1878.67 | 1847.81 | 0.059 | 0.014 |
| 18 | 1911.46 | 99.596 | 0.128 | 1928.82 | 1896.03 | 0.048 | 0.009 |
| 19 | 2019.47 | 99.245 | 0.415 | 2071.55 | 1973.18 | 0.248 | 0.103 |
| 20 | 2148.7 | 99.337 | 0.436 | 2210.42 | 2071.55 | 0.27 | 0.126 |
| 21 | 2256.71 | 99.481 | 0.321 | 2281.79 | 2210.42 | 0.107 | 0.049 |
| 22 | 2360.87 | 90.149 | 5.419 | 2393.66 | 2343.51 | 1.257 | 0.49 |
| 23 | 2426.45 | 99.828 | 0.045 | 2434.17 | 2393.66 | 0.019 | 0.009 |
| 24 | 2617.4 | 91.517 | 8.191 | 2729.27 | 2434.17 | 5.042 | 4.698 |
| 25 | 2754.35 | 99.406 | 0.235 | 2781.35 | 2729.27 | 0.108 | 0.027 |
| 26 | 2945.3 | 94.594 | 2.811 | 2989.66 | 2866.22 | 1.836 | 0.735 |
| 27 | [illegible] | [illegible] | 1.257 | 3116.97 | 2991.59 | 1.443 | 0.291 |
| 28 | [illegible] | [illegible] | 0.073 | 3149.76 | 3116.97 | 0.034 | 0.005 |
| 29 | [illegible] | [illegible] | 35.816 | 3668.61 | 3192.19 | 53.906 | 53.95 |

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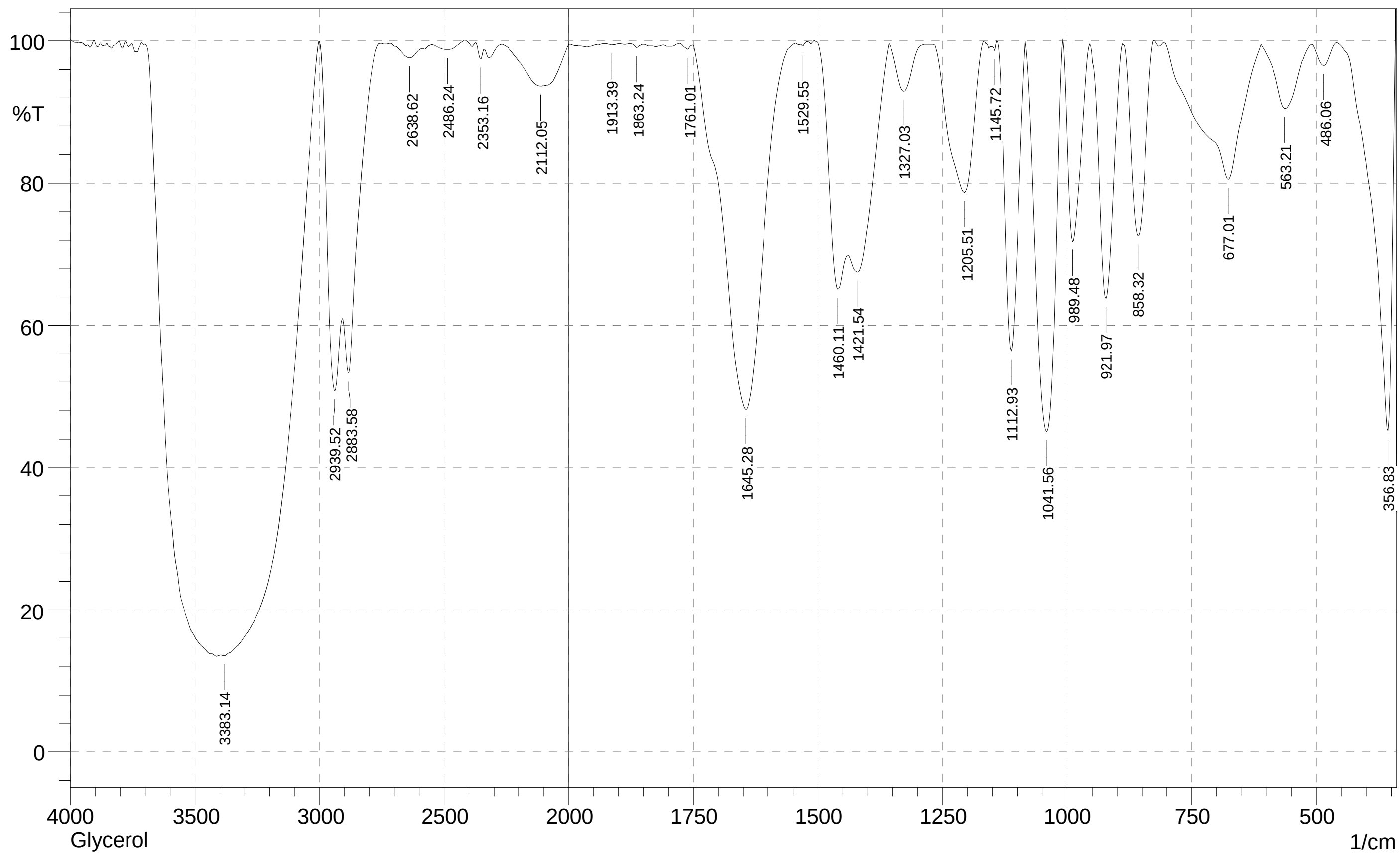


| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 356.83 | 45.138 | 50.692 | 459.06 | 343.33 | 12.449 | 11.166 |
| 2 | 486.06 | 96.551 | 3.079 | 509.21 | 459.06 | 0.431 | 0.353 |
| 3 | 563.21 | 90.501 | 8.894 | 609.51 | 509.21 | 2.191 | 1.932 |
| 4 | 677.01 | 80.516 | 19.105 | 804.32 | 611.43 | 9.053 | 8.778 |
| 5 | 858.32 | 72.586 | 27.145 | 887.26 | 827.46 | 4.251 | 4.185 |
| 6 | 921.97 | 63.737 | 35.75 | 952.84 | 889.18 | 5.802 | 5.662 |
| 7 | 989.48 | 71.803 | 28.169 | 1008.77 | 954.76 | 3.972 | 3.942 |
| 8 | 1041.56 | 45.077 | 53.926 | 1082.07 | 1010.7 | 13.561 | 13.248 |
| 9 | 1112.93 | 56.401 | 43.52 | 1139.93 | 1083.99 | 6.815 | 6.796 |
| 10 | 1145.72 | 98.642 | 1.054 | 1151.5 | 1141.86 | 0.034 | 0.018 |
| 11 | 1205.51 | 78.696 | 21.145 | 1271.09 | 1166.93 | 5.692 | 5.594 |
| 12 | 1327.03 | 92.915 | 6.562 | 1355.96 | 1273.02 | 1.155 | 0.972 |
| 13 | 1421.54 | 67.489 | 8.746 | 1438.9 | 1357.89 | 8.546 | 2.323 |
| 14 | 1460.11 | 65.046 | 13.681 | 1506.41 | 1440.83 | 6.872 | 1.916 |
| 15 | 1529.55 | 99.266 | 0.426 | 1535.34 | 1521.84 | 0.025 | 0.009 |
| 16 | 1645.28 | 48.138 | 51.376 | 1749.44 | 1544.98 | 26.02 | 25.586 |
| 17 | 1761.01 | 98.804 | 0.709 | 1778.37 | 1751.36 | 0.089 | 0.036 |
| 18 | 1863.24 | 99.07 | 0.501 | 1878.67 | 1849.73 | 0.078 | 0.025 |
| 19 | 1913.39 | 99.449 | 0.163 | 1923.03 | 1897.95 | 0.051 | 0.009 |
| 20 | 2112.05 | 93.658 | 5.87 | 2268.29 | 2000.18 | 4.573 | 4.023 |
| 21 | 2353.16 | 97.454 | 1.742 | 2374.37 | 2339.65 | 0.236 | 0.13 |
| 22 | 2486.24 | 98.8 | 0.975 | 2547.97 | 2416.81 | 0.451 | 0.333 |
| 23 | 2638.62 | 97.64 | 1.452 | 2698.41 | 2588.47 | 0.794 | 0.366 |
| 24 | 2883.58 | 53.257 | 14.059 | 2908.65 | 2756.28 | 17.273 | 2.95 |
| 25 | 2939.52 | 50.807 | 22.5 | 3001.24 | 2910.58 | 16.367 | 6.496 |
| 26 | 3383.14 | 13.535 | 3.057 | 3396.64 | 3003.17 | 206.55 | 37.475 |

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No. of Scans;

Resolution;

Apodization;

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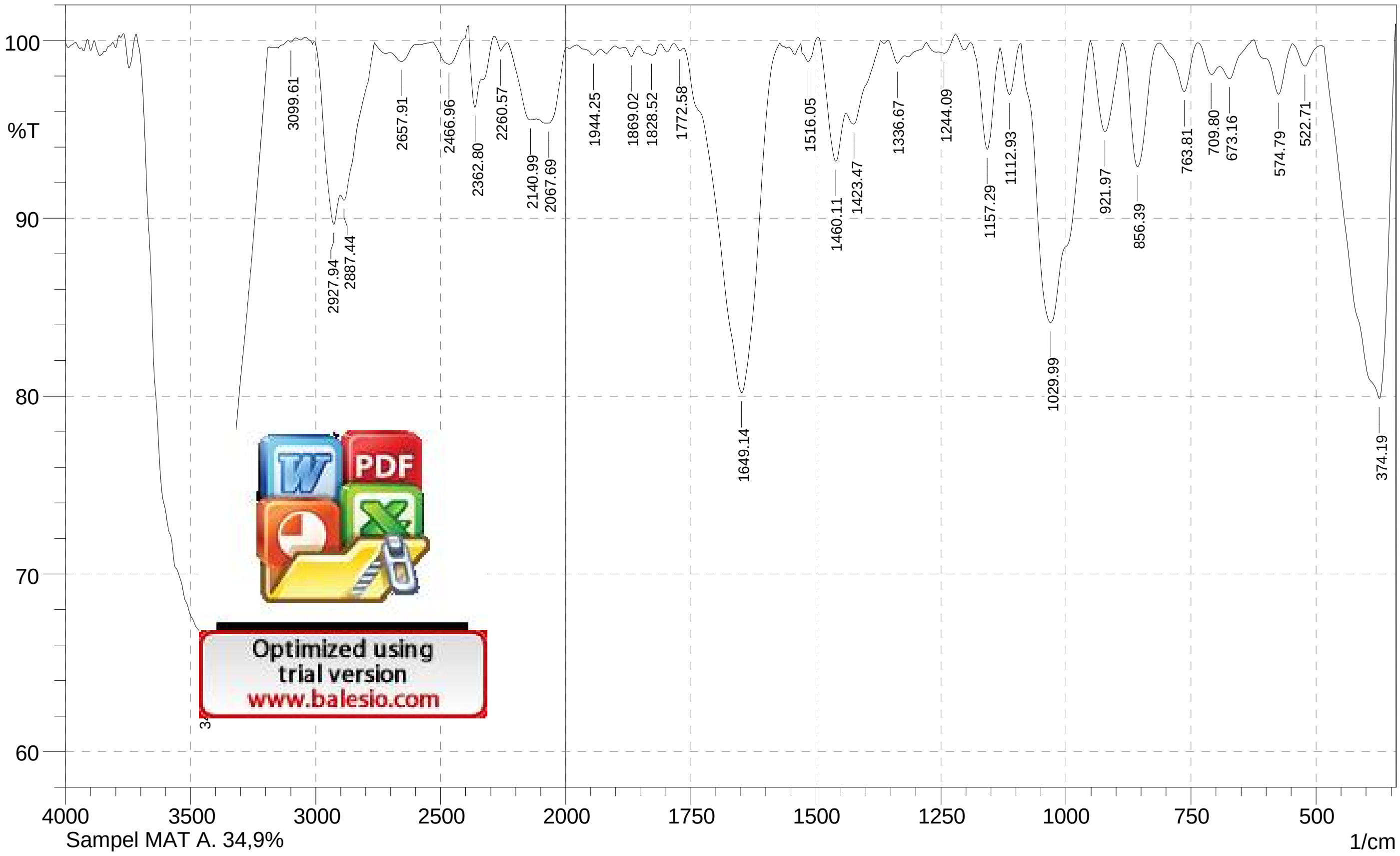


| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 374.19 | 79.859 | 19.9 | 484.13 | 343.33 | 8.188 | 8.016 |
| 2 | 522.71 | 98.554 | 1.229 | 547.78 | 489.92 | 0.191 | 0.135 |
| 3 | 574.79 | 96.975 | 2.433 | 601.79 | 547.78 | 0.405 | 0.265 |
| 4 | 673.16 | 97.849 | 1.114 | 692.44 | 624.94 | 0.332 | 0.12 |
| 5 | 709.8 | 98.085 | 0.974 | 736.81 | 692.44 | 0.241 | 0.087 |
| 6 | 763.81 | 97.123 | 2.743 | 813.96 | 736.81 | 0.425 | 0.379 |
| 7 | 856.39 | 92.905 | 6.913 | 885.33 | 813.96 | 1.113 | 1.059 |
| 8 | 921.97 | 94.865 | 5.06 | 950.91 | 887.26 | 0.803 | 0.781 |
| 9 | 1029.99 | 84.125 | 15.708 | 1089.78 | 952.84 | 5.667 | 5.569 |
| 10 | 1112.93 | 96.966 | 2.747 | 1132.21 | 1091.71 | 0.307 | 0.257 |
| 11 | 1157.29 | 93.878 | 5.848 | 1190.08 | 1132.21 | 0.757 | 0.692 |
| 12 | 1244.09 | 99.281 | 0.407 | 1255.66 | 1220.94 | 0.062 | 0.04 |
| 13 | 1336.67 | 98.717 | 0.778 | 1355.96 | 1323.17 | 0.116 | 0.055 |
| 14 | 1423.47 | 95.297 | 1.542 | 1438.9 | 1371.39 | 0.853 | 0.239 |
| 15 | 1460.11 | 93.21 | 4.214 | 1494.83 | 1440.83 | 1.025 | 0.536 |
| 16 | 1516.05 | 98.795 | 1.176 | 1529.55 | 1494.83 | 0.098 | 0.099 |
| 17 | 1649.14 | 80.19 | 19.537 | 1762.94 | 1571.99 | 8.265 | 8.016 |
| 18 | 1772.58 | 99.421 | 0.249 | 1784.15 | 1764.87 | 0.034 | 0.009 |
| 19 | 1828.52 | 99.175 | 0.586 | 1853.59 | 1811.16 | 0.114 | 0.068 |
| 20 | 1869.02 | 99.086 | 0.568 | 1882.52 | 1853.59 | 0.075 | 0.031 |
| 21 | 1944.25 | 99.175 | 0.333 | 1961.61 | 1930.74 | 0.087 | 0.021 |
| 22 | 2067.69 | 95.348 | 0.541 | 2077.33 | 2000.18 | 1.069 | 0.225 |
| 23 | 2140.99 | 95.541 | 0.854 | 2231.64 | 2119.77 | 1.416 | 0.272 |
| 24 | 2260.57 | 99.402 | 0.673 | 2285.65 | 2231.64 | 0.051 | 0.065 |
| 25 | 2362.8 | 96.251 | 3.081 | 2389.8 | 2335.8 | 0.565 | 0.405 |
| 26 | 2466.96 | 98.663 | 1.675 | 2532.54 | 2389.8 | 0.38 | 0.612 |
| 27 | 2657.91 | 98.823 | 0.696 | 2702.27 | 2596.19 | 0.362 | 0.157 |
| 28 | 2887.44 | 91.018 | 1.139 | 2900.94 | 2765.92 | 3.06 | 0.394 |
| 29 | 2927.94 | 89.666 | 3.786 | 3003.17 | 2902.87 | 2.962 | 0.934 |
| 30 | 3099.61 | 99.907 | 0.139 | 3111.18 | 3078.39 | -0.001 | 0.009 |
| 31 | 3446.79 | 66.272 | 33.679 | 3716.83 | 3192.19 | 58.778 | 58.687 |

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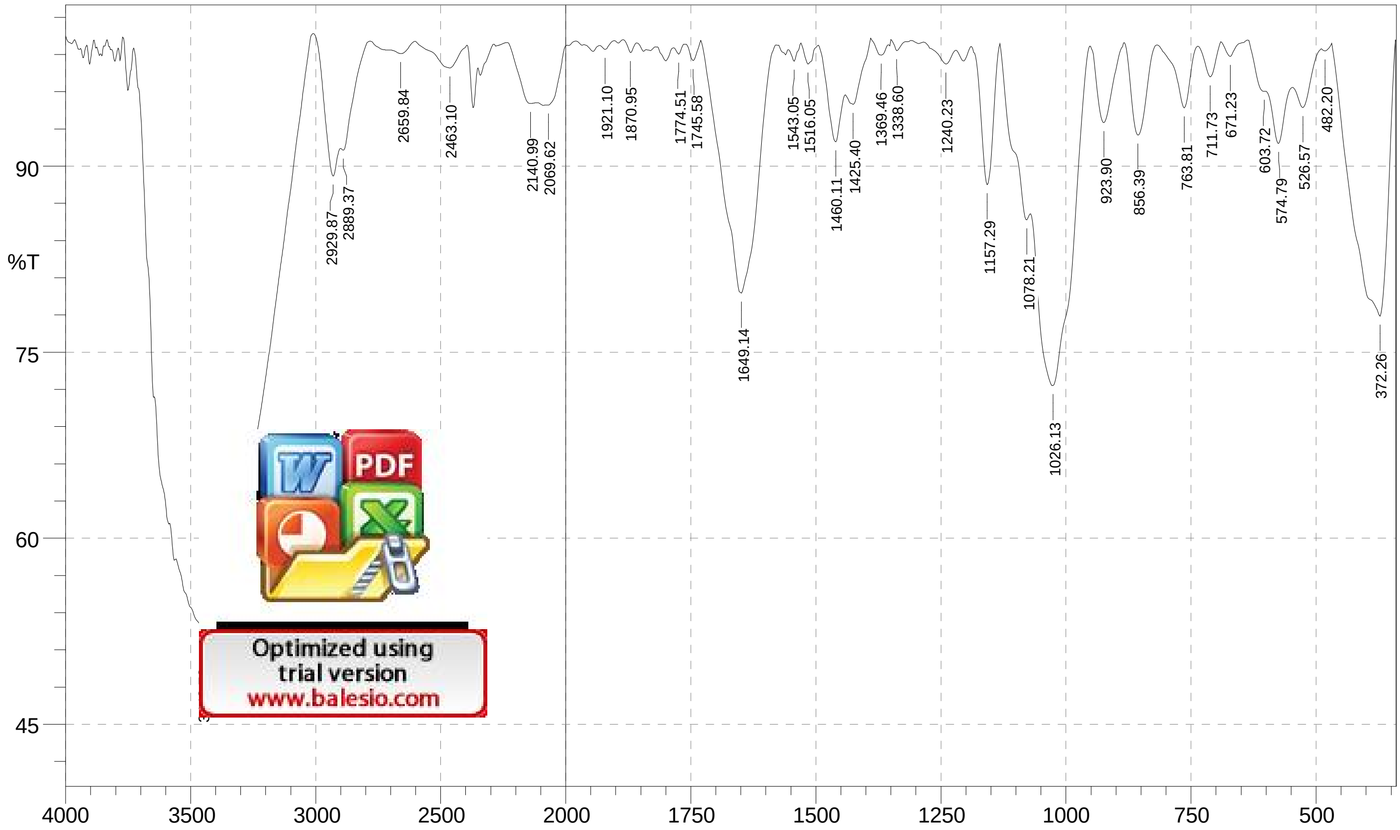
No. of Scans;
Resolution;
Apodization;




Sampel MAT. B 11,3%

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 372.26 | 77.9 | 21.398 | 468.7 | 343.33 | 8.231 | 7.958 |
| 2 | 482.2 | 99.295 | 0.324 | 489.92 | 468.7 | 0.05 | 0.02 |
| 3 | 526.57 | 94.731 | 2.761 | 547.78 | 489.92 | 0.849 | 0.314 |
| 4 | 574.79 | 91.827 | 4.371 | 601.79 | 547.78 | 1.377 | 0.469 |
| 5 | 603.72 | 96.046 | 0.217 | 638.44 | 601.79 | 0.359 | 0.05 |
| 6 | 671.23 | 98.858 | 1.226 | 690.52 | 638.44 | 0.095 | 0.117 |
| 7 | 711.73 | 97.205 | 2.665 | 736.81 | 690.52 | 0.302 | 0.272 |
| 8 | 763.81 | 94.709 | 4.996 | 817.82 | 736.81 | 0.795 | 0.697 |
| 9 | 856.39 | 92.495 | 7.374 | 883.4 | 819.75 | 1.116 | 1.075 |
| 10 | 923.9 | 93.512 | 6.262 | 950.91 | 885.33 | 0.99 | 0.933 |
| 11 | 1026.13 | 72.3 | 18.954 | 1070.49 | 952.84 | 10.613 | 6.785 |
| 12 | 1078.21 | 85.67 | 1.793 | 1132.21 | 1072.42 | 2.481 | 0.464 |
| 13 | 1157.29 | 88.498 | 11.107 | 1188.15 | 1134.14 | 1.38 | 1.288 |
| 14 | 1240.23 | 98.242 | 1.301 | 1284.59 | 1220.94 | 0.262 | 0.17 |
| 15 | 1338.6 | 99.32 | 0.835 | 1350.17 | 1319.31 | 0.032 | 0.05 |
| 16 | 1369.46 | 98.963 | 1.041 | 1390.68 | 1354.03 | 0.084 | 0.092 |
| 17 | 1425.4 | 94.989 | 2.16 | 1440.83 | 1390.68 | 0.714 | 0.274 |
| 18 | 1460.11 | 91.964 | 5.09 | 1494.83 | 1442.75 | 1.142 | 0.6 |
| 19 | 1516.05 | 98.232 | 1.63 | 1529.55 | 1494.83 | 0.15 | 0.126 |
| 20 | 1543.05 | 98.462 | 1.184 | 1554.63 | 1529.55 | 0.099 | 0.063 |
| 21 | 1649.14 | 79.773 | 20.082 | 1728.22 | 1579.7 | 7.279 | 7.188 |
| 22 | 1745.58 | 98.512 | 1.477 | 1761.01 | 1730.15 | 0.104 | 0.102 |
| 23 | 1774.51 | 99.034 | 0.651 | 1784.15 | 1764.87 | 0.054 | 0.028 |
| 24 | 1870.95 | 99.159 | 0.895 | 1886.38 | 1857.45 | 0.038 | 0.046 |
| 25 | 1921.1 | 99.412 | 0.474 | 1932.67 | 1903.74 | 0.037 | 0.028 |
| 26 | 2069.62 | 94.929 | 0.477 | 2077.33 | 1998.25 | 1.147 | 0.239 |
| 27 | 2140.99 | 95.047 | 1.15 | 2235.5 | 2113.98 | 1.7 | 0.365 |
| 28 | 2463.1 | 97.916 | 1.938 | 2601.97 | 2395.59 | 0.964 | 0.879 |
| 29 | 2659.84 | 99.082 | 0.608 | 2709.99 | 2601.97 | 0.28 | 0.146 |
| 30 | 2889.37 | 91.293 | 0.982 | 2900.94 | 2783.28 | 2.089 | 0.12 |
| 31 | 2929.87 | 89.207 | 4.567 | 3008.95 | 2902.87 | 2.888 | 0.991 |
| 32 | 3448.72 | 52.412 | 1.011 | 3558.67 | 3433.29 | 32.994 | 0.858 |

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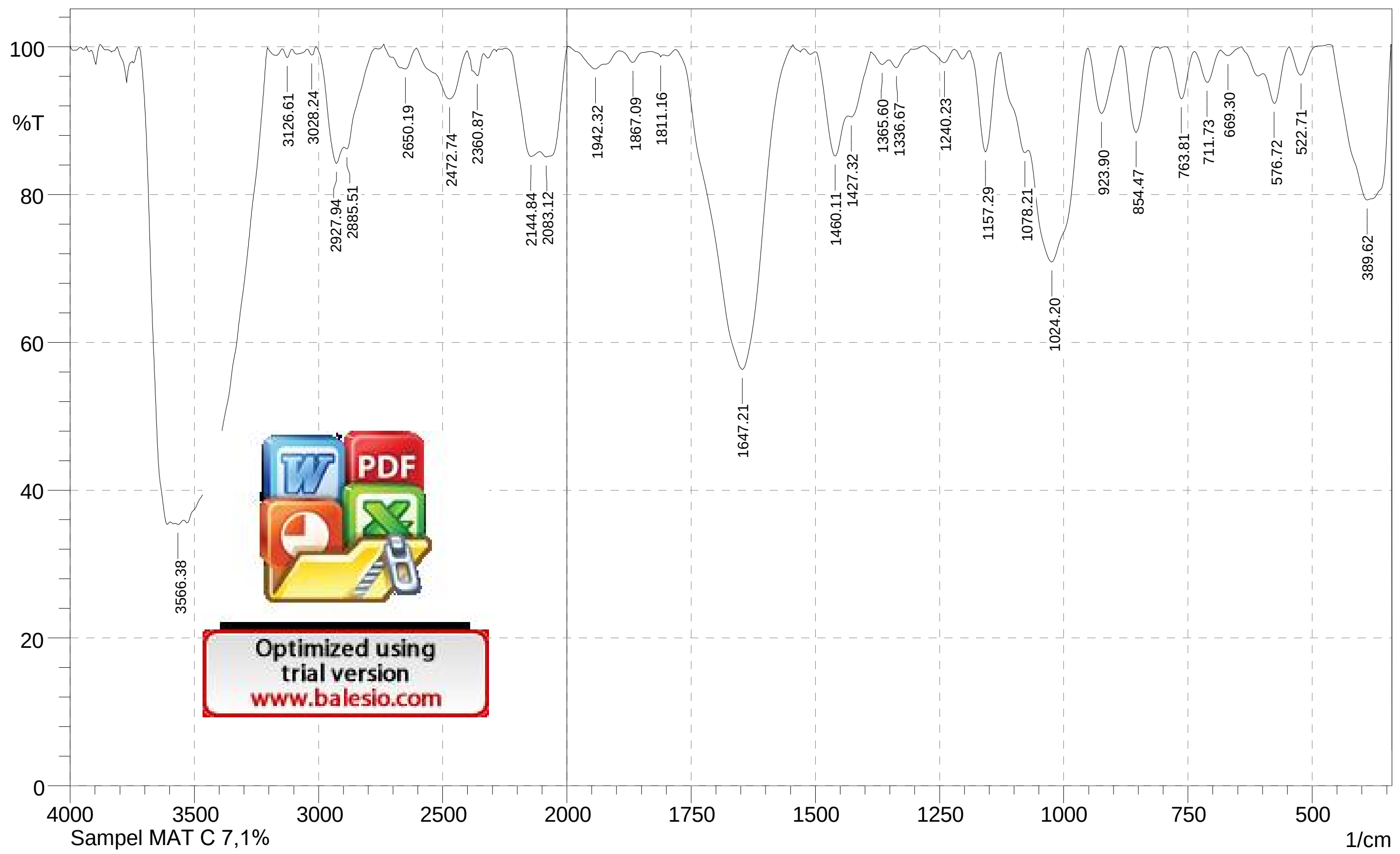
Resolution;

SHIMADZU






| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 389.62 | 79.286 | 19.7071 | 464.84 | 343.33 | 7.8579 | 7.4474 |
| 2 | 522.71 | 96.1741 | 3.9275 | 545.85 | 466.77 | 0.4189 | 0.4761 |
| 3 | 576.72 | 92.3328 | 5.5255 | 597.93 | 547.78 | 1.013 | 0.6138 |
| 4 | 669.3 | 98.8 | 0.9287 | 684.73 | 642.3 | 0.1249 | 0.086 |
| 5 | 711.73 | 95.1875 | 4.2678 | 736.81 | 684.73 | 0.6116 | 0.489 |
| 6 | 763.81 | 92.9484 | 6.6947 | 796.6 | 736.81 | 0.8441 | 0.7593 |
| 7 | 854.47 | 88.403 | 11.6316 | 885.33 | 815.89 | 1.7814 | 1.786 |
| 8 | 923.9 | 90.9925 | 8.9287 | 950.91 | 887.26 | 1.4115 | 1.3971 |
| 9 | 1024.2 | 70.898 | 20.4885 | 1070.49 | 952.84 | 11.6527 | 7.7851 |
| 10 | 1078.21 | 85.6719 | 1.7165 | 1126.43 | 1072.42 | 2.3055 | 0.3764 |
| 11 | 1157.29 | 85.784 | 13.5289 | 1188.15 | 1128.36 | 1.9324 | 1.7534 |
| 12 | 1240.23 | 97.8641 | 1.9488 | 1280.73 | 1220.94 | 0.2841 | 0.2575 |
| 13 | 1336.67 | 97.1858 | 1.5519 | 1352.1 | 1307.74 | 0.3432 | 0.1418 |
| 14 | 1365.6 | 97.5937 | 1.0278 | 1388.75 | 1352.1 | 0.2823 | 0.0841 |
| 15 | 1427.32 | 90.519 | 1.2457 | 1433.11 | 1388.75 | 1.1934 | 0.2172 |
| 16 | 1460.11 | 85.2019 | 8.8387 | 1498.69 | 1435.04 | 2.8271 | 1.3315 |
| 17 | 1647.21 | 56.3485 | 43.5261 | 1780.3 | 1546.91 | 25.9404 | 25.7809 |
| 18 | 1811.16 | 98.6485 | 0.3697 | 1830.45 | 1805.37 | 0.1013 | 0.0075 |
| 19 | 1867.09 | 97.8914 | 1.5256 | 1894.1 | 1830.45 | 0.3113 | 0.1482 |
| 20 | 1942.32 | 97.0052 | 1.2128 | 1998.25 | 1924.96 | 0.5372 | 0.1693 |
| 21 | 2083.12 | 85.0951 | 3.9653 | 2108.2 | 1998.25 | 5.6758 | 2.1037 |
| 22 | 2144.84 | 85.1534 | 4.2537 | 2245.14 | 2110.12 | 5.5504 | 1.1554 |
| 23 | 2360.87 | 96.0743 | 2.698 | 2389.8 | 2335.8 | 0.6815 | 0.3863 |
| 24 | 2472.74 | 92.9412 | 6.6036 | 2605.83 | 2403.3 | 3.527 | 3.1836 |
| 25 | 2650.19 | 96.9954 | 2.2632 | 2702.27 | 2605.83 | 0.8692 | 0.5358 |
| 26 | 2885.51 | 86.1934 | 1.4397 | 2897.08 | 2771.71 | 3.7779 | 0.1571 |
| 27 | 2927.94 | 84.2249 | 5.7445 | 3008.95 | 2899.01 | 4.8456 | 1.367 |
| 28 | 3028.24 | 98.8882 | 0.9374 | 3045.6 | 3008.95 | 0.1052 | 0.0787 |
| 29 | 3126.61 | 98.5582 | 1.1391 | 3145.9 | 3107.32 | 0.1467 | 0.0959 |
| 30 | 3566.38 | 35.3699 | 0.2623 | 3576.02 | 3545.16 | 13.8519 | 0.0556 |

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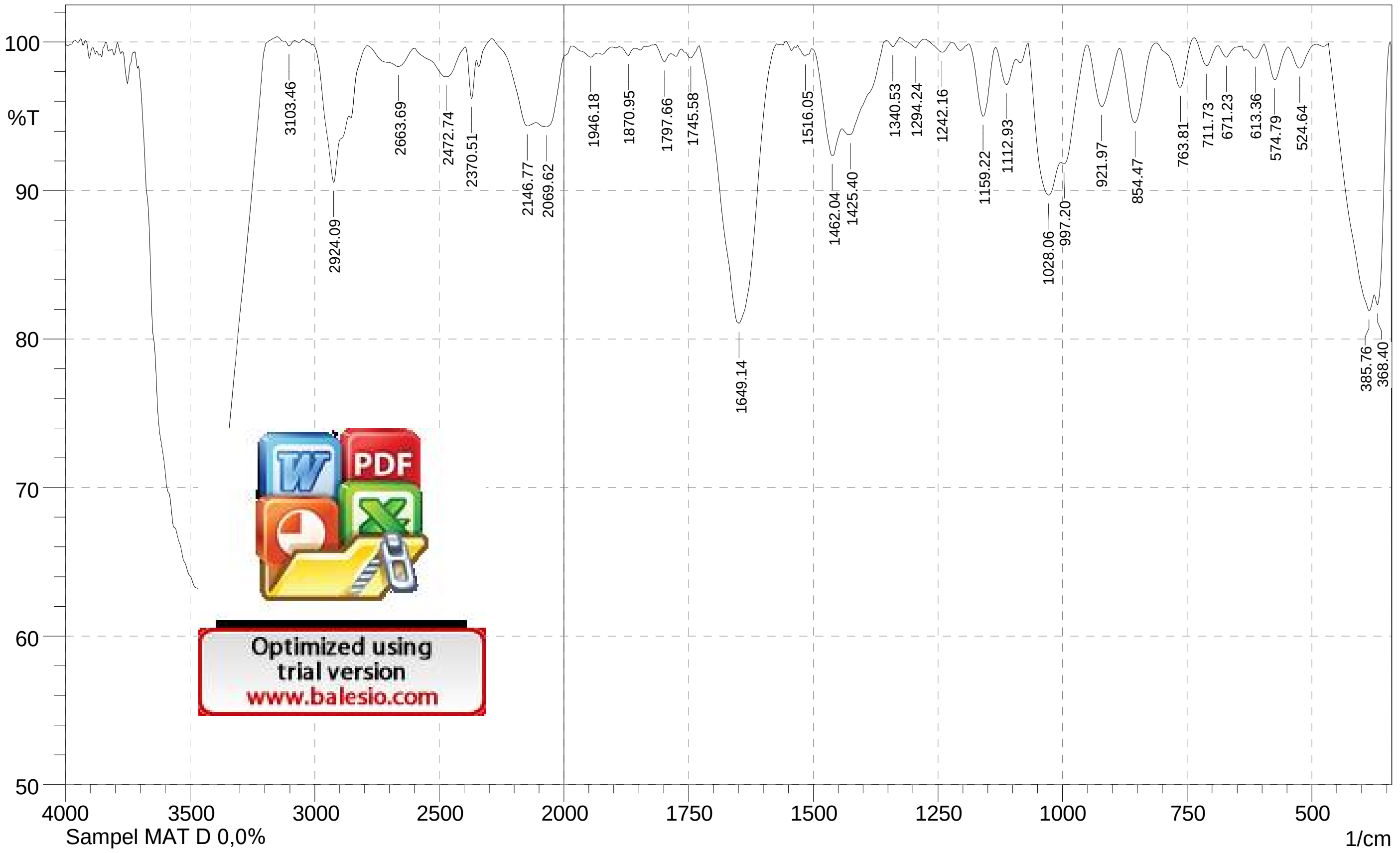
Date/Time; 2/6/2023 12:12:31 PM

No. of Scans;

Resolution;

Apodization;






| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 368.4 | 82.306 | 3.847 | 374.19 | 343.33 | 1.486 | 0.353 |
| 2 | 385.76 | 81.899 | 2.858 | 466.77 | 376.12 | 4.915 | 1.139 |
| 3 | 524.64 | 98.238 | 1.513 | 547.78 | 489.92 | 0.229 | 0.171 |
| 4 | 574.79 | 97.451 | 2.339 | 596 | 547.78 | 0.292 | 0.245 |
| 5 | 613.36 | 98.913 | 0.778 | 632.65 | 596 | 0.117 | 0.066 |
| 6 | 671.23 | 98.986 | 0.765 | 688.59 | 640.37 | 0.119 | 0.066 |
| 7 | 711.73 | 98.407 | 1.606 | 736.81 | 688.59 | 0.161 | 0.165 |
| 8 | 763.81 | 96.948 | 3.214 | 812.03 | 736.81 | 0.409 | 0.446 |
| 9 | 854.47 | 94.581 | 5.137 | 885.33 | 812.03 | 0.884 | 0.804 |
| 10 | 921.97 | 95.664 | 4.044 | 950.91 | 885.33 | 0.701 | 0.613 |
| 11 | 997.2 | 91.804 | 0.972 | 1002.98 | 950.91 | 1.061 | 0.143 |
| 12 | 1028.06 | 89.695 | 5.102 | 1068.56 | 1004.91 | 2.24 | 1.021 |
| 13 | 1112.93 | 97.128 | 2.088 | 1134.14 | 1093.64 | 0.33 | 0.195 |
| 14 | 1159.22 | 95 | 4.747 | 1188.15 | 1134.14 | 0.603 | 0.546 |
| 15 | 1242.16 | 99.313 | 0.75 | 1276.88 | 1220.94 | 0.067 | 0.088 |
| 16 | 1294.24 | 99.594 | 0.638 | 1327.03 | 1276.88 | 0.006 | 0.06 |
| 17 | 1340.53 | 99.691 | 0.511 | 1354.03 | 1327.03 | 0.007 | 0.031 |
| 18 | 1425.4 | 93.758 | 0.188 | 1427.32 | 1354.03 | 1.078 | 0.108 |
| 19 | 1462.04 | 92.349 | 3.551 | 1502.55 | 1442.75 | 1.297 | 0.443 |
| 20 | 1516.05 | 99.062 | 0.231 | 1531.48 | 1512.19 | 0.058 | 0.013 |
| 21 | 1649.14 | 81.062 | 18.751 | 1728.22 | 1573.91 | 6.984 | 6.858 |
| 22 | 1745.58 | 98.926 | 0.567 | 1757.15 | 1728.22 | 0.096 | 0.038 |
| 23 | 1797.66 | 98.654 | 0.79 | 1816.94 | 1786.08 | 0.115 | 0.051 |
| 24 | 1870.95 | 99.09 | 0.539 | 1888.31 | 1859.38 | 0.075 | 0.029 |
| 25 | 1946.18 | 98.982 | 0.415 | 1984.75 | 1930.74 | 0.16 | 0.042 |
| 26 | 2069.62 | 94.293 | 1.971 | 2110.12 | 1986.68 | 2.239 | 0.693 |
| 27 | 2146.77 | 94.345 | 1.339 | 2289.5 | 2112.05 | 2.237 | 0.32 |
| 28 | 2370.51 | 96.194 | 2.966 | 2395.59 | 2351.23 | 0.422 | 0.271 |
| 29 | 2472.74 | 97.661 | 1.972 | 2600.04 | 2397.52 | 1.236 | 0.903 |
| 30 | 2663.69 | 98.359 | 1.287 | 2789.07 | 2600.04 | 0.899 | 0.636 |
| 31 | 2924.09 | 90.557 | 6.465 | 3007.02 | 2864.29 | 3.446 | 1.787 |
| 32 | 3103.46 | 99.75 | 0.428 | 3149.76 | 3080.32 | -0.007 | 0.06 |
| 33 | 3450.65 | 62.796 | 36.477 | 3707.18 | 3151.69 | 63.865 | 62.287 |

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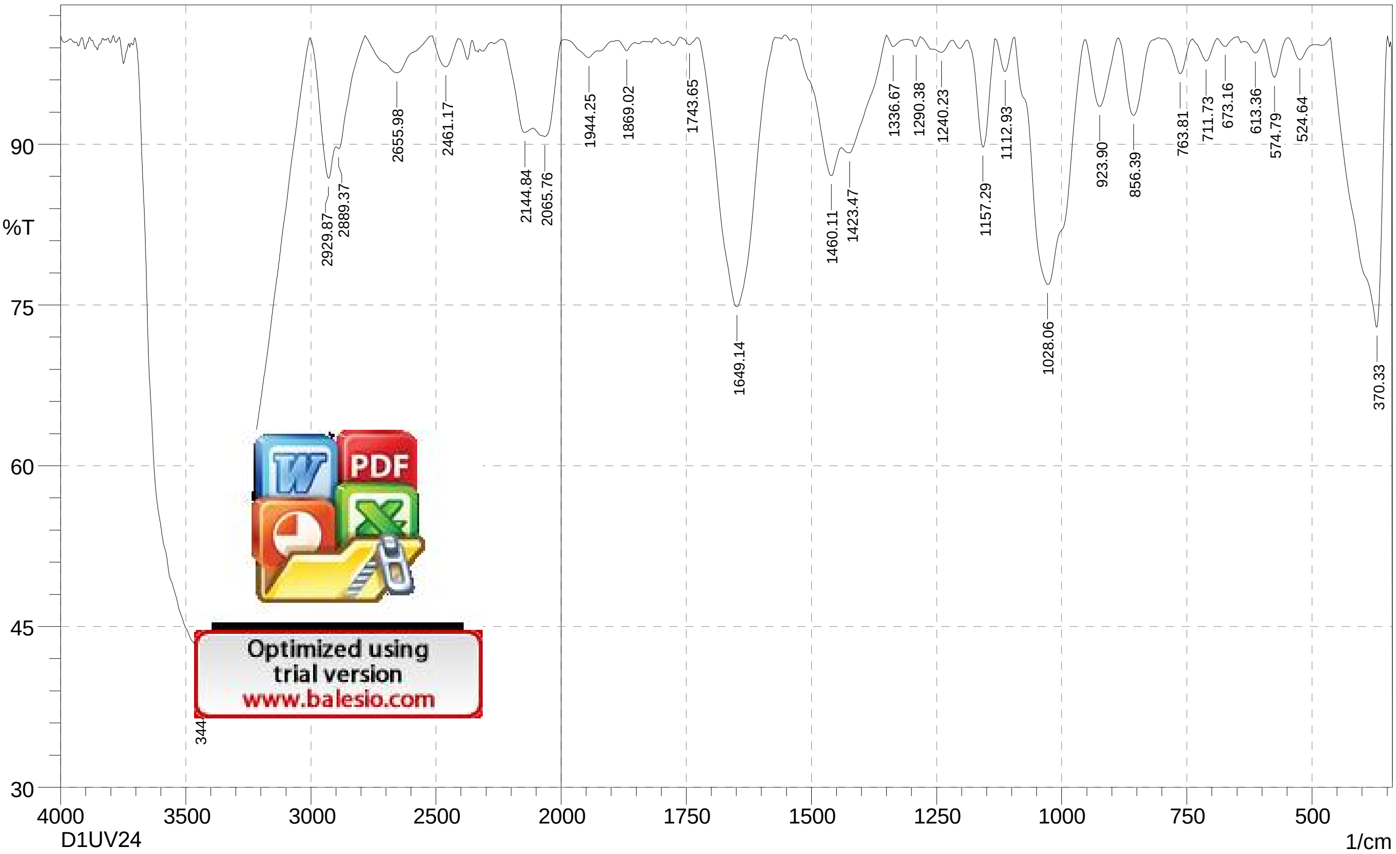


| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 370.33 | 72.949 | 26.638 | 462.92 | 351.04 | 8.513 | 8.379 |
| 2 | 524.64 | 97.901 | 1.763 | 547.78 | 495.71 | 0.268 | 0.183 |
| 3 | 574.79 | 96.259 | 3.611 | 596 | 547.78 | 0.39 | 0.365 |
| 4 | 613.36 | 98.516 | 1.194 | 634.58 | 596 | 0.155 | 0.104 |
| 5 | 673.16 | 99.132 | 0.827 | 688.59 | 648.08 | 0.073 | 0.068 |
| 6 | 711.73 | 97.778 | 2.093 | 738.74 | 688.59 | 0.258 | 0.229 |
| 7 | 763.81 | 96.58 | 3.257 | 792.74 | 738.74 | 0.392 | 0.354 |
| 8 | 856.39 | 92.691 | 7.153 | 887.26 | 817.82 | 1.153 | 1.102 |
| 9 | 923.9 | 93.518 | 6.297 | 952.84 | 889.18 | 1.028 | 0.979 |
| 10 | 1028.06 | 76.92 | 22.931 | 1093.64 | 954.76 | 8.633 | 8.538 |
| 11 | 1112.93 | 96.792 | 3.124 | 1134.14 | 1095.57 | 0.285 | 0.269 |
| 12 | 1157.29 | 89.733 | 10.042 | 1188.15 | 1134.14 | 1.232 | 1.178 |
| 13 | 1240.23 | 98.583 | 0.694 | 1259.52 | 1219.01 | 0.186 | 0.062 |
| 14 | 1290.38 | 99.155 | 0.814 | 1309.67 | 1282.66 | 0.049 | 0.04 |
| 15 | 1336.67 | 99.124 | 0.94 | 1350.17 | 1309.67 | 0.077 | 0.077 |
| 16 | 1423.47 | 89.184 | 2.314 | 1438.9 | 1350.17 | 2.673 | 0.656 |
| 17 | 1460.11 | 87.075 | 4.811 | 1529.55 | 1440.83 | 3.044 | 0.865 |
| 18 | 1649.14 | 74.844 | 25.127 | 1728.22 | 1571.99 | 9.596 | 9.577 |
| 19 | 1743.65 | 99.3 | 0.594 | 1755.22 | 1728.22 | 0.05 | 0.038 |
| 20 | 1869.02 | 98.722 | 0.843 | 1888.31 | 1853.59 | 0.118 | 0.054 |
| 21 | 1944.25 | 98.088 | 0.895 | 1994.4 | 1926.89 | 0.335 | 0.11 |
| 22 | 2065.76 | 90.727 | 4.02 | 2112.05 | 1994.4 | 3.559 | 1.274 |
| 23 | 2144.84 | 91.101 | 2.466 | 2237.43 | 2113.98 | 3.054 | 0.636 |
| 24 | 2461.17 | 97.222 | 2.747 | 2519.03 | 2409.09 | 0.756 | 0.744 |
| 25 | 2655.98 | 96.674 | 3.41 | 2781.35 | 2519.03 | 1.995 | 2.091 |
| 26 | 2889.37 | 89.597 | 1.021 | 2899.01 | 2783.28 | 2.569 | 0.139 |
| 27 | 2929.87 | 86.826 | 5.788 | 3003.17 | 2900.94 | 3.749 | 1.294 |
| 28 | 3444.87 | 42.361 | 2.641 | 3703.33 | 3433.29 | 69.541 | 19.12 |

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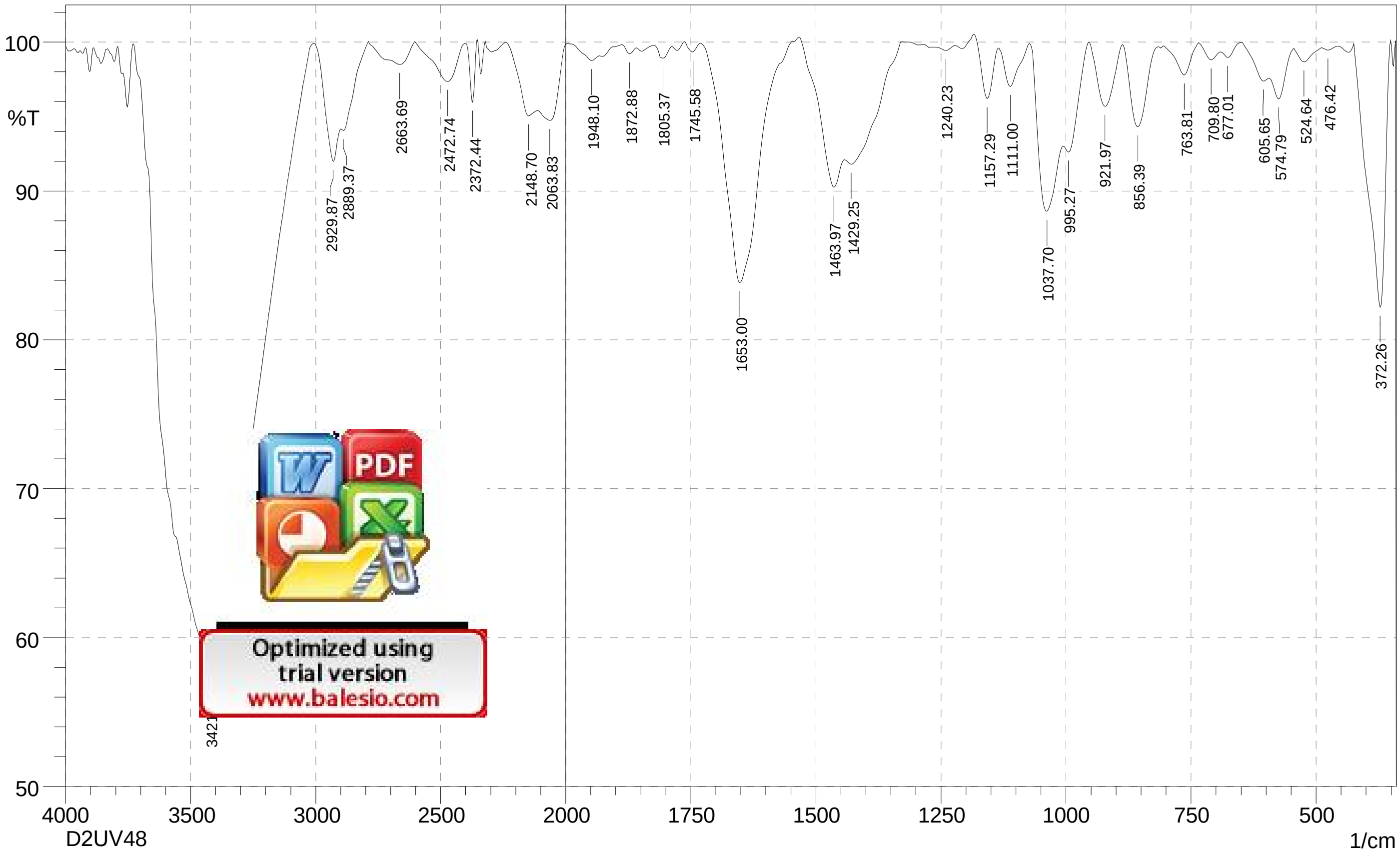
Resolution;

Apodization;






| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 372.26 | 82.185 | 17.596 | 424.34 | 352.97 | 3.168 | 3.11 |
| 2 | 476.42 | 99.472 | 0.194 | 489.92 | 457.13 | 0.061 | 0.015 |
| 3 | 524.64 | 98.672 | 0.919 | 543.93 | 489.92 | 0.206 | 0.112 |
| 4 | 574.79 | 96.183 | 2.16 | 594.08 | 543.93 | 0.532 | 0.219 |
| 5 | 605.65 | 97.382 | 0.71 | 648.08 | 594.08 | 0.368 | 0.079 |
| 6 | 677.01 | 98.977 | 0.568 | 690.52 | 648.08 | 0.107 | 0.045 |
| 7 | 709.8 | 98.809 | 0.801 | 734.88 | 690.52 | 0.148 | 0.081 |
| 8 | 763.81 | 97.795 | 2.084 | 804.32 | 734.88 | 0.334 | 0.293 |
| 9 | 856.39 | 94.314 | 5.454 | 887.26 | 815.89 | 0.933 | 0.858 |
| 10 | 921.97 | 95.679 | 4.241 | 954.76 | 887.26 | 0.7 | 0.676 |
| 11 | 995.27 | 92.617 | 1.737 | 1004.91 | 954.76 | 0.974 | 0.223 |
| 12 | 1037.7 | 88.645 | 7.604 | 1072.42 | 1006.84 | 2.351 | 1.276 |
| 13 | 1111 | 97.029 | 2.694 | 1136.07 | 1072.42 | 0.437 | 0.369 |
| 14 | 1157.29 | 96.211 | 3.799 | 1184.29 | 1136.07 | 0.382 | 0.396 |
| 15 | 1240.23 | 99.443 | 0.281 | 1263.37 | 1220.94 | 0.076 | 0.024 |
| 16 | 1429.25 | 91.788 | 1.255 | 1442.75 | 1330.88 | 2.487 | 0.519 |
| 17 | 1463.97 | 90.25 | 3.651 | 1531.48 | 1444.68 | 2.16 | 0.626 |
| 18 | 1653 | 83.857 | 16.133 | 1730.15 | 1546.91 | 5.632 | 5.634 |
| 19 | 1745.58 | 99.351 | 0.623 | 1762.94 | 1730.15 | 0.052 | 0.049 |
| 20 | 1805.37 | 98.932 | 0.813 | 1824.66 | 1788.01 | 0.108 | 0.067 |
| 21 | 1872.88 | 99.214 | 0.503 | 1888.31 | 1859.38 | 0.066 | 0.031 |
| 22 | 1948.1 | 98.77 | 0.503 | 1996.32 | 1932.67 | 0.195 | 0.052 |
| 23 | 2063.83 | 94.748 | 2.528 | 2112.05 | 1996.32 | 1.932 | 0.748 |
| 24 | 2148.7 | 95.05 | 1.62 | 2239.36 | 2113.98 | 1.664 | 0.378 |
| 25 | 2372.44 | 95.972 | 4.117 | 2401.38 | 2355.08 | 0.363 | 0.374 |
| 26 | 2472.74 | 97.361 | 2.595 | 2601.97 | 2401.38 | 1.192 | 1.163 |
| 27 | 2663.69 | 98.499 | 1.545 | 2789.07 | 2603.9 | 0.749 | 0.785 |
| 28 | 2889.37 | 94.065 | 0.611 | 2899.01 | 2789.07 | 1.45 | 0.116 |
| 29 | 2929.87 | 91.996 | 3.728 | 3007.02 | 2900.94 | 2.196 | 0.788 |
| 30 | 3421.72 | 58.688 | 41.189 | 3728.4 | 3008.95 | 89.413 | 89.045 |

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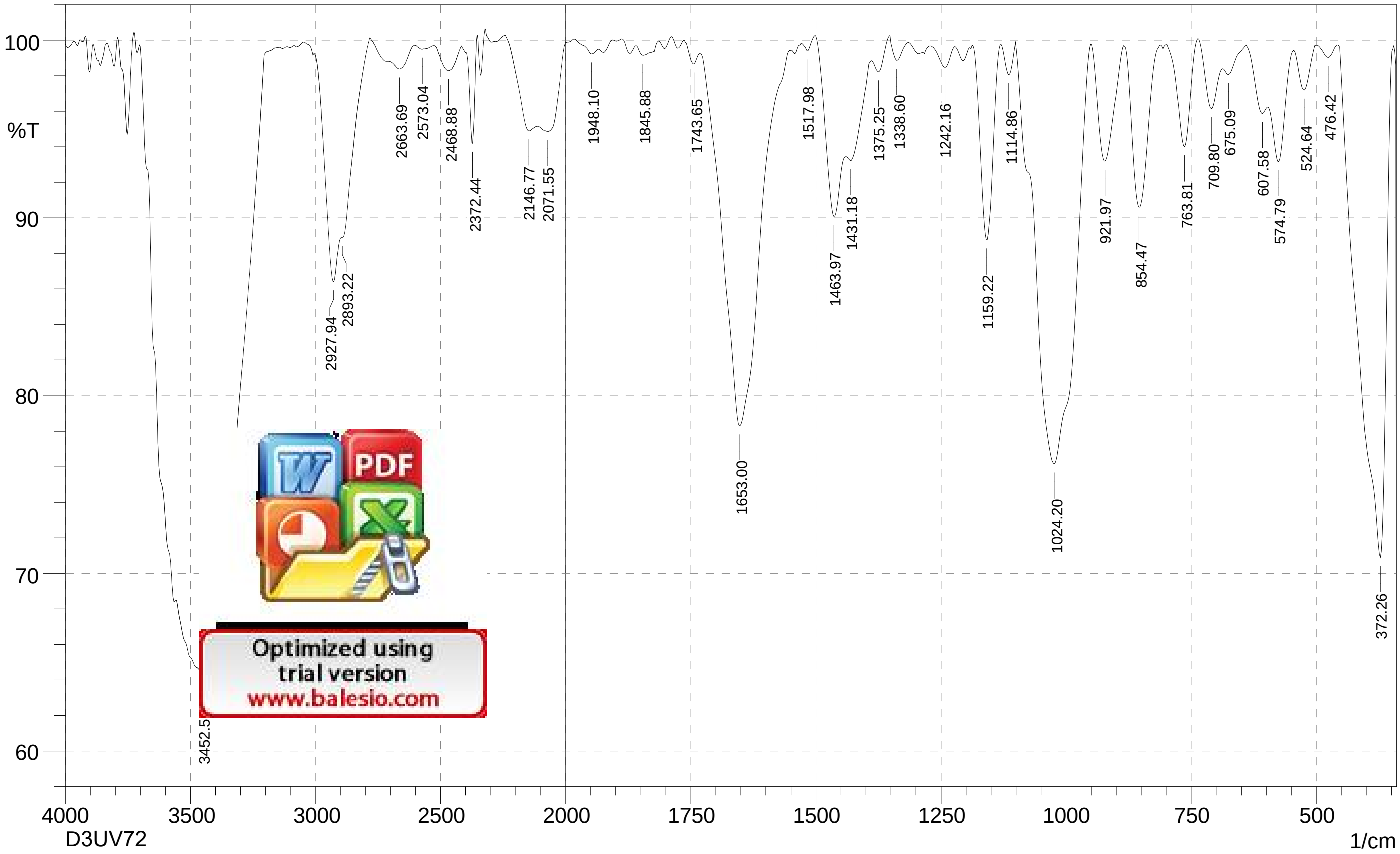





| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 372.26 | 70.897 | 28.643 | 453.27 | 347.19 | 8.609 | 8.406 |
| 2 | 476.42 | 99.031 | 0.695 | 499.56 | 457.13 | 0.114 | 0.063 |
| 3 | 524.64 | 97.188 | 2.37 | 545.85 | 499.56 | 0.319 | 0.232 |
| 4 | 574.79 | 93.166 | 4.484 | 597.93 | 545.85 | 0.978 | 0.478 |
| 5 | 607.58 | 95.88 | 1.148 | 640.37 | 597.93 | 0.486 | 0.107 |
| 6 | 675.09 | 98.068 | 0.658 | 686.66 | 640.37 | 0.242 | 0.052 |
| 7 | 709.8 | 96.143 | 3.031 | 736.81 | 686.66 | 0.491 | 0.324 |
| 8 | 763.81 | 94.006 | 5.945 | 798.53 | 736.81 | 0.747 | 0.729 |
| 9 | 854.47 | 90.59 | 9.098 | 883.4 | 812.03 | 1.493 | 1.399 |
| 10 | 921.97 | 93.197 | 6.534 | 948.98 | 885.33 | 1.081 | 1.006 |
| 11 | 1024.2 | 76.158 | 23.671 | 1101.35 | 950.91 | 9.896 | 9.784 |
| 12 | 1114.86 | 98.06 | 1.76 | 1130.29 | 1101.35 | 0.15 | 0.127 |
| 13 | 1159.22 | 88.769 | 10.95 | 1186.22 | 1132.21 | 1.397 | 1.331 |
| 14 | 1242.16 | 98.469 | 1.19 | 1271.09 | 1222.87 | 0.193 | 0.122 |
| 15 | 1338.6 | 98.872 | 1.249 | 1352.1 | 1315.45 | 0.1 | 0.111 |
| 16 | 1375.25 | 98.226 | 1.139 | 1388.75 | 1352.1 | 0.164 | 0.093 |
| 17 | 1431.18 | 93.226 | 1.076 | 1438.9 | 1390.68 | 0.987 | 0.181 |
| 18 | 1463.97 | 90.075 | 6.004 | 1500.62 | 1440.83 | 1.676 | 0.799 |
| 19 | 1517.98 | 99.405 | 0.603 | 1529.55 | 1502.55 | 0.03 | 0.034 |
| 20 | 1653 | 78.3 | 21.035 | 1730.15 | 1550.77 | 8.441 | 7.931 |
| 21 | 1743.65 | 98.666 | 0.867 | 1764.87 | 1732.08 | 0.113 | 0.062 |
| 22 | 1845.88 | 99.157 | 0.62 | 1859.38 | 1815.02 | 0.119 | 0.085 |
| 23 | 1948.1 | 99.231 | 0.419 | 1982.82 | 1934.6 | 0.086 | 0.039 |
| 24 | 2071.55 | 94.868 | 1.778 | 2110.12 | 1982.82 | 1.874 | 0.581 |
| 25 | 2146.77 | 94.896 | 1.644 | 2241.28 | 2112.05 | 1.777 | 0.453 |
| 26 | 2372.44 | 94.2 | 5.675 | 2399.45 | 2353.16 | 0.56 | 0.519 |
| 27 | 2468.88 | 98.291 | 1.392 | 2528.68 | 2416.81 | 0.542 | 0.388 |
| 28 | 2573.04 | 99.502 | 0.202 | 2603.9 | 2528.68 | 0.136 | 0.039 |
| 29 | 2663.69 | 98.383 | 0.818 | 2709.99 | 2603.9 | 0.539 | 0.196 |
| 30 | 2893.22 | 88.899 | 0.382 | 2897.08 | 2783.28 | 2.666 | 0.093 |
| 31 | 2927.94 | 86.402 | 5.451 | 3005.1 | 2897.08 | 4.194 | 1.244 |
| 32 | 3452.58 | 64.281 | 12.124 | 3556.74 | 3147.83 | 47.302 | 14.461 |

Date/Time; 6/21/2023 10:35:22 AM
No. of Scans;
Resolution;

# LAMPIRAN

## Pengujian Uji SEM (*Scanning Electron Microscope*).

**Laboratorium Microstruktur**
**Fakultas Teknik Sipil**
**UNIVERSITAS MUSLIM INDONESIA**
**MAKASSAR**

**KARAKTERISASI PATI SAGU *(Metroxylon SP)* DALAM MENGEMBANGKAN MATERIAL BIOPLASTIK**

**CHARACTERIZATION OF SAGO (Metroxylon SP) STARCH IN DEVELOPING BIOPLASTIC MATERIALS**

**BUDIAWAN SULAEMAN**
**D043181001**

**PROGRAM STUDI DOKTOR ILMU TEKNIK MESIN**
**DEPARTEMEN TEKNIK MESIN**
**FAKULTAS TEKNIK**
**UNIVERSITAS HASANUDDIN**
**GOWA**
**2023**

KEMENTERIAN RISET, TEKNOLOGI DAN PENDIDIKAN TINGGI
**UNIVERSITAS HASANUDDIN**
**FAKULTAS TEKNIK**
Jalan Poros Malino, Km.6 Gowa, 92171, Sulawesi Selatan
☎ (0411) 586015, 586262 Fax (0411) 586015.
http://eng.unhas.ac.id. E-mail:teknik@unhas.ac.id

Nomor : 13298/UN4.7.1/PT.01.04/2023 20 Juni 2023
Lamp. : -
Hal : Permohonan izin Pengujian Material

Yth : Kepala Laboratorium Microstruktur
Fakultas Teknik Sipil Universitas Muslim Indonesia
di
Tempat

Dengan hormat, berdasarkan surat Ketua Program Studi S3 Teknik Mesin Fakultas Teknik Universitas Hasanuddin Nomor: 13223/UN4.7.8/PT.01.04/2023 tanggal 20 Juni 2023 tentang permohonan pengantar izin Pengujian Material Mahasiswa Program Doktor (S3) Teknik Mesin Fakultas Teknik Universitas Hasanuddin tersebut dibawah ini:

| | |
|---|---|
| Nama | : Budiawan Sulaeman |
| Nomor Pokok | : D043181001 |
| Program Pendidikan | : Doktor (S3) |
| Program Studi | : Teknik Mesin |

bermaksud melakukan Pengujian Material dalam rangka penyelesaian disertasinya.

Sehubungan dengan hal tersebut kami mohon kebijaksanaan bapak/ibu kiranya berkenan memberi izin kepada yang bersangkutan.

Atas perkenan dan kerjasamanya disampaikan terima kasih.

a.n. Dekan
Wakil Dekan Bidang Akademik dan Kemahasiswaan,

**Dr. Amil Ahmad Ilham, S.T., M.IT**
NIP 19731010 199802 1 001

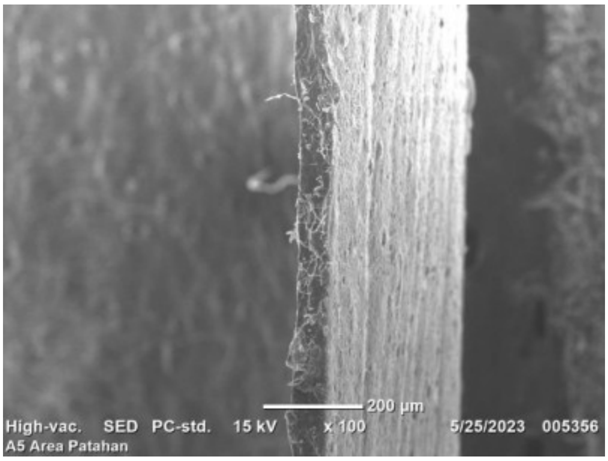
Tembusan :
1. Dekan FT-Unhas;
2. Ketua Departemen Teknik Mesin;
3. Ketua Program Studi S3 Teknik Mesin;
ang bersangkutan.

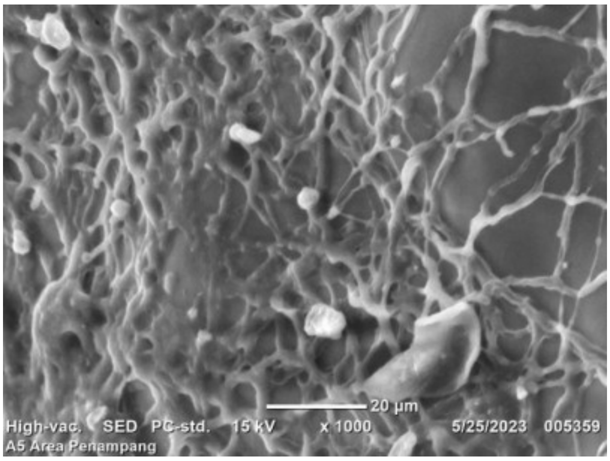
# Specimen A

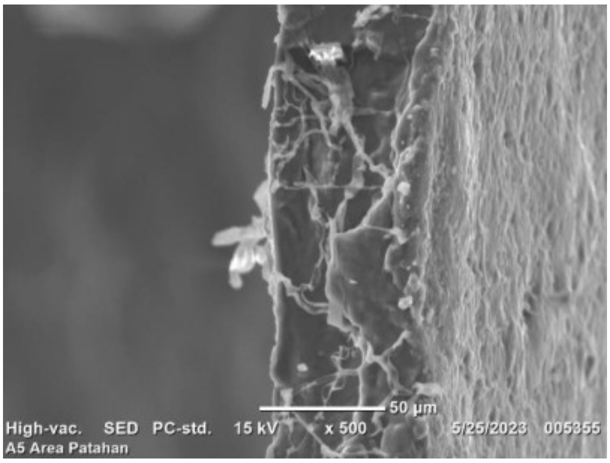
**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***

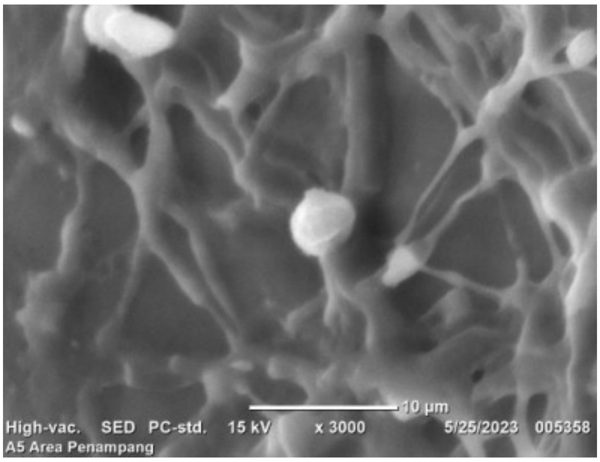
**Labortorium Mikrostrur**

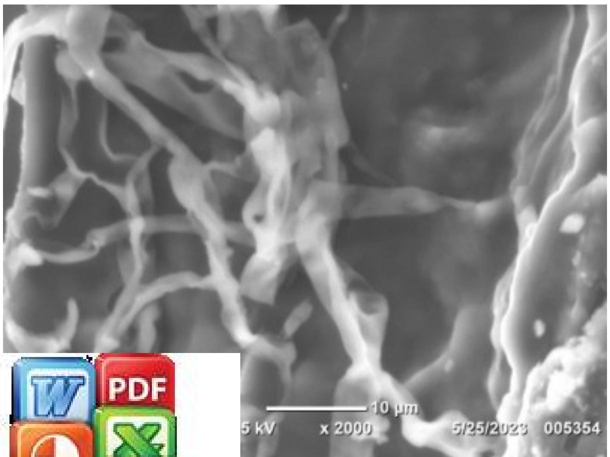
**UNIVERSITAS MUSLIM INDONESIA - MAKASSAR**

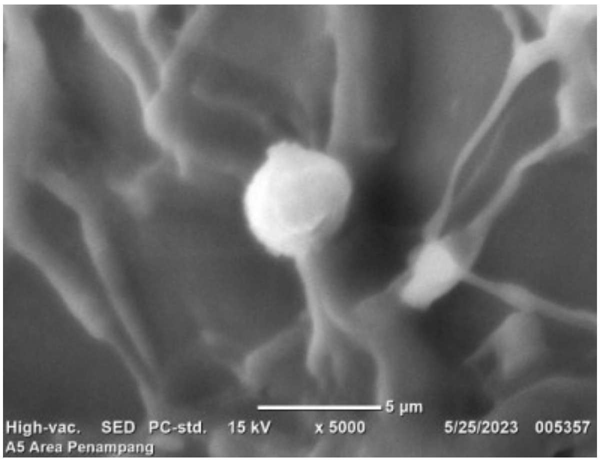


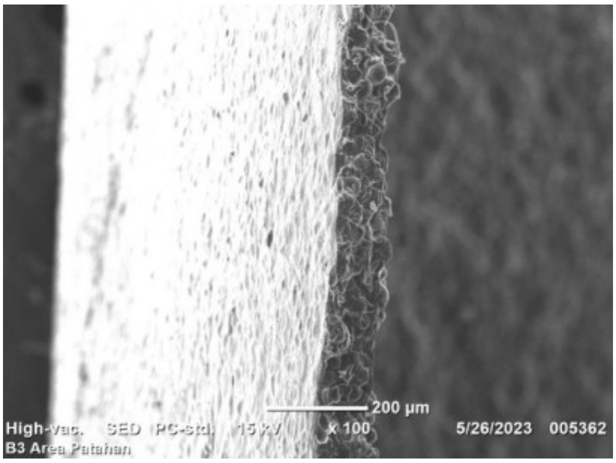



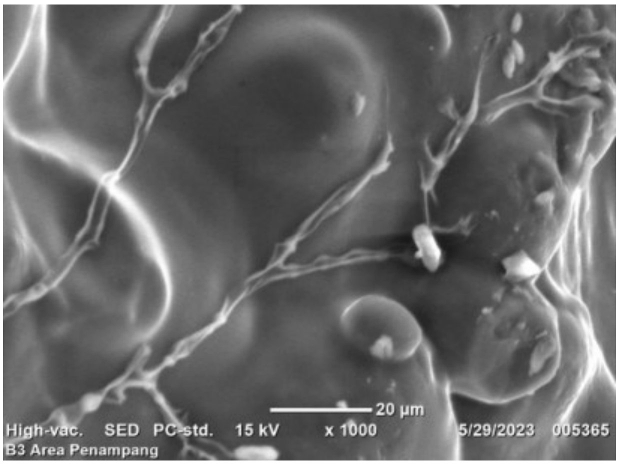
# Specimen B

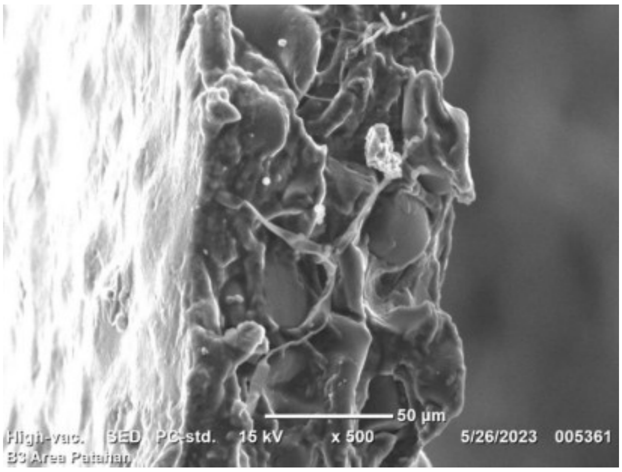
**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***

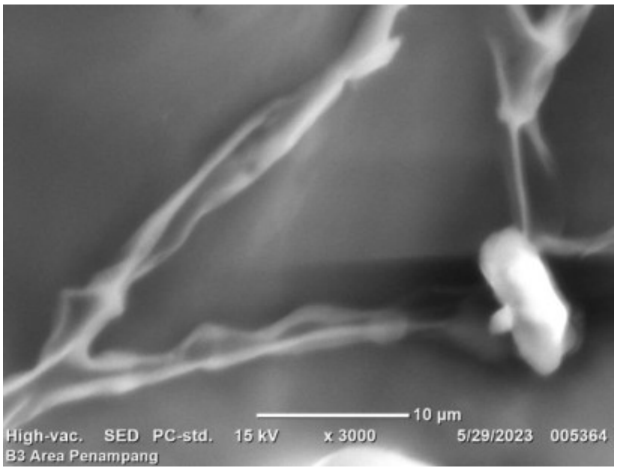
**Labortorium Mikrostrur**

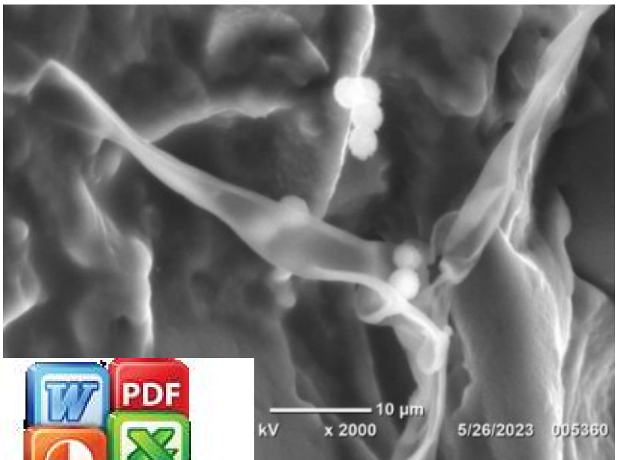
**UNIVERSITAS MUSLIM INDONESIA - MAKASSAR**

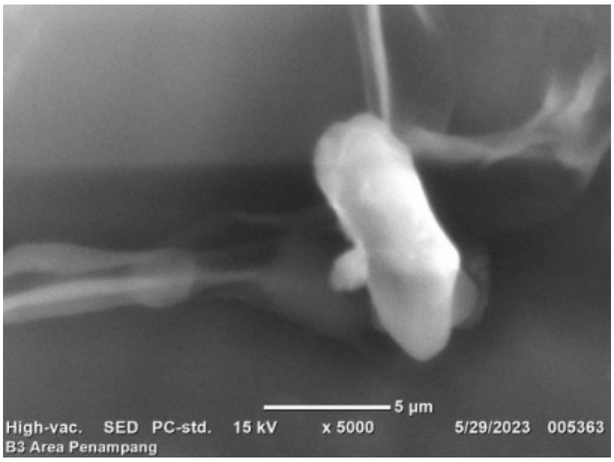


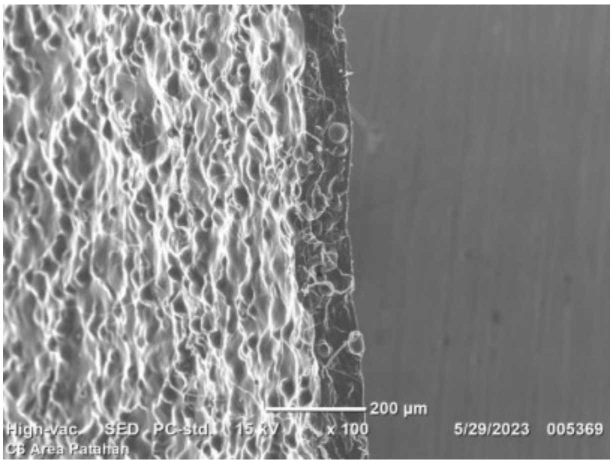



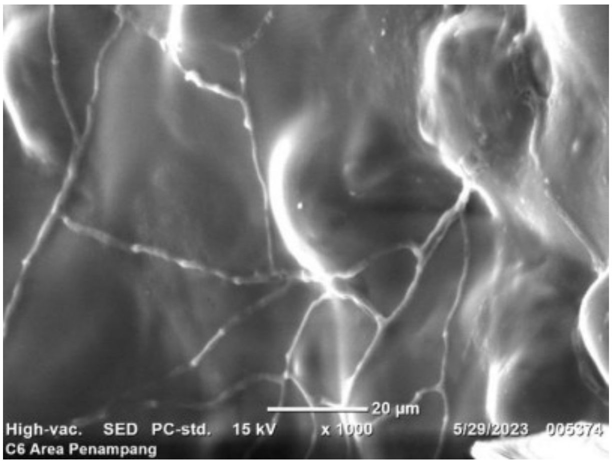



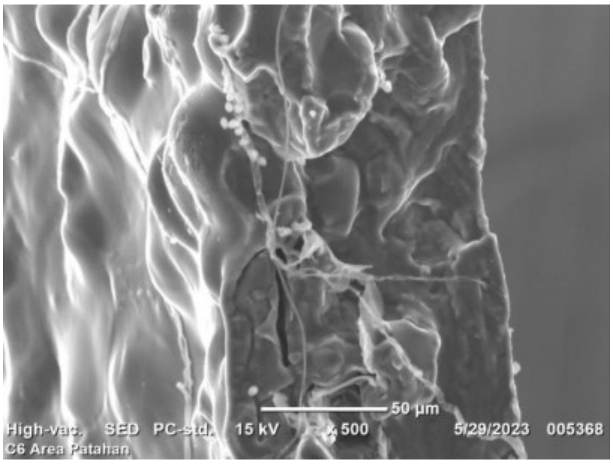



# Specimen C

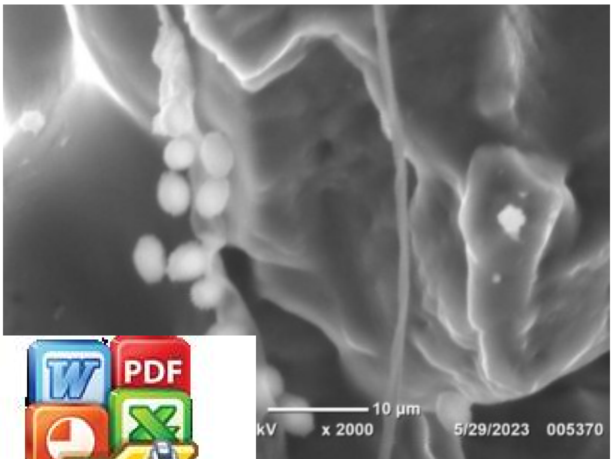
**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***
**Labortorium Mikrostrur**
**UNIVERSITAS MUSLIM INDONESIA - MAKASSAR**

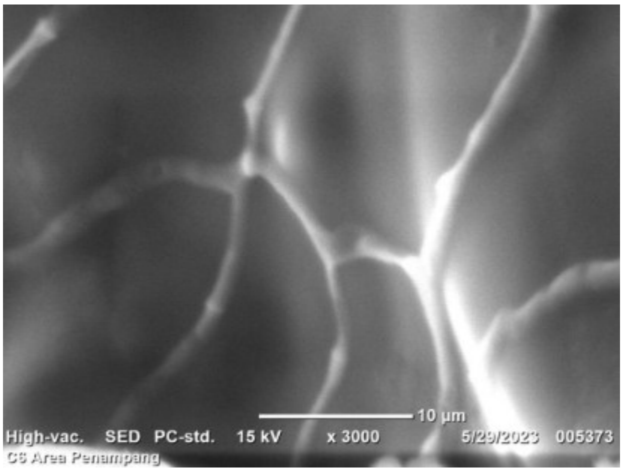






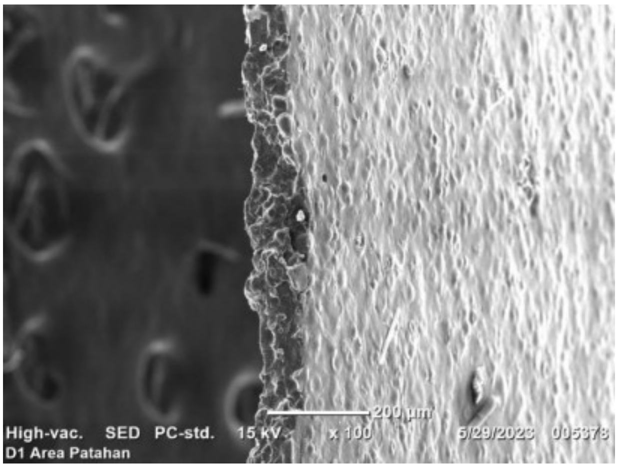



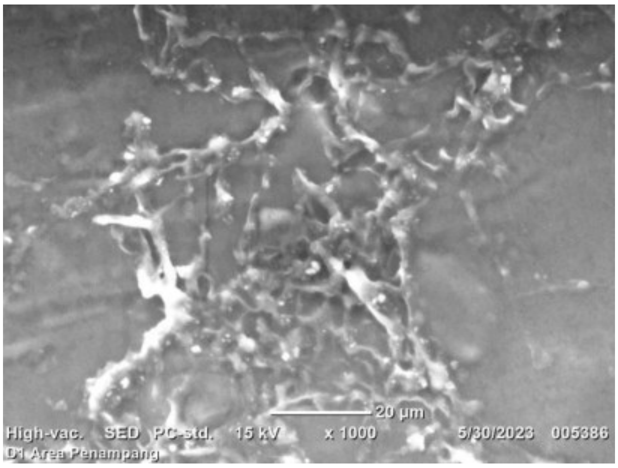
**Specimen D**

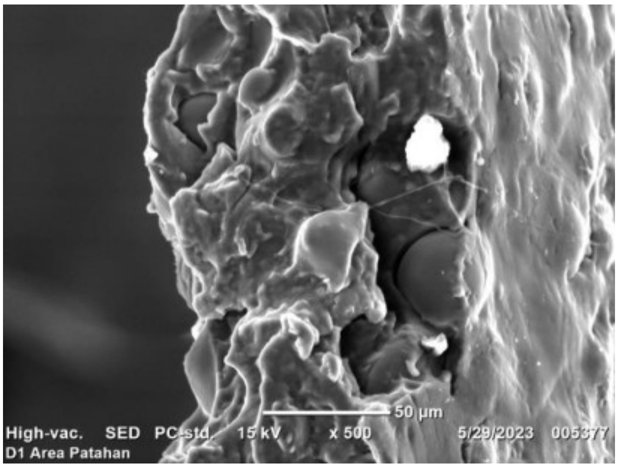
**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***

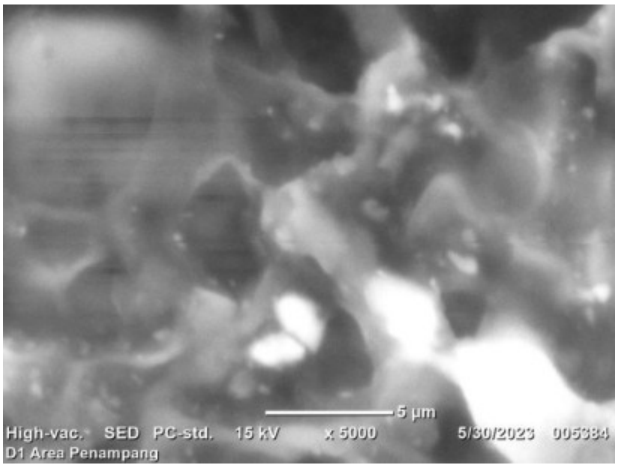
**Labortorium Mikrostrur**

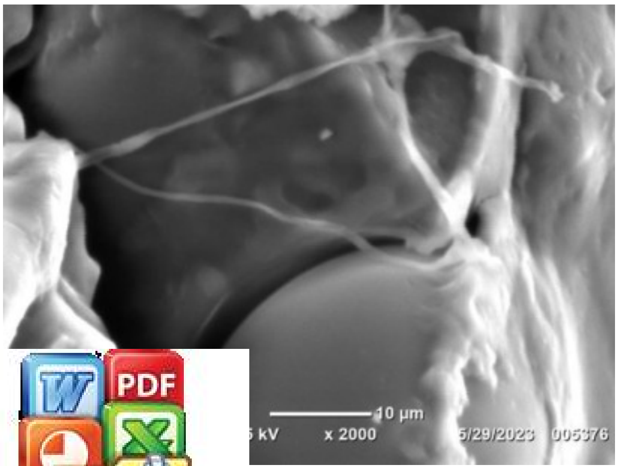
**UNIVERSITAS MUSLIM INDONESIA - MAKASSAR**

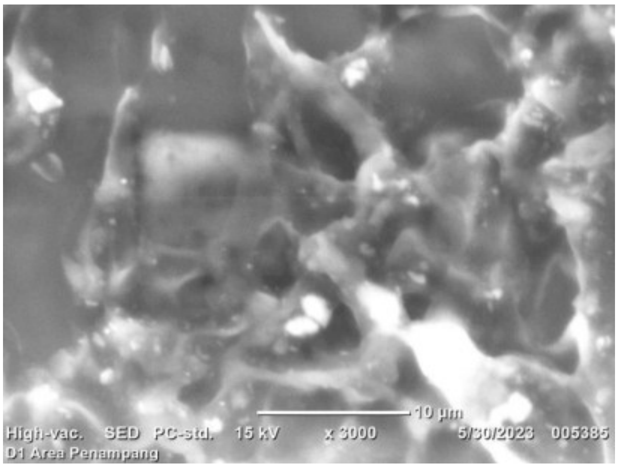


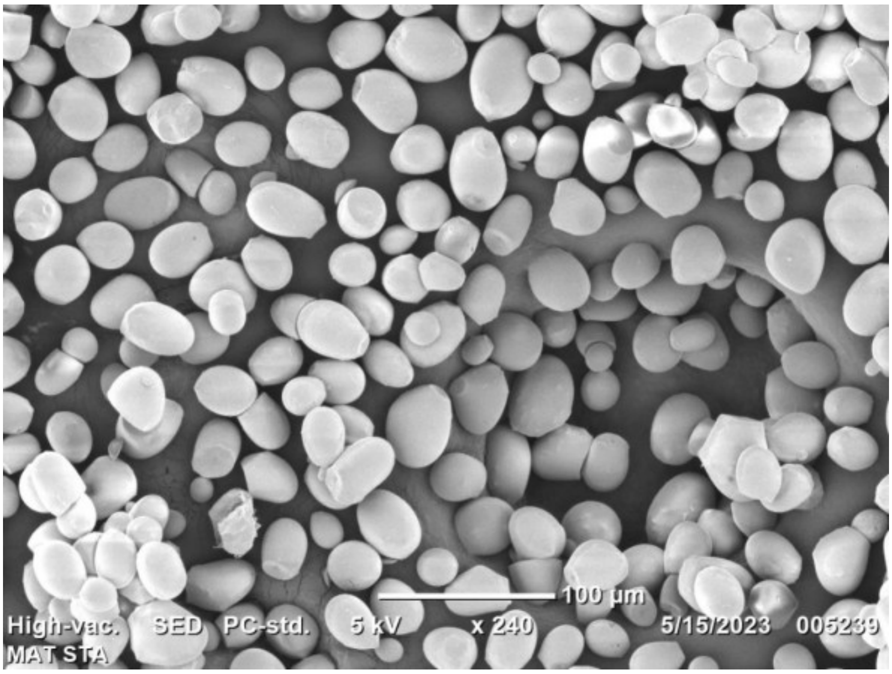



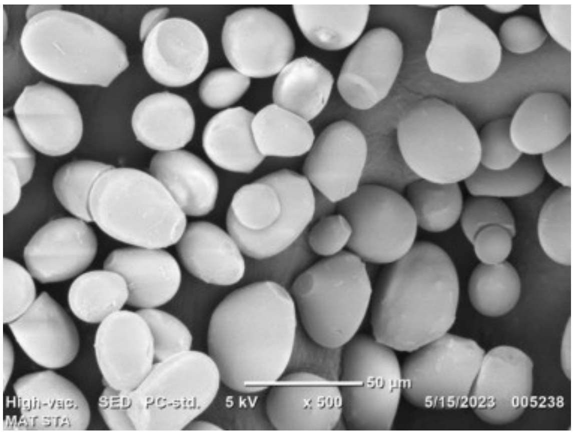
# Pati Sagu Tawaro (STA)

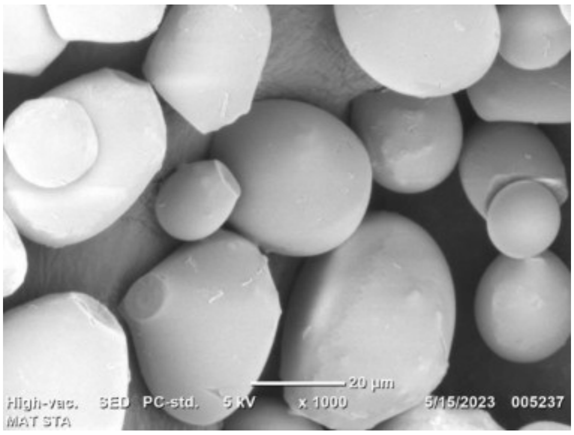
**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***

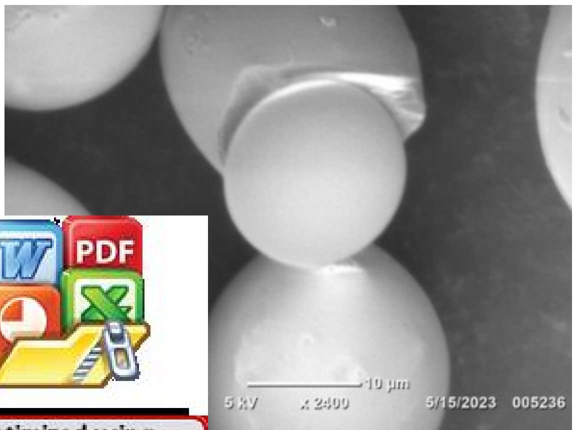
**Labortorium Mikrostrur**

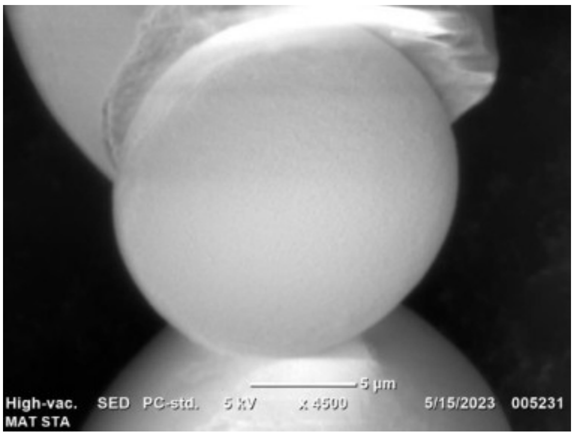
**UNIVERSITAS MUSLIM INDONESIA - MAKASSAR**



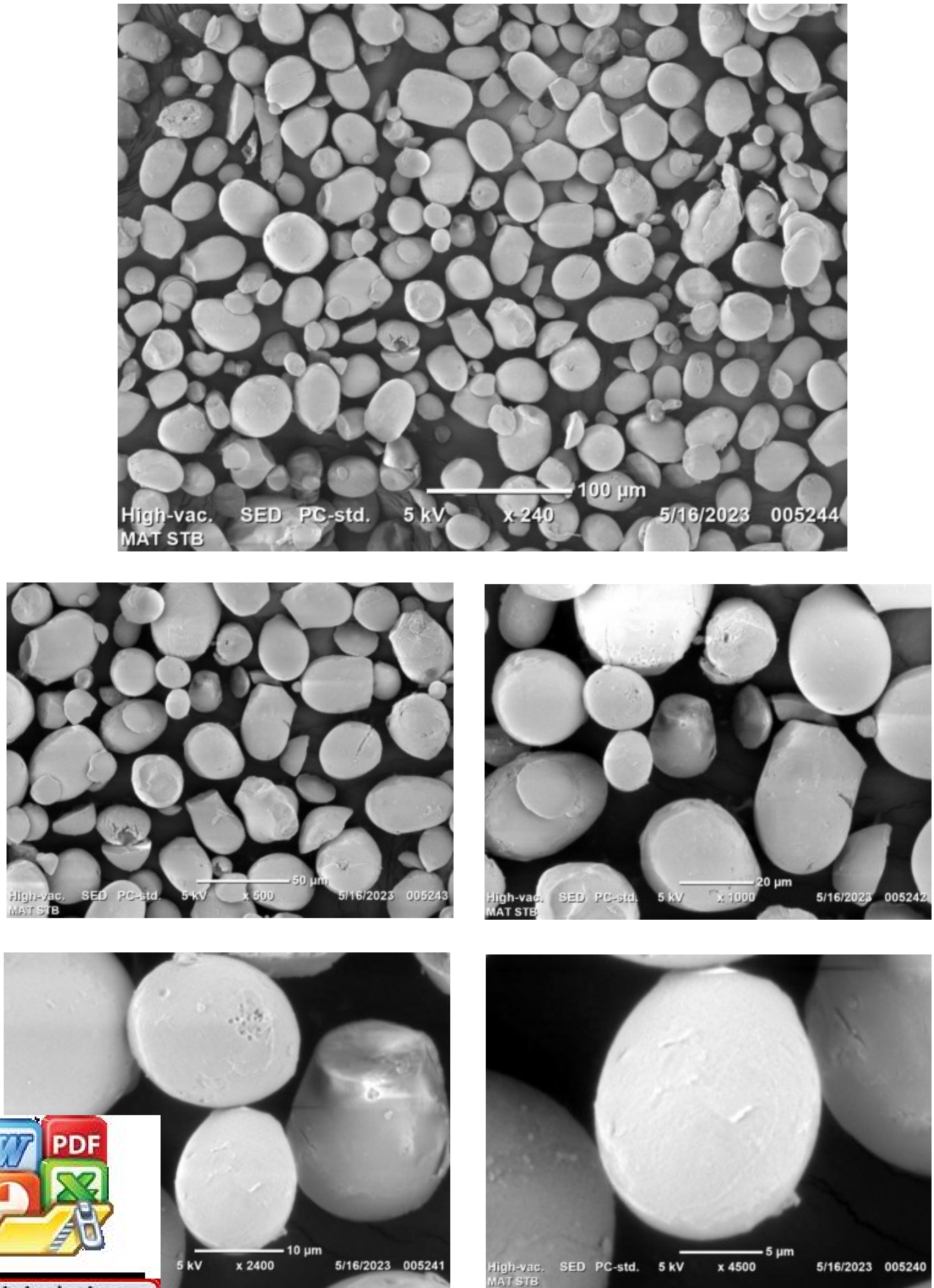



# Pati Sagu Tawaroduri (STB)

**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***

**Labortorium Mikrostrur**

**UNIVERSITAS MUSLIM INDONESIA - MAKASSAR**

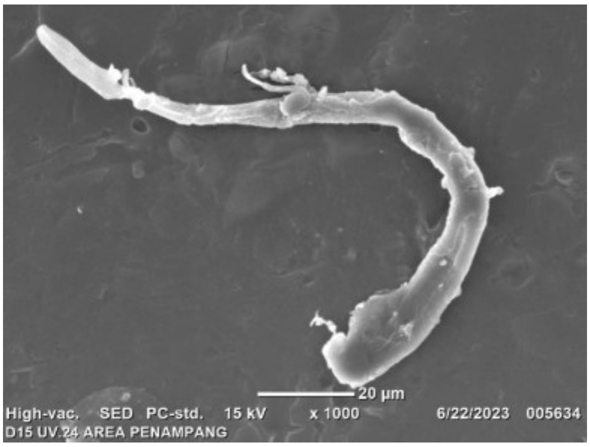


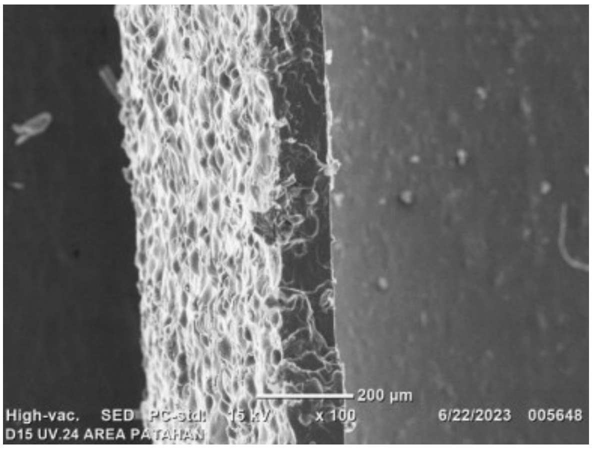
# Specimen D1UV24

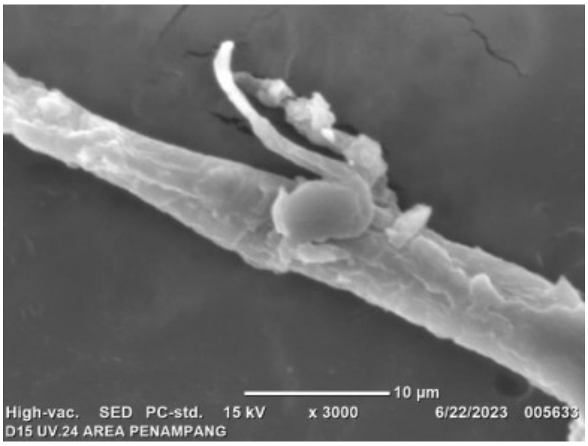
**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***

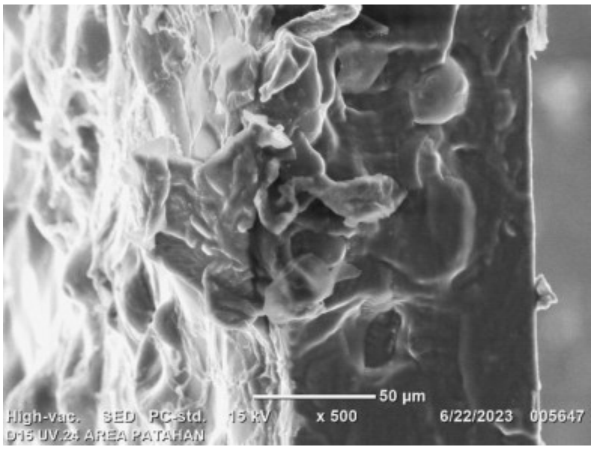
**Labortorium Mikrostrur**

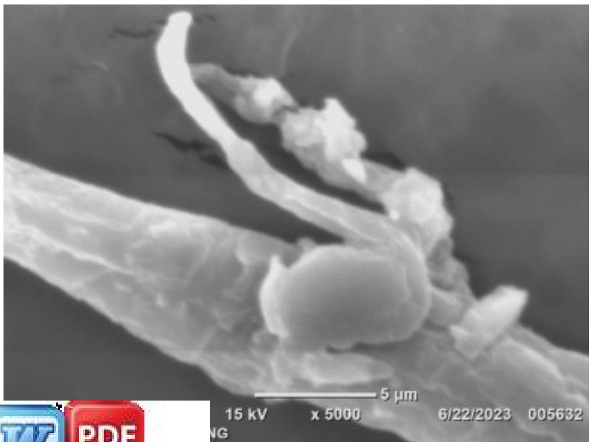
**UNIVERSITAS MUSLIM INDONESIA – MAKASSAR**

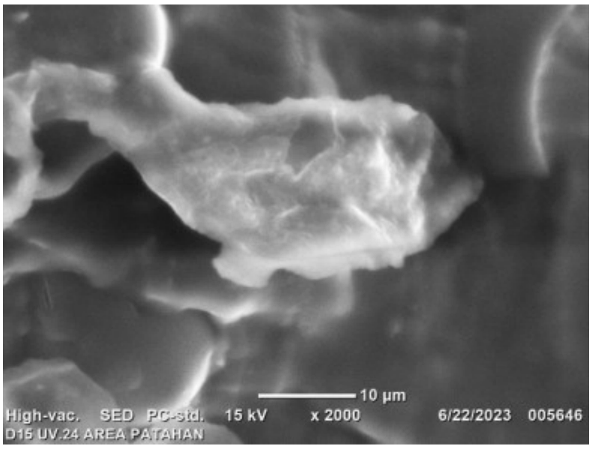


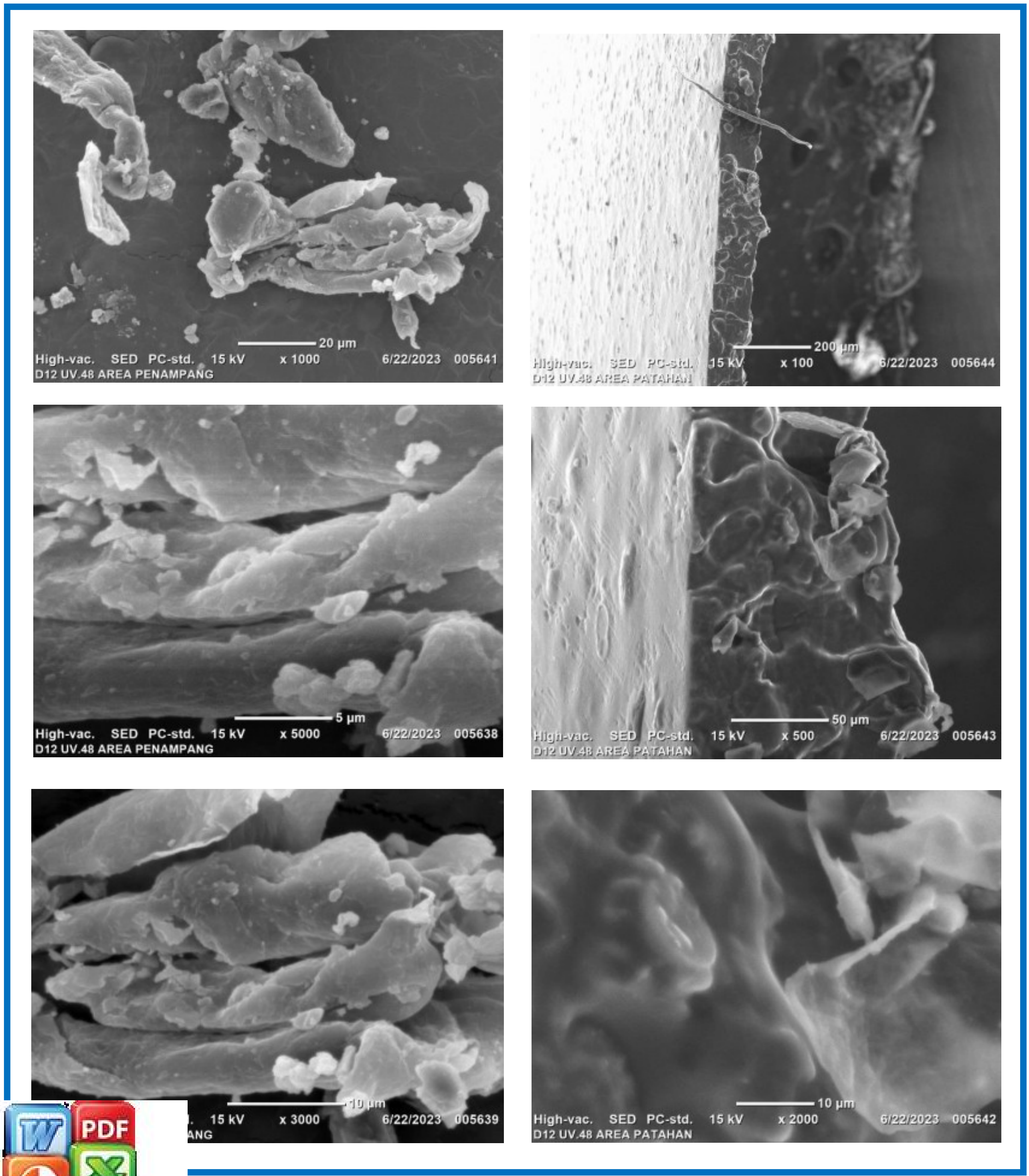



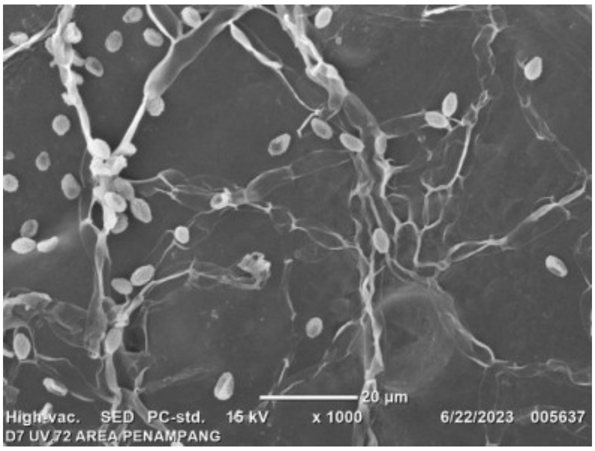
# Specimen D2UV48

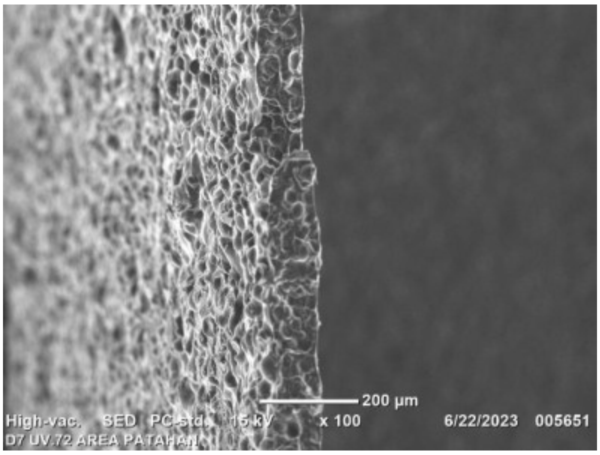
**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***
**Labortorium Mikrostrur**
**UNIVERSITAS MUSLIM INDONESIA – MAKASSAR**

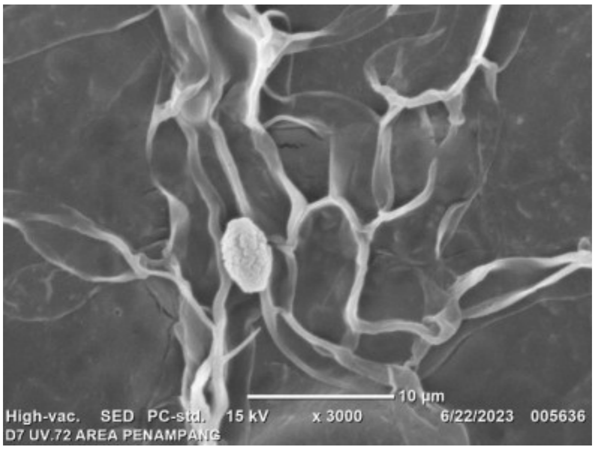


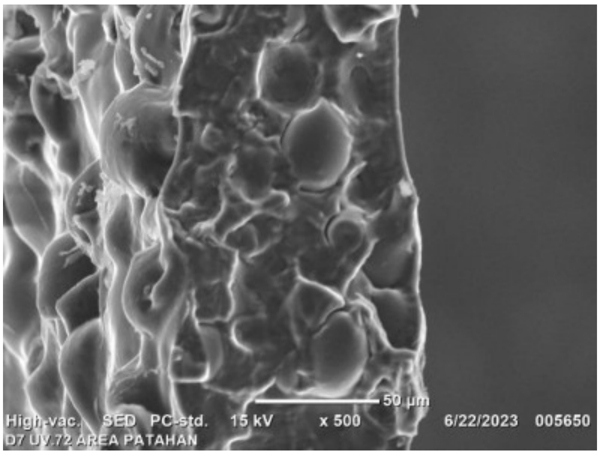
# Specimen D2UV72

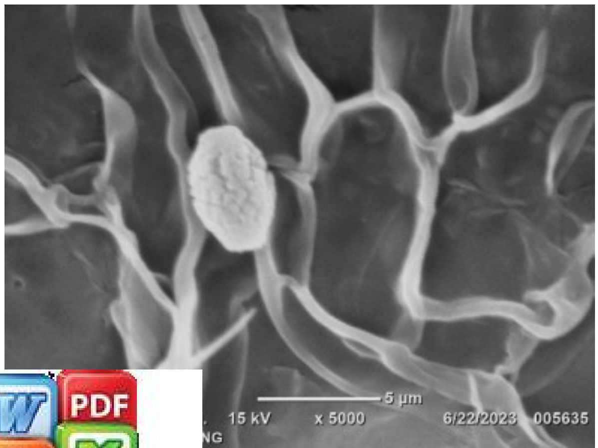
**Pengujian Pengujian Uji SEM (*Scanning Electron Microscope)***
**Labortorium Mikrostrur**
**UNIVERSITAS MUSLIM INDONESIA – MAKASSAR**

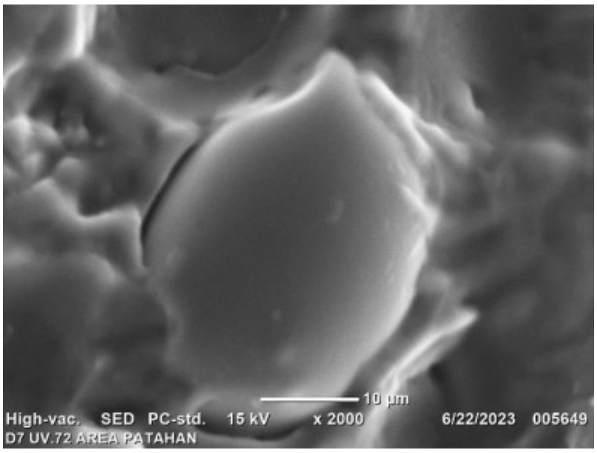


# LAMPIRAN

## PENGUJIAN MEKANIK

**Laboratorium Pengujian material dan Mesin Fluida**

**POLITEKNIK ATI MAKASSAR**

**KARAKTERISASI PATI SAGU *(Metroxylon SP)* DALAM MENGEMBANGKAN MATERIAL BIOPLASTIK**

**CHARACTERIZATION OF SAGO (Metroxylon SP) STARCH IN DEVELOPING BIOPLASTIC MATERIALS**

**BUDIAWAN SULAEMAN**
**D043181001**

**PROGRAM STUDI DOKTOR ILMU TEKNIK MESIN**
**DEPARTEMEN TEKNIK MESIN**
**FAKULTAS TEKNIK**
**UNIVERSITAS HASANUDDIN**
**GOWA**
**2023**

KEMENTERIAN RISET, TEKNOLOGI DAN PENDIDIKAN TINGGI
**UNIVERSITAS HASANUDDIN**
**FAKULTAS TEKNIK**
Jalan Poros Malino, Km.6 Gowa, 92171, Sulawesi Selatan
☎ (0411) 586015, 586262 Fax (0411) 586015.
http://eng.unhas.ac.id. E-mail:teknik@unhas.ac.id

| | | |
|---|---|---|
| Nomor | : 13298/UN4.7.1/PT.01.04/2023 | 20 Juni 2023 |
| Lamp. | : - | |
| Hal | : Permohonan izin Pengujian Material | |

Yth : Kepala Laboratorium Mechanical
Politeknik ATIM Makassar
di
Tempat

Dengan hormat, berdasarkan surat Ketua Program Studi S3 Teknik Mesin Fakultas Teknik Universitas Hasanuddin Nomor: 13223/UN4.7.8/PT.01.04/2023 tanggal 20 Juni 2023 tentang permohonan pengantar izin Pengujian Material Mahasiswa Program Doktor (S3) Teknik Mesin Fakultas Teknik Universitas Hasanuddin tersebut dibawah ini:

| | |
|---|---|
| Nama | : Budiawan Sulaeman |
| Nomor Pokok | : D043181001 |
| Program Pendidikan | : Doktor (S3) |
| Program Studi | : Teknik Mesin |

bermaksud melakukan Pengujian Material dalam rangka penyelesaian disertasinya.

Sehubungan dengan hal tersebut kami mohon kebijaksanaan bapak/ibu kiranya berkenan memberi izin kepada yang bersangkutan.

Atas perkenan dan kerjasamanya disampaikan terima kasih.

a.n. Dekan
Wakil Dekan Bidang Akademik dan Kemahasiswaan,

**Dr. Amil Ahmad Ilham, S.T., M.IT**
NIP 19731010 199802 1 001

Tembusan :
1. Dekan FT-Unhas;
2. Ketua Departemen Teknik Mesin;
3. Ketua Program Studi S3 Teknik Mesin;
ang bersangkutan.

Lampiran: Tabel pengukuran micrometer (0,001) ketebalan material bioplastik

| No | SPC | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | Ē | Tp | Tegangan (σmax) | Regangan (εmax) | KET. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A1 | 0,597 | 0,603 | 0,603 | 0,602 | 0,606 | 0,603 | 0,602 | 0,594 | 0,600 | 0,602 | 0,601 | 0,602 | 1,530 | 12,130 | A1T10 |
| 2 | A2 | 0,607 | 0,609 | 0,609 | 0,612 | 0,610 | 0,613 | 0,611 | 0,610 | 0,610 | 0,614 | 0,611 | 0,607 | 0,900 | 6,120 | A2T1 |
| 3 | A3 | 0,606 | 0,805 | 0,601 | 0,601 | 0,604 | 0,598 | 0,600 | 0,599 | 0,599 | 0,601 | 0,621 | 0,601 | 0,570 | 4,750 | A3T3 |
| 4 | A4 | 0,600 | 0,597 | 0,596 | 0,600 | 0,604 | 0,605 | 0,610 | 0,614 | 0,616 | 0,613 | 0,606 | 0,600 | 1,750 | 9,220 | A4T1 |
| 5 | A5 | 0,590 | 0,592 | 0,582 | 0,595 | 0,595 | 0,594 | 0,597 | 0,596 | 0,596 | 0,602 | 0,594 | 0,592 | 1,370 | 13,130 | A5T2 |
| 6 | A6 | 0,605 | 0,600 | 0,595 | 0,601 | 0,606 | 0,603 | 0,603 | 0,599 | 0,595 | 0,603 | 0,601 | | | | |
| 7 | A7 | 0,601 | 0,601 | 0,603 | 0,599 | 0,598 | 0,595 | 0,594 | 0,595 | 0,596 | 0,598 | 0,598 | | | | |
| 8 | A8 | 0,601 | 0,599 | 0,593 | 0,592 | 0,596 | 0,593 | 0,596 | 0,595 | 0,602 | 0,605 | 0,597 | | | | |
| 9 | A9 | 0,597 | 0,594 | 0,593 | 0,594 | 0,596 | 0,595 | 0,605 | 0,596 | 0,596 | 0,598 | 0,596 | | | | |
| 10 | A10 | 0,597 | 0,602 | 0,599 | 0,596 | 0,596 | 0,593 | 0,596 | 0,593 | 0,604 | 0,626 | 0,600 | | | | |
| 11 | A11 | 0,596 | 0,595 | 0,597 | 0,595 | 0,595 | 0,596 | 0,596 | 0,595 | 0,594 | 0,596 | 0,596 | | | | |
| 12 | A12 | 0,595 | 0,594 | 0,593 | 0,595 | 0,593 | 0,593 | 0,594 | 0,592 | 0,592 | 0,601 | 0,594 | | | | |
| 13 | A13 | 0,601 | 0,598 | 0,596 | 0,596 | 0,596 | 0,598 | 0,600 | 0,598 | 0,598 | 0,599 | 0,598 | | | | |
| 14 | B1 | 0,641 | 0,637 | 0,641 | 0,643 | 0,639 | 0,637 | 0,642 | 0,637 | 0,634 | 0,635 | 0,639 | 0,635 | 2,520 | 12,030 | B1T10 |
| 15 | B2 | 0,625 | 0,622 | 0,637 | 0,631 | 0,625 | 0,629 | 0,637 | 0,635 | 0,634 | 0,636 | 0,631 | 0,622 | 2,410 | 8,590 | B2T2 |
| 16 | B3 | 0,637 | 0,636 | 0,634 | 0,635 | 0,627 | 0,631 | 0,630 | 0,633 | 0,629 | 0,625 | 0,632 | 0,635 | 2,590 | 12,710 | B3T4 |
| 17 | B4 | 0,635 | 0,629 | 0,627 | 0,628 | 0,626 | 0,632 | 0,635 | 0,633 | 0,629 | 0,634 | 0,631 | 0,628 | 3,180 | 13,080 | B4T4 |
| 18 | B5 | 0,645 | 0,632 | 0,634 | 0,636 | 0,635 | 0,640 | 0,640 | 0,640 | 0,644 | 0,643 | 0,639 | 0,636 | 3,180 | 15,970 | B5T4 |
| [illegible] | [illegible] | [illegible] | 0,647 | 0,651 | 0,649 | 0,646 | 0,647 | 0,648 | 0,643 | 0,642 | 0,636 | 0,646 | | | | |
| [illegible] | [illegible] | [illegible] | 0,641 | 0,639 | 0,638 | 0,636 | 0,632 | 0,633 | 0,630 | 0,629 | 0,631 | 0,636 | | | | |
| [illegible] | [illegible] | [illegible] | 0,640 | 0,639 | 0,646 | 0,644 | 0,647 | 0,652 | 0,650 | 0,651 | 0,655 | 0,647 | | | | |
| [illegible] | [illegible] | [illegible] | 0,652 | 0,647 | 0,650 | 0,644 | 0,640 | 0,640 | 0,637 | 0,634 | 0,635 | 0,643 | | | | |
| [illegible] | [illegible] | [illegible] | 0,647 | 0,649 | 0,646 | 0,644 | 0,642 | 0,640 | 0,639 | 0,634 | 0,636 | 0,643 | | | | |
| [illegible] | [illegible] | [illegible] | 0,641 | 0,642 | 0,636 | 0,633 | 0,641 | 0,635 | 0,630 | 0,629 | 0,636 | 0,637 | | | | |
| 25 | B12 | 0,630 | 0,633 | 0,637 | 0,642 | 0,634 | 0,637 | 0,635 | 0,634 | 0,634 | 0,636 | 0,635 | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | B13 | 0,643 | 0,633 | 0,638 | 0,638 | 0,640 | 0,647 | 0,642 | 0,637 | 0,636 | 0,642 | 0,640 | | | | |
| 27 | B14 | 0,644 | 0,641 | 0,642 | 0,646 | 0,640 | 0,643 | 0,643 | 0,643 | 0,640 | 0,634 | 0,642 | | | | |
| 28 | B17 | 0,646 | 0,642 | 0,667 | 0,642 | 0,653 | 0,643 | 0,645 | 0,645 | 0,642 | 0,646 | 0,647 | | | | |
| 29 | C1 | 0,650 | 0,648 | 0,646 | 0,648 | 0,649 | 0,658 | 0,657 | 0,656 | 0,656 | 0,658 | 0,653 | | | | rusak |
| 30 | C2 | 0,630 | 0,630 | 0,630 | 0,628 | 0,628 | 0,628 | 0,617 | 0,621 | 0,624 | 0,627 | 0,626 | 0,627 | 0,770 | 5,850 | C2T9 |
| 31 | C3 | 0,628 | 0,623 | 0,624 | 0,621 | 0,621 | 0,626 | 0,630 | 0,630 | 0,630 | 0,633 | 0,627 | 0,624 | 1,740 | 9,250 | C3T3 |
| 32 | C4 | 0,624 | 0,620 | 0,620 | 0,616 | 0,618 | 0,626 | 0,621 | 0,616 | 0,613 | 0,614 | 0,619 | 0,613 | 2,800 | 7,930 | C4T8 |
| 33 | C5 | 0,630 | 0,632 | 0,624 | 0,632 | 0,632 | 0,634 | 0,625 | 0,623 | 0,622 | 0,632 | 0,629 | 0,630 | 2,580 | 12,380 | C5T1 |
| 34 | C6 | 0,643 | 0,636 | 0,629 | 0,631 | 0,640 | 0,645 | 0,643 | 0,644 | 0,644 | 0,655 | 0,641 | 0,629 | 2,710 | 13,550 | C6T3 |
| 35 | C7 | 0,661 | 0,655 | 0,653 | 0,650 | 0,648 | 0,651 | 0,645 | 0,636 | 0,643 | 0,655 | 0,650 | | | | |
| 36 | C8 | 0,646 | 0,649 | 0,644 | 0,643 | 0,640 | 0,642 | 0,637 | 0,625 | 0,639 | 0,638 | 0,640 | | | | |
| 37 | C9 | 0,649 | 0,649 | 0,649 | 0,652 | 0,651 | 0,656 | 0,653 | 0,649 | 0,649 | 0,652 | 0,651 | | | | |
| 38 | C10 | 0,648 | 0,646 | 0,650 | 0,650 | 0,653 | 0,656 | 0,657 | 0,656 | 0,654 | 0,657 | 0,653 | | | | |
| 39 | C11 | 0,654 | 0,654 | 0,647 | 0,646 | 0,646 | 0,646 | 0,645 | 0,639 | 0,640 | 0,646 | 0,646 | | | | |
| 40 | C12 | 0,654 | 0,654 | 0,654 | 0,655 | 0,654 | 0,662 | 0,661 | 0,660 | 0,659 | 0,655 | 0,657 | | | | |
| 41 | C13 | 0,647 | 0,644 | 0,645 | 0,645 | 0,646 | 0,648 | 0,641 | 0,640 | 0,636 | 0,637 | 0,643 | | | | |
| 42 | C14 | 0,644 | 0,640 | 0,640 | 0,637 | 0,655 | 0,657 | 0,655 | 0,650 | 0,645 | 0,646 | 0,647 | | | | |
| 43 | D1 | 0,633 | 0,633 | 0,636 | 0,636 | 0,632 | 0,635 | 0,635 | 0,633 | 0,633 | 0,631 | 0,634 | 0,633 | 1,500 | 2,920 | D1T1 |
| 44 | D2 | 0,632 | 0,626 | 0,626 | 0,628 | 0,629 | 0,628 | 0,632 | 0,625 | 0,626 | 0,624 | 0,628 | 0,626 | 2,020 | 5,950 | D2T3 |
| 45 | D3 | 0,625 | 0,626 | 0,625 | 0,627 | 0,626 | 0,631 | 0,636 | 0,634 | 0,634 | 0,633 | 0,630 | 0,625 | 2,350 | 10,000 | D3T1 |
| [illegible] | [illegible] | [illegible] | 0,632 | 0,634 | 0,631 | 0,633 | 0,627 | 0,637 | 0,636 | 0,634 | 0,637 | 0,634 | 0,631 | 2,150 | 5,420 | D4T4 |
| [illegible] | [illegible] | [illegible] | 0,636 | 0,636 | 0,638 | 0,638 | 0,646 | 0,645 | 0,644 | 0,645 | 0,645 | 0,641 | 0,645 | 2,500 | 12,660 | D5T6 |
| [illegible] | [illegible] | [illegible] | 0,639 | 0,640 | 0,636 | 0,638 | 0,640 | 0,637 | 0,634 | 0,631 | 0,634 | 0,636 | | | | |
| [illegible] | [illegible] | [illegible] | 0,639 | 0,639 | 0,640 | 0,645 | 0,648 | 0,645 | 0,644 | 0,636 | 0,642 | 0,642 | | | | |
| [illegible] | [illegible] | [illegible] | 0,632 | 0,633 | 0,631 | 0,631 | 0,636 | 0,635 | 0,630 | 0,629 | 0,627 | 0,631 | | | | |
| [illegible] | [illegible] | [illegible] | 0,632 | 0,630 | 0,628 | 0,628 | 0,636 | 0,632 | 0,632 | 0,632 | 0,636 | 0,632 | | | | |
| 52 | D10 | 0,629 | 0,631 | 0,634 | 0,633 | 0,636 | 0,645 | 0,633 | 0,634 | 0,633 | 0,631 | 0,634 | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | D11 | 0,634 | 0,634 | 0,635 | 0,637 | 0,641 | 0,640 | 0,636 | 0,633 | 0,632 | 0,635 | 0,636 | | | |
| 54 | D12 | 0,644 | 0,644 | 0,644 | 0,644 | 0,643 | 0,646 | 0,644 | 0,642 | 0,639 | 0,640 | 0,643 | | | |
| 55 | D13 | 0,633 | 0,636 | 0,640 | 0,636 | 0,638 | 0,642 | 0,645 | 0,638 | 0,640 | 0,640 | 0,639 | | | |

Keternagan :
Nilai terbesar/Maksimal 0,667 (B17T3), nilai tengah 0,629 (B2T6, B3T2, B3T9, B4T9, B11T9, C6T3, D2T5, D3T5, D8T1, D10T1) dan nilai terkecil/minimal 0,582 (A5T3).

**Perlakuan UV**

| No | Specimen | | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | Ē | Load (N) | Strain (mm) | KET. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | D1 | Specimen D (0.0%) 5 Jam | 0,633 | 0,633 | 0,636 | 0,636 | 0,632 | 0,635 | 0,635 | 0,633 | 0,633 | 0,631 | 0,634 | 1,530 | 12,165 | D1T1 |
| 2 | D2 | | 0,632 | 0,626 | 0,626 | 0,628 | 0,629 | 0,628 | 0,632 | 0,625 | 0,626 | 0,624 | 0,628 | 0,921 | 6,186 | D2T3 |
| 3 | D3 | | 0,625 | 0,626 | 0,625 | 0,627 | 0,626 | 0,631 | 0,636 | 0,634 | 0,634 | 0,633 | 0,630 | 0,570 | 5,912 | Gagal |
| 4 | D4 | | 0,634 | 0,632 | 0,634 | 0,631 | 0,633 | 0,627 | 0,637 | 0,636 | 0,634 | 0,637 | 0,634 | 1,740 | 9,696 | D4T4 |
| 5 | D5 | | 0,634 | 0,636 | 0,636 | 0,638 | 0,638 | 0,646 | 0,645 | 0,644 | 0,645 | 0,645 | 0,641 | 1,370 | 13,403 | D5T7 |
| 6 | D17 | UV 24 JAM | 0,644 | 0,641 | 0,642 | 0,646 | 0,640 | 0,643 | 0,643 | 0,643 | 0,640 | 0,634 | 0,642 | 4,194 | 10,893 | D17 T7 |
| 7 | D18 | | 0,661 | 0,655 | 0,653 | 0,650 | 0,648 | 0,651 | 0,645 | 0,636 | 0,643 | 0,655 | 0,650 | 4,217 | 9,280 | D18T3 |
| 8 | D19 | | 0,646 | 0,649 | 0,644 | 0,643 | 0,640 | 0,642 | 0,637 | 0,625 | 0,639 | 0,638 | 0,640 | 6,481 | 16,871 | D19T9 |
| 9 | D25 | UV 48 JAM | 0,655 | 0,652 | 0,647 | 0,650 | 0,644 | 0,640 | 0,640 | 0,637 | 0,634 | 0,635 | 0,643 | 5,412 | 11,309 | D25T9 |
| 10 | D26 | | 0,655 | 0,647 | 0,649 | 0,646 | 0,644 | 0,642 | 0,640 | 0,639 | 0,634 | 0,636 | 0,643 | 7,933 | 14,124 | D26T1 |
| | | | 0,645 | 0,641 | 0,642 | 0,636 | 0,633 | 0,641 | 0,635 | 0,630 | 0,629 | 0,636 | 0,637 | 9,210 | 8,841 | D27T9 |
| | | 72 JAM | 0,647 | 0,644 | 0,645 | 0,645 | 0,646 | 0,648 | 0,641 | 0,640 | 0,636 | 0,637 | 0,643 | 5,081 | 10,560 | D21T4 |
| | | | 0,640 | 0,639 | 0,639 | 0,640 | 0,645 | 0,648 | 0,645 | 0,644 | 0,636 | 0,642 | 0,642 | 7,508 | 12,710 | D22 T2 |
| | | | 0,629 | 0,632 | 0,633 | 0,631 | 0,631 | 0,636 | 0,635 | 0,630 | 0,629 | 0,627 | 0,631 | 6,923 | 12,996 | D24T10 |

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LABORATORIUM PENGUJIAN MATERIAL DAN MESIN FLUIDA
Jl. Sunu No.220, Suangga, Kec. Tallo, Kota Makassar, Sulawesi Selatan 90211

Kementerian Perindustrian
REPUBLIK INDONESIA

POLITEKNIK ATI MAKASSAR
ATIM

# LAPORAN HASIL UJI

No. 09/Lab. Material-TMIA/BPSDMI/Poltek-ATIM/2023

**Informasi Pelanggan**

| | | |
|---|---|---|
| Nama Perusahaan/Pelanggan | : | **Budiawan Sulaeman** |
| Alamat Lengkap | : | Jalan Toa Daeng V No. 3 Makassar |
| No. Telp. /Email | : | 08124262598/ budiawan.sulaeman77@gmail.com |

**Informasi Sampel**

| | | |
|---|---|---|
| Jenis Sampel | : | Pengujian Tarik Bioplastik Sagu |
| Kondisi Saat Diterima | : | Baik dalam Kemasan |
| Tanggal diterima | : | 10 April 2023 |
| Tanggal Pengujian | : | 11 April 2023 |
| Tujuan | : | Kuat Tarik setiap sampel. |

**Informasi Hasil Pengujian**

| **No** | **Uraian** | | **Max. Force (Kuat Maks.) ($N/mm^2$)** | **Max. Disp (Regangan Maks.) (mm)** | **Keterangan** |
|---|---|---|---|---|---|
| 1 | Specimen A (34,9%) 0 Jam | A1 | 1.530 | 12.165 | 0,300 mm/min |
| 2 | | A2 | 0.921 | 6.186 | 0,500 mm/min |
| 3 | | A3 | 0.570 | 5.912 | 0,500 mm/min |
| 4 | | A4 | 1.740 | 9.696 | 0,300 mm/min |
| 5 | | A5 | 1.370 | 13.403 | 0,300 mm/min |
| 6 | Specimen B (11,32%) 2 Jam | B1 | 2.292 | 12.046 | 0,300 mm/min |
| 7 | | B2 | 1.693 | 6.044 | 0,300 mm/min |
| 8 | | B3 | 1.567 | 9.230 | 0,300 mm/min |
| 9 | | B4 | 1.600 | 6.133 | 0,300 mm/min |
| 10 | | B5 | 1.167 | 3.264 | 0,300 mm/min |
| 11 | Specimen C (7,11%) 4 Jam | C1 | | | Rusak |
| 12 | | C2 | 0.770 | 5.850 | 0,300 mm/min |
| 13 | | C3 | 2.177 | 12.718 | 0,300 mm/min |
| 14 | | C4 | 2.447 | 6.155 | 0,300 mm/min |
| 15 | | C5 | 2.474 | 12.717 | 0,300 mm/min |
| 16 | | C6 | 2.710 | 13.477 | 0,300 mm/min |
| 17 | Specimen D (0.0%) 5 Jam | D1 | 3.061 | 13.316 | 0,300 mm/min |
| 18 | | D2 | 3.187 | 16.562 | 0,300 mm/min |
| 19 | | D3 | 2.262 | 10.029 | 0,300 mm/min |
| 20 | | D4 | 2.447 | 6.166 | 0,300 mm/min |
| 21 | | D5 | 2.568 | 12.65 | 0,300 mm/min |

Makassar, 13 April 2023
Kepala Laboratorium Pengujian Material
Politeknik ATI Makassar

Enni Sulfiana, ST., MT.
NIP. 19880403 202012 2 001



n Tarik Material menggunakan Mesin
*l Testing Machine – Llyod L10 K Plus*

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POLITEKNIK ATI MAKASSAR
LABORATORIUM PENGUJIAN MATERIAL DAN MESIN FLUIDA
Jl. Sunu No.220, Suangga, Kec. Tallo, Kota Makassar, Sulawesi Selatan 90211

# LAPORAN HASIL UJI

No. 10/Lab. Material-TMIA/BPSDMI/Poltek-ATIM/2023

**Informasi Pelanggan**

Nama Perusahaan/Pelanggan : **Budiawan Sulaeman**
Alamat Lengkap : Jalan Toa Daeng V No. 3 Makassar
No. Telp. /Email : 08124262598/ budiawan.sulaeman77@gmail.com

**Informasi Sampel**

Jenis Sampel : Pengujian Tarik Bioplastik Sagu
Kondisi Saat Diterima : Baik dalam Kemasan
Tanggal diterima : 21 Juni 2023
Tanggal Pengujian : 21 Juni 2023
Tujuan : Kuat Tarik setiap sampel.

**Informasi Hasil Pengujian**

| No | Uraian | | Max. Force (Kuat Maks.) ($N/mm^2$) | Max. Disp (Regangan Maks.) (mm) | Keterangan |
|---|---|---|---|---|---|
| 1 | UV 24 Jam | D18 | 4.220 | 5.420 | 0,300 mm/min |
| 2 | | D17 | 5.090 | 4.630 | 0,300 mm/min |
| 3 | | D19 | 6.490 | 8.280 | 0,300 mm/min |
| 4 | UV 48 Jam | D25 | 12.110 | 6.320 | 0,300 mm/min |
| 5 | | D26 | 8.220 | 7.130 | 0,300 mm/min |
| 6 | | D27 | 9.230 | 4.360 | 0,300 mm/min |
| 7 | UV 72 Jam | D21 | 5.080 | 5.330 | 0,300 mm/min |
| 8 | | D22 | 5.460 | 5.640 | 0,300 mm/min |
| 9 | | D24 | 7.090 | 6.400 | 0,300 mm/min |

Makassar, 26 Juni 2023
Kepala Laboratorium Pengujian Material
Politeknik ATI Makassar

Enni Sulfiana, ST., MT.
NIP. 19880403 202012 2 001

n Tarik Material menggunakan Mesin
*l Testing Machine – Llyod L10 K Plus*

# LAMPIRAN

## PENGUJIAN CONTACT ANGLE

**Laboratorium Fisika**
**Fakultas Matematika dan Ilmu Pengetahuan Alam**
**UNIVERSITAS NEGERI MAKASSAR**

**KARAKTERISASI PATI SAGU *(Metroxylon SP)* DALAM MENGEMBANGKAN MATERIAL BIOPLASTIK**

**CHARACTERIZATION OF SAGO (Metroxylon SP) STARCH IN DEVELOPING BIOPLASTIC MATERIALS**

**BUDIAWAN SULAEMAN**
**D043181001**

**PROGRAM STUDI DOKTOR ILMU TEKNIK MESIN**
**DEPARTEMEN TEKNIK MESIN**
**FAKULTAS TEKNIK**
**UNIVERSITAS HASANUDDIN**
**GOWA**
**2023**

KEMENTERIAN RISET, TEKNOLOGI DAN PENDIDIKAN TINGGI
**UNIVERSITAS HASANUDDIN**
**FAKULTAS TEKNIK**
Jalan Poros Malino, Km.6 Gowa, 92171, Sulawesi Selatan
☎ (0411) 586015, 586262 Fax (0411) 586015.
http://eng.unhas.ac.id. E-mail:teknik@unhas.ac.id

| | | |
|---|---|---|
| Nomor | : 13298/UN4.7.1/PT.01.04/2023 | 20 Juni 2023 |
| Lamp. | : - | |
| Hal | : Permohonan izin Pengujian Material | |

Yth : Kepala Laboratorium Microstruktur Jurusan Fisika
Universitas Negeri Makassar
di
Tempat

Dengan hormat, berdasarkan surat Ketua Program Studi S3 Teknik Mesin Fakultas Teknik Universitas Hasanuddin Nomor: 13223/UN4.7.8/PT.01.04/2023 tanggal 20 Juni 2023 tentang permohonan pengantar izin Pengujian Material Mahasiswa Program Doktor (S3) Teknik Mesin Fakultas Teknik Universitas Hasanuddin tersebut dibawah ini:

| | |
|---|---|
| Nama | : Budiawan Sulaeman |
| Nomor Pokok | : D043181001 |
| Program Pendidikan | : Doktor (S3) |
| Program Studi | : Teknik Mesin |

bermaksud melakukan Pengujian Material dalam rangka penyelesaian disertasinya.

Sehubungan dengan hal tersebut kami mohon kebijaksanaan bapak/ibu kiranya berkenan memberi izin kepada yang bersangkutan.

Atas perkenan dan kerjasamanya disampaikan terima kasih.

a.n. Dekan
Wakil Dekan Bidang Akademik dan Kemahasiswaan,

**Dr. Amil Ahmad Ilham, S.T., M.IT**
NIP 19731010 199802 1 001

Tembusan :
1. Dekan FT-Unhas;
2. Ketua Departemen Teknik Mesin;
3. Ketua Program Studi S3 Teknik Mesin;
4. ang bersangkutan.

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LABORATORIUM FISIKA
Alamat : Jalan Mallengkeri Raya, Makassar
Laman: https://fisika.fmipa.unm.ac.id/

**LAPORAN HASIL PENGUJIAN**
**CONTACT ANGLE**
Nomor Pengerjaan: VI-05

Kepada Yth
**Budiawan Sulaeman**

| | |
|---|---|
| Nama Pengirim | : Budiawan Sulaeman |
| Alamat/Universitas | : Universitasn Hasanuddin |
| Tanggal Sampel Diterima | : 20 Juni 2023 |
| E-Mail | : budiawan.sulaeman77@gmail.com |
| No. Handphone | : 081242625598 |
| Nama Pengujian | : **Contact Angle** |
| Tujuan Pengujian | : Analisis Sifat Hidrofobik Spesimen Bioplastik |

Dengan hormat, kami sampaikan bahwa hasil pengukuran contact angle untuk 4 sampel anda dengan kode sampel : D0, DU1V24, D2UV48, dan D3UV72 telah selesai pada tanggal 23 Juni 2023. Hasil pengujian dapat dilihat pada lampiran laporan ini

Atas perhatian dan kerja sama yang baik, kami ucapkan terima kasih.

Makassar, 23 Juni 2023
Kepala Laboratorium Fisika UNM

**Drs. Subaer, M.Phil., Ph.D.**
**NIP. 19640414 1989 03 1 004**

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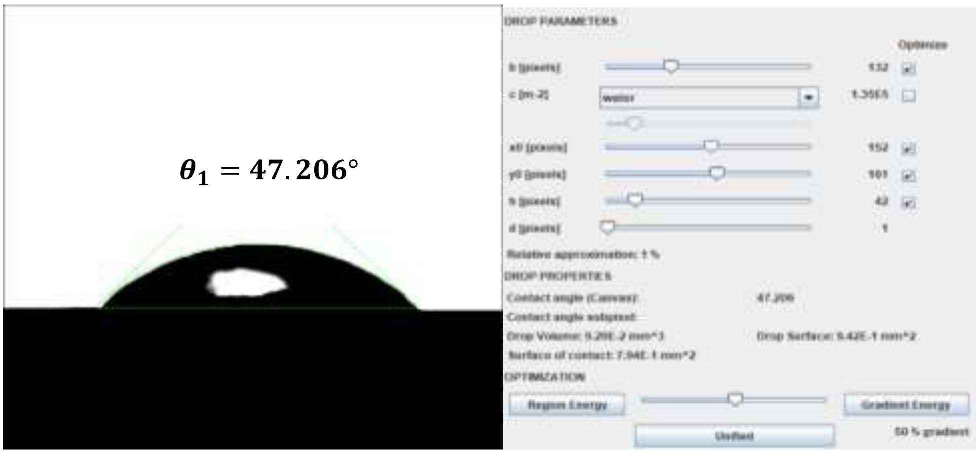
**Lampiran:**

**Do (Tanpa Perlakuan UV)**

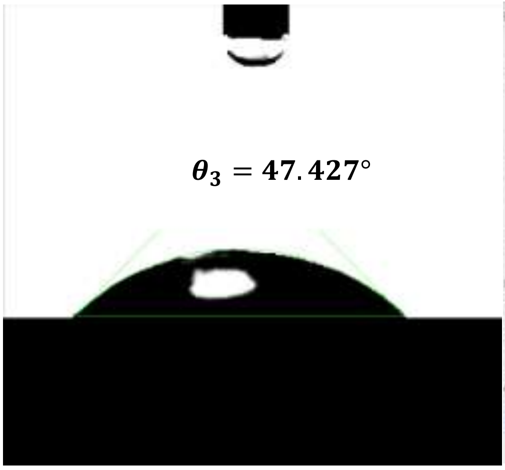
**Specimen D23**

**DATA 1**




**DATA 2**


**DATA 3**

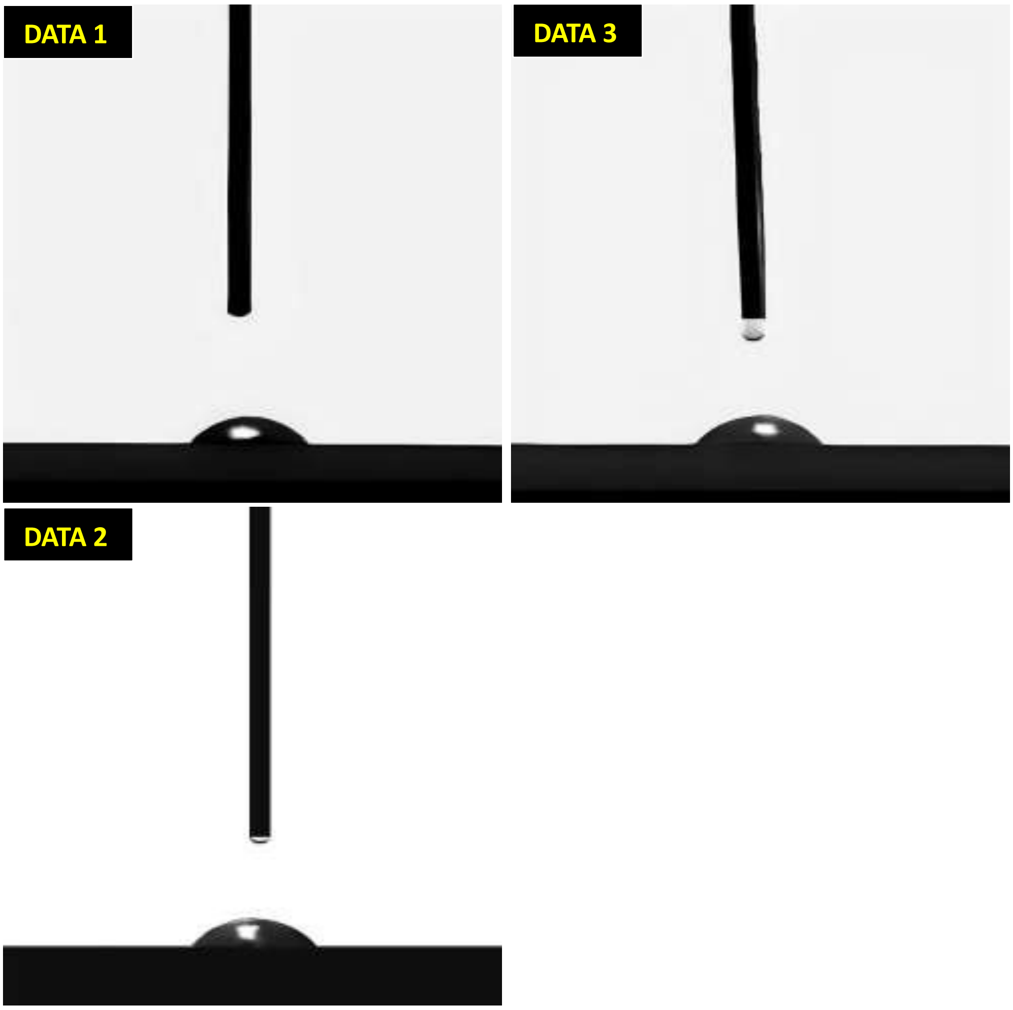




**CONTACT ANGLE**

| θ | σ |
|---|---|
| 47.206 | 0.219 |
| 47.641 | 0.216 |
| 47.427 | 0.002 |
| **θavg** | **σmax** |
| 47.425 | 0.219 |

$\theta = |47.425 \pm 0.219|°$

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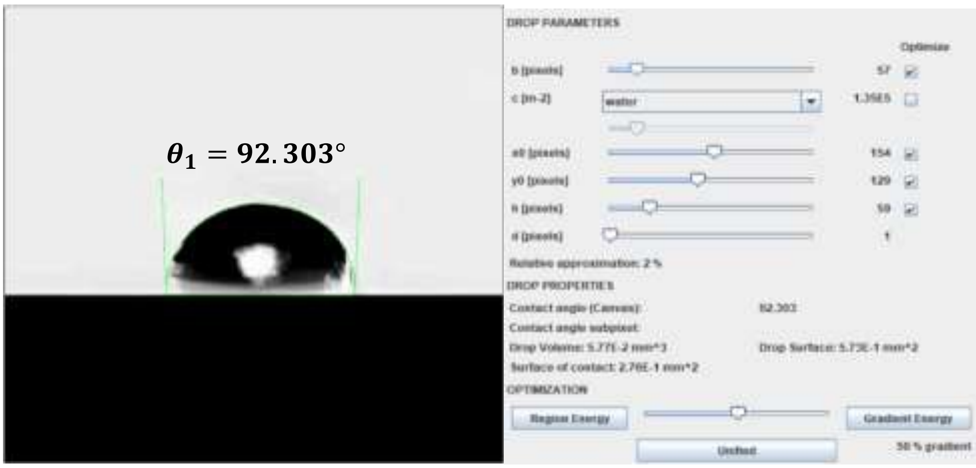
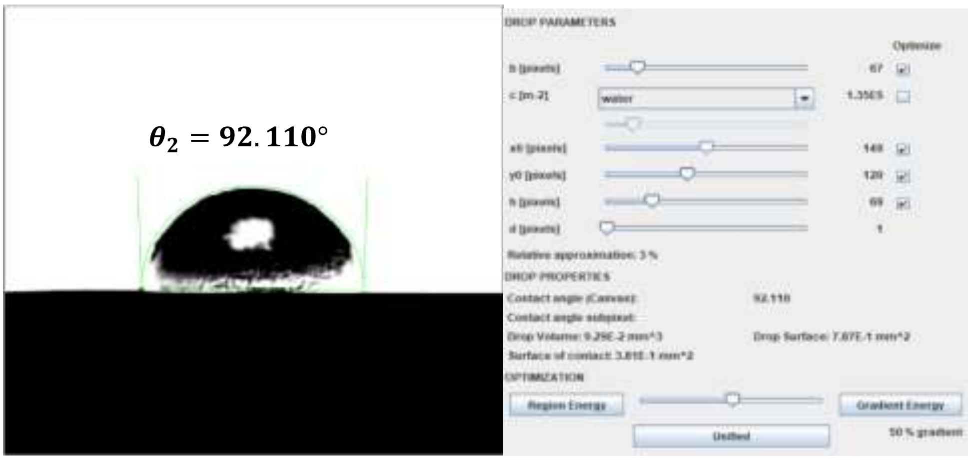
## D1UV24 (Perlakuan UV 24 Jam)
## Specimen D20

**DATA 1**




**DATA 2**




**DATA 3**

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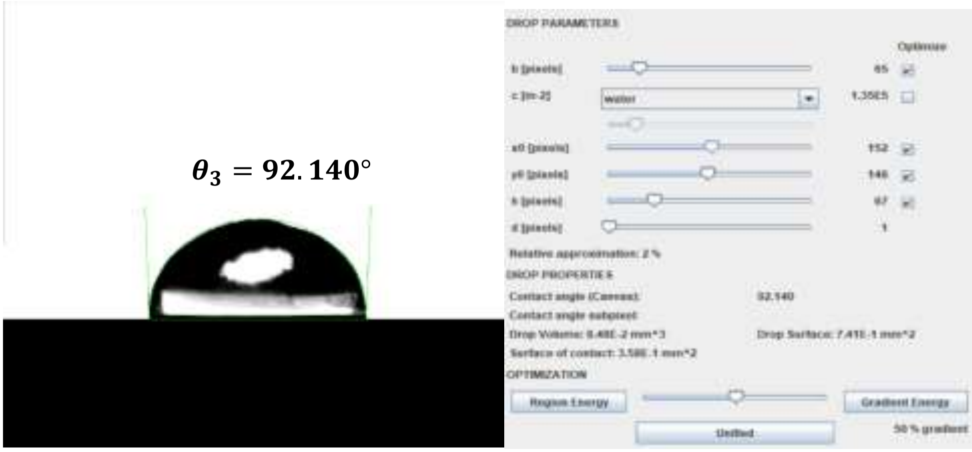


**CONTACT ANGLE**

| θ | σ |
|---|---|
| 92.303 | 0.119 |
| 92.110 | 0.074 |
| 92.140 | 0.044 |
| **θavg** | **σmax** |
| 92.184 | 0.119 |

n Fisika U


$\theta = |92.184 \pm 0.119|°$

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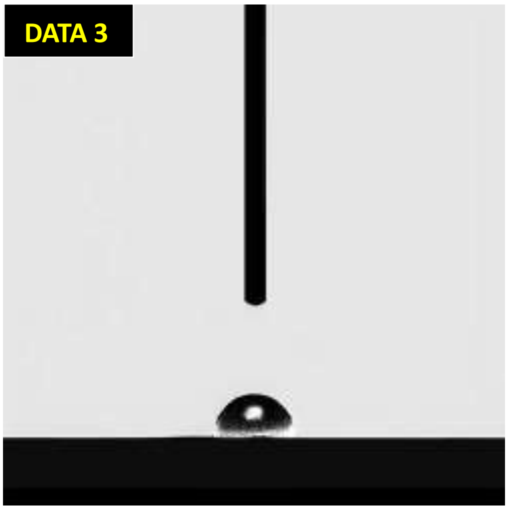



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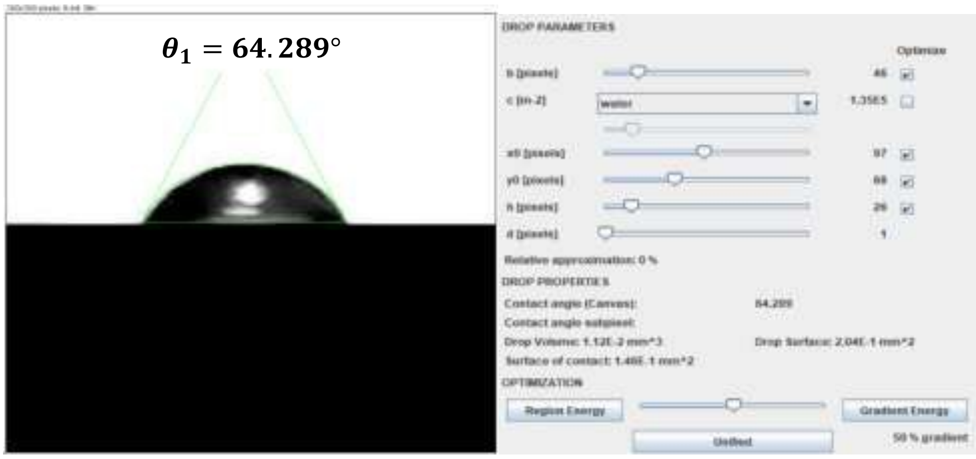
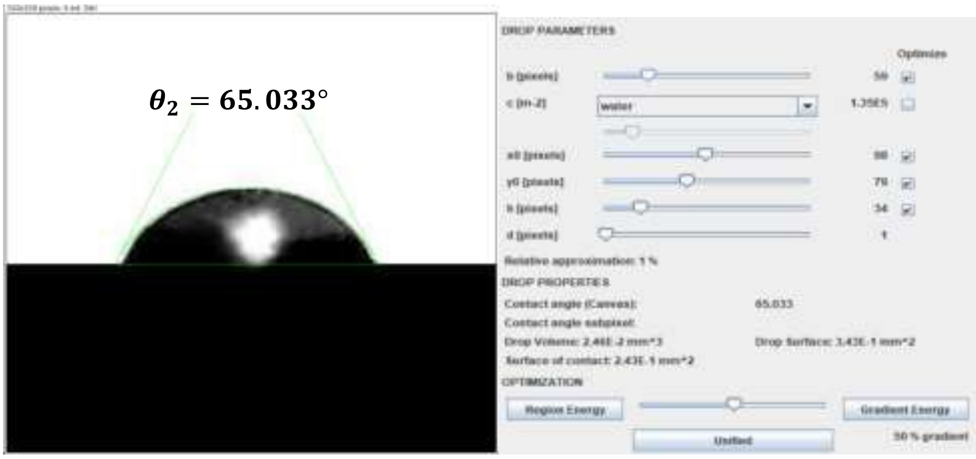
**D2UV48 (Perlakuan UV 48 Jam)**
**Specimen D14**

## DATA 1




## DATA 2




## DATA 3

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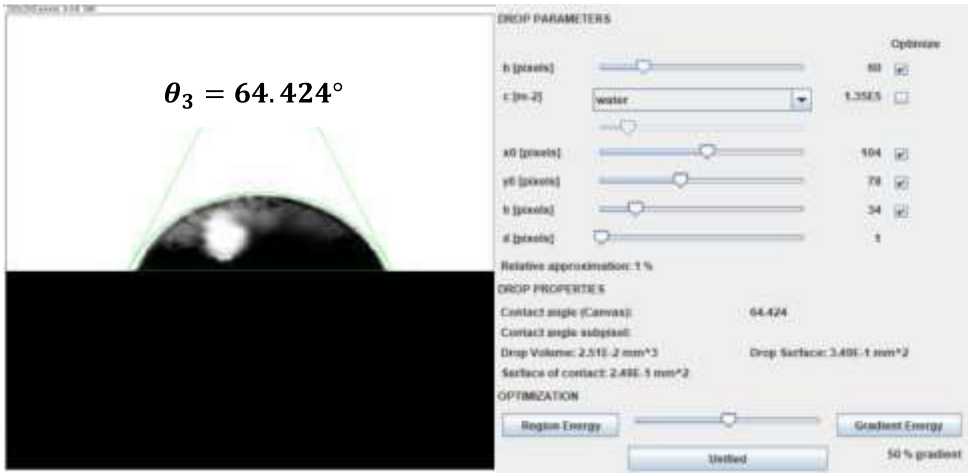
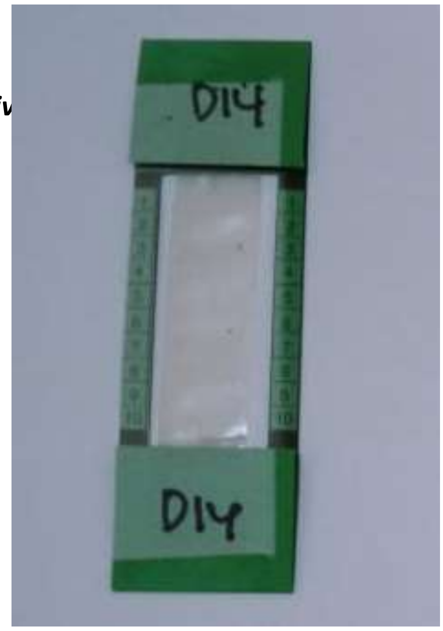



**CONTACT ANGLE**

| θ | σ |
|---|---|
| 64.289 | 0.293 |
| 65.033 | 0.451 |
| 64.424 | 0.158 |
| **θavg** | **σmax** |
| 64.582 | 0.451 |

$\boldsymbol{\theta = |64.582 \pm 0.451|°}$



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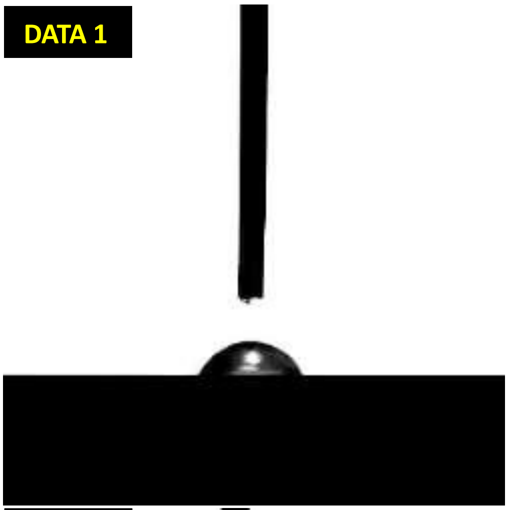
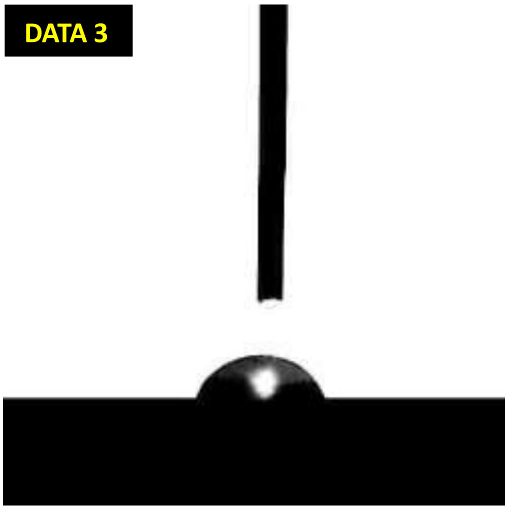
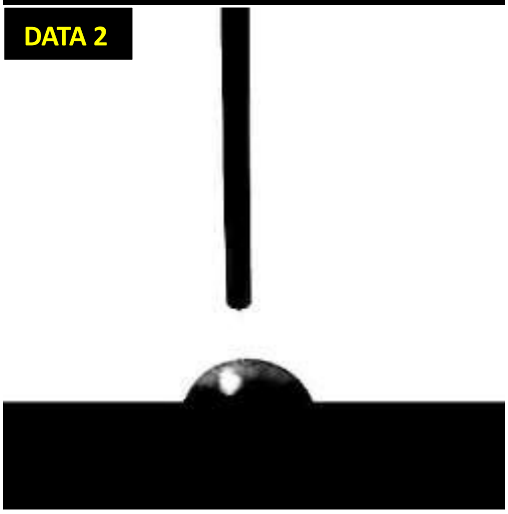
**FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM**

# LABORATORIUM FISIKA

Alamat : Jalan Mallengkeri Raya, Makassar
Laman: https://fisika.fmipa.unm.ac.id/




***Laboratorium Mikrostruktur Jurusan Fisika Universitas Negeri Makassar 2023***

KEMENTERIAN PENDIDIKAN, KEBUDAYAAN, RISET, DAN TEKNOLOGI
UNIVERSITAS NEGERI MAKASSAR
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM

## LABORATORIUM FISIKA

Alamat : Jalan Mallengkeri Raya, Makassar
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**D3UV72 (Perlakuan UV 72 Jam)**
**Specimen D11**

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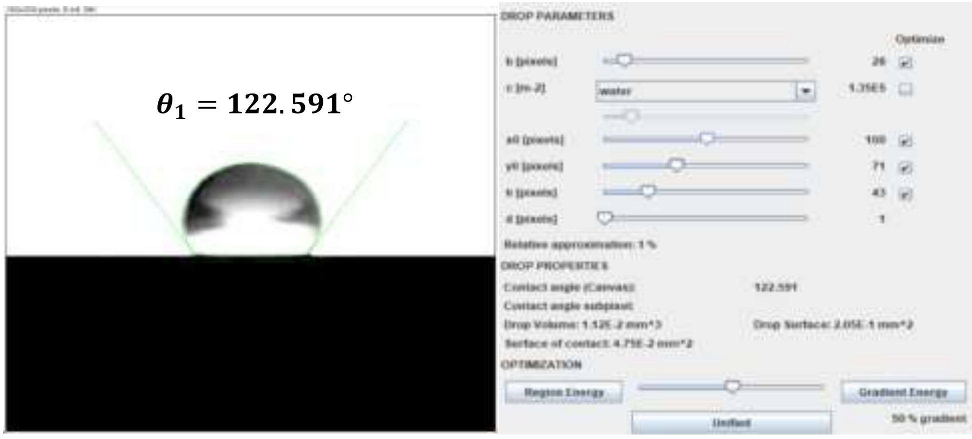


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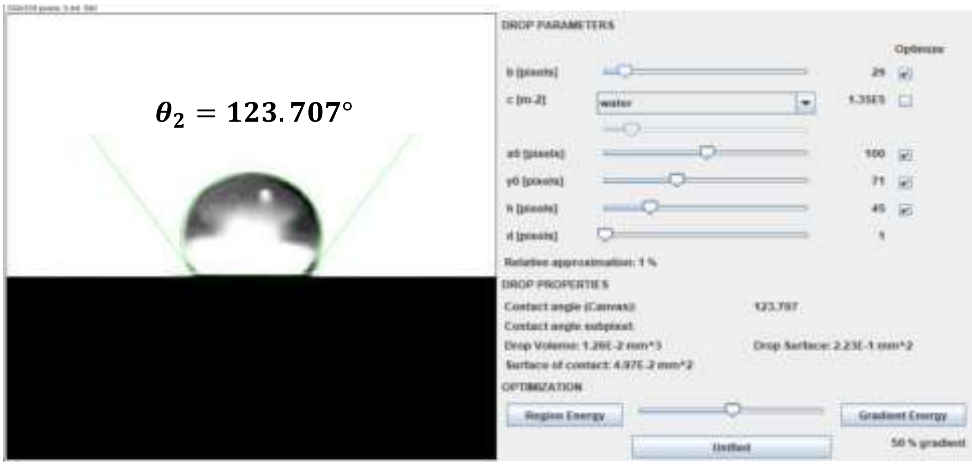


**DATA 3**

KEMENTERIAN PENDIDIKAN, KEBUDAYAAN, RISET, DAN TEKNOLOGI
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FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM

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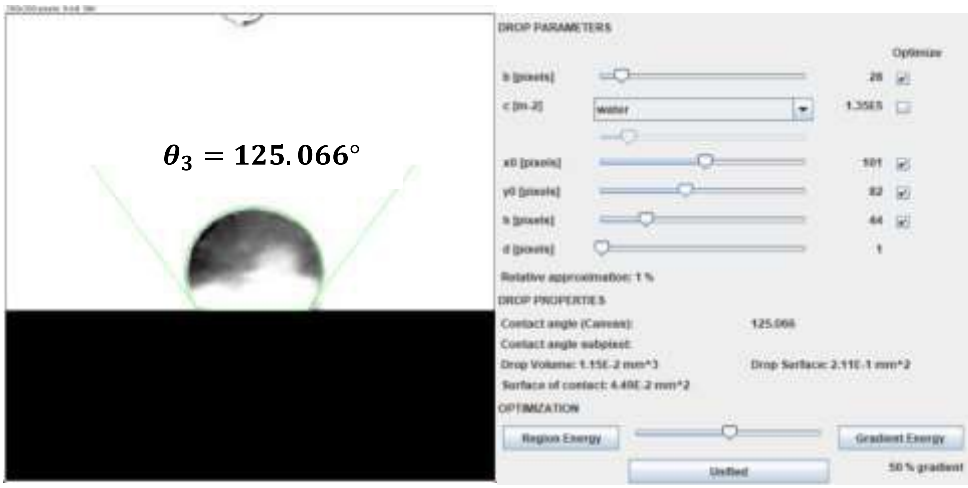


## CONTACT ANGLE

| θ | σ |
|---|---|
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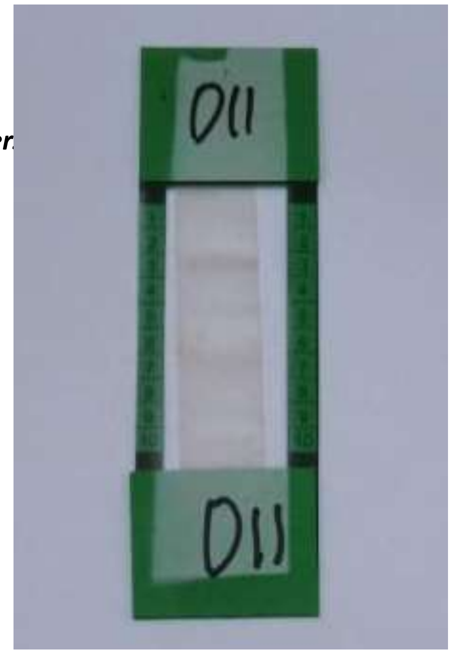
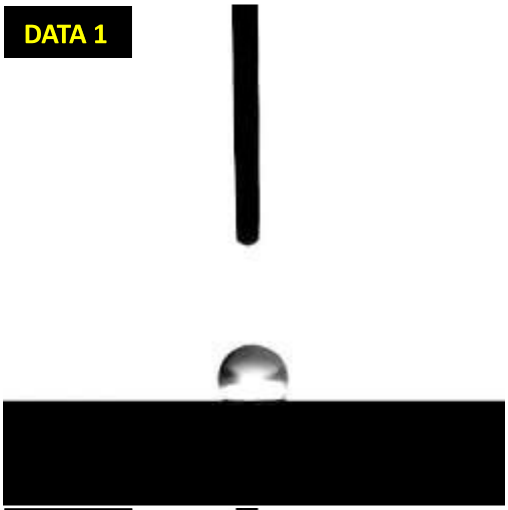
| 123.707 | 0.081 |
| 125.066 | 1.278 |
| **θavg** | **σmax** |
| 123.788 | 1.278 |

Univer




$\theta = |123.788 \pm 1.278|°$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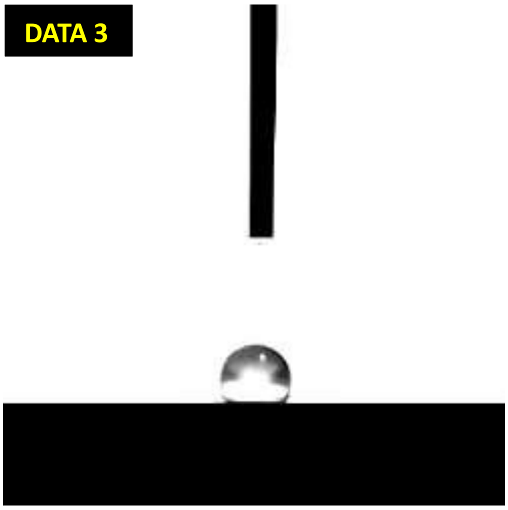
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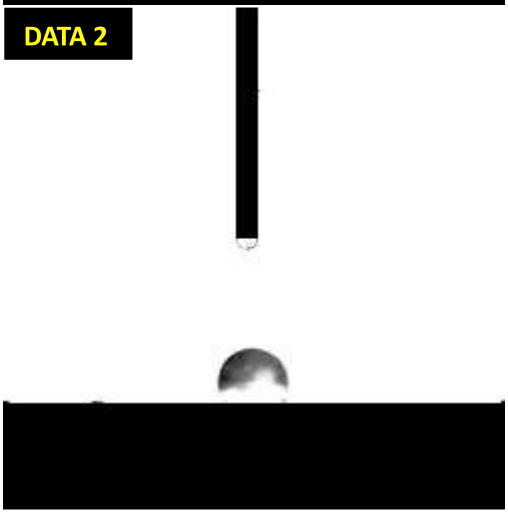

DATA 2

# LAMPIRAN

## Pengujian Microba

**Laboratorium Microbiologi**
**Fakultas Kedokteran**
**UNIVERSITAS HASANUDDIN**

**KARAKTERISASI PATI SAGU *(Metroxylon SP)* DALAM MENGEMBANGKAN MATERIAL BIOPLASTIK**

**CHARACTERIZATION OF SAGO (Metroxylon SP) STARCH IN DEVELOPING BIOPLASTIC MATERIALS**

**BUDIAWAN SULAEMAN**
**D043181001**

**PROGRAM STUDI DOKTOR ILMU TEKNIK MESIN**
**DEPARTEMEN TEKNIK MESIN**
**FAKULTAS TEKNIK**
**UNIVERSITAS HASANUDDIN**
**GOWA**
**2023**

**KEMENTERIAN PENDIDIKAN, KEBUDAYAAN, RISET DAN TEKNOLOGI**
**UNIVERSITAS HASANUDDIN**
**FAKULTAS TEKNIK**
**PROGRAM STUDI S3 TEKNIK MESIN**
**Jl. Poros Malino KM. 6 Bontomarannu (92127) Gowa Sulawesi Selatan.0411 – 586015, 586262**
**http://eng.unhas.ac.id. E-mail:teknik@unhas.ac.id**

14 Agustus 2023

Nomor : 017/UN4.7.8/S3-TM/PP.26/2023
Lamp. : -
Perihal : Pengujian Material

Kepada Yth.
Kepala Laboratorium Mikrobiologi Fak Kedokteran UNHAS
di
Makassar

Dengan hormat,

Bersama ini kami sampaikan bahwa Mahasiswa Program Doktor (S3) Teknik Mesin Universitas Hasanuddin an. Budiawan Sulaeman/D043181001 mengajukan permohonan untuk melakukan Pengujian **Material di Laboratorium Mikrobiologi Fak Kedokteran UNHAS** dengan judul Disertasi Karakterisasi Sagu (metroxlylon SP.) dalam mengembangkan Material Bioplastik.

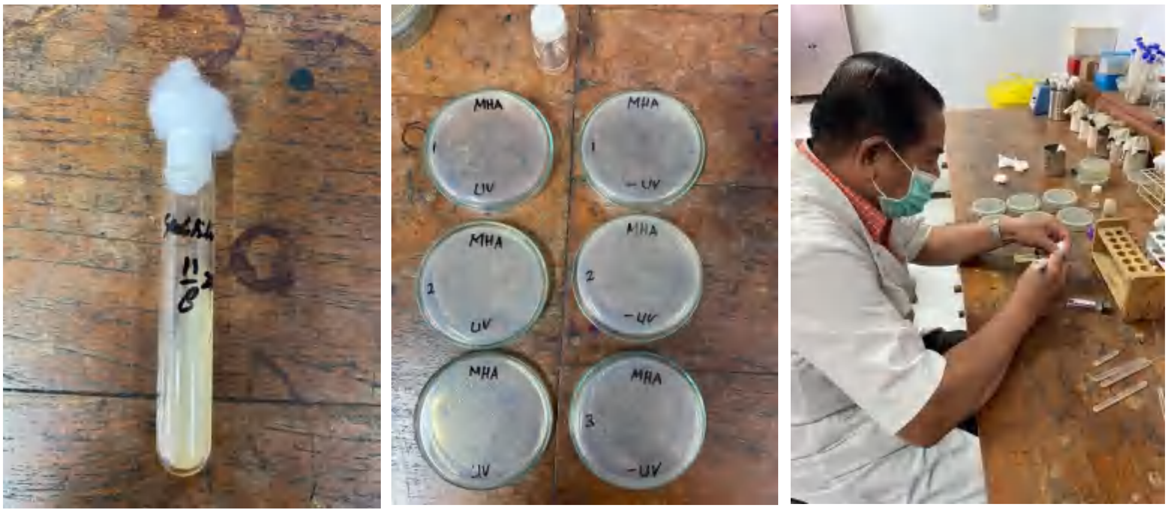
Demikian penyampain kami, atas bantuan dan kerjasamanya diucapkan terima kasih.

Ketua Program Studi S3 Teknik Mesin

Dr. Eng. Andi Amijoyo Mochtar, ST., M.Sc
NIP. 19760216 201012 1 002

*Arsip*

Persiapan pengujian Bakteri di Lab. Microbiologi Fakultas Kedokteran




Persiapan pengujian Bakteri di Lab. Microbiologi Fakultas Kedokteran
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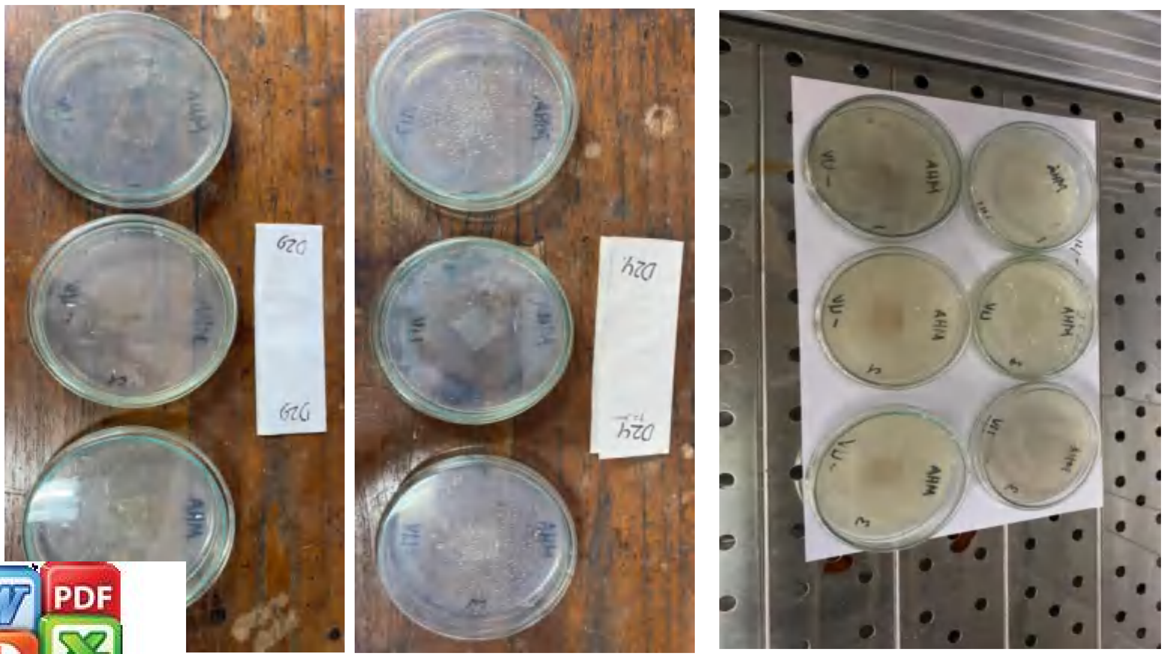
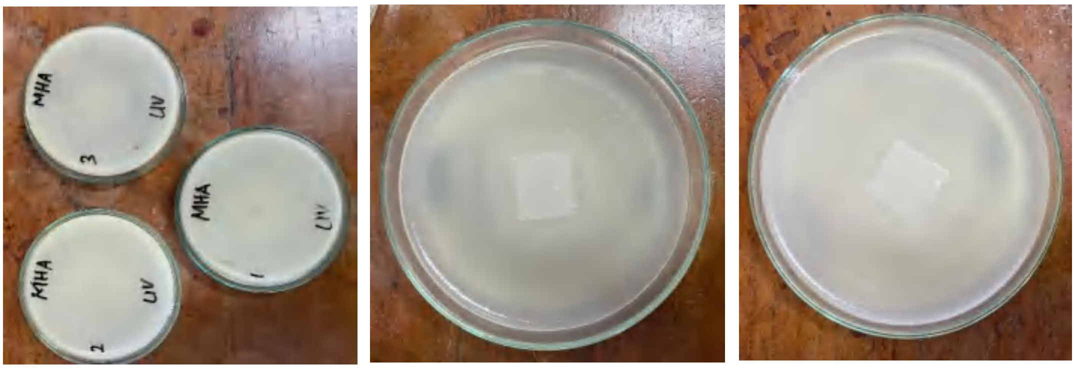


pan pengujian Bakteri di Lab. Microbiologi Fakultas Kedokteran
Memasukkan Specimen kedalam Inkubator

Hari Kedua Pengujian Bakteri terhadap Specimen tanpa perlakuan UV.



Hari Kedua Pengujian Bakteri terhadap Specimen yang terpapar UV

Hari Keempat Pengujian Bakteri terhadap Specimen tanpa perlakuan UV.

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Hari Keenam Pengujian Bakteri terhadap Specimen Tanpa terpapar UV.

Hari Keenam Pengujian Bakteri terhadap Specimen yang terpapar UV.

Hari Ketujuh Material Bioplastik terurai

# LAMPIRAN

## Jurnal Internasional

**Developmen of Bioplastiks From Tawaro's Environmentally Friendly Sago Starch (Metroxylon)**


**Eastern-European Journal of Enterprise Technologies**
**ISSN 1729-3774_5/12 (125) 2023**
**https://journals.uran.ua/eejet/article/view/289626**
**https://doi.org/10.15587/1729-4061.2023.289626**


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**GOWA**
**2023**

UDC 678
DOI: 10.15587/1729-4061.2023.289626

# DEVELOPMENT OF BIOPLASTICS FROM TAWARO'S ENVIRONMENTALLY FRIENDLY SAGO STARCH (METROXYLON)

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***Sustainable bioplastics made from Tawaro sago starch are investigated in the study. This study is motivated by the global need to lessen the environmental impact of petroleum-based polymers and discover greener alternatives. Tawaro sago starch's amylose concentration, moisture levels, and ecologically friendly qualities are examined in the study. It carefully blends sago starch, glycerol, and an acetic acid and water activator solution to create a bioplastic. The study will examine these bioplastics' chemical composition, crystalline structure, mechanical properties, and reactions to UV radiation and microbial development. Researchers and developers are interested in sago starch, a staple meal in Palopo City, South Sulawesi Province, Indonesia, as a sustainable material. Sago starch is advantageous due to its renewable nature and eco-friendly properties. XRD, mechanical characteristics, and microbiological development in sago bioplastic are examined in the study, providing valuable insights. Tawaro sago bioplastic has no heavy metals, according to XRD. The mechanical characteristics have improved significantly, reaching 2,867 N/mm$^2$. A 48-hour UV radiation exposure within limitations changed the chemical chain, causing the improvement. Furthermore, bacteria grow swiftly on sago bioplastic. This research promotes sago-based bioplastics as an eco-friendly alternative to traditional plastics, promoting environmental sustainability. This research supports the global drive to create eco-friendly materials. Using Tawaro sago starch, creative solutions for a greener, more sustainable future are possible, with bioplastics offering a compelling alternative to existing plastics and lowering their environmental impact***

***Keywords: X-ray diffraction, tawaro starch, ultraviolet radiation treatment, mechanical properties***

*Received date 14.08.2023*
*Accepted date 23.10.2023*
*Published date 30.10.2023*

***How to Cite:*** *Sulaeman, B., Salam, N., Putra, A. E. E., Arma, L. H. (2023). Development of bioplastics from Tawaro's environmentally friendly sago starch (Metroxylon). Eastern-European Journal of Enterprise Technologies, 5 (12 (125)), 6–16. doi: https://doi.org/10.15587/1729-4061.2023.289626*

## 1. Introduction

Plastic packaging protects, preserves, and attracts customers [1]. Petrochemical-based plastics are becoming more prevalent, causing environmental issues. Petrochemical plastics are a social issue due to an ecological crisis [2]. Researchers are seeking renewable, sustainable alternatives to non-organic materials. Bioplastics are exciting alternatives to traditional polymers since they decompose quickly [1–3]. Biodegradable materials could solve plastic waste's environmental problems. The natural breakdown of these items meets packaging and product protection requirements, making them environmentally friendly. Innovation in non-petroleum materials improves sustainability [4]. Renewable materials are essential for lowering fossil fuel use and plastic production's environmental impact.

Conservation and environmental awareness have grown ... ıding this subject has changed our ... environmental impact. This global ... ; biodegradable polymers instead of ... trial applications and packaging [5]. ... evolutionized material science and ... ners are made from biodegradable ... carbohydrates, and proteins [6–9]. ... rom standard synthetic polymers, which can pollute for years. Renewable polysaccharides and proteins help reduce plastic waste's environmental impact. The promotion of sustainable behavior helps the circular economy. A closed-loop system of natural sources, function, and breakdown makes biodegradable polymers a sustainable solution. Developing and using biodegradable polymers demonstrates a dedication to reducing industrial and packaging waste.

Tawaro's sustainable sago starch could revolutionize bioplastic manufacture by improving biodegradability [10]. Starch's ability to form strong, flexible sheets makes it a promising bioplastic material. This alternative is chosen for its film-forming capabilities, cost-effectiveness, widespread availability, and renewable properties. These qualities make it a promising sustainable material development alternative. Biodegradable films contain lipids, proteins, fibers, and polysaccharides. Starch-based films have succeeded more than others. Potatoes, rice, corn, taro, and root tuber starches are used to make these films. These films show the many uses of starch as a bioplastic precursor. Starch makes up about 50 % of commercial biodegradable plastics [11].

Bioplastics constructed from different starches have been thoroughly investigated, revealing many sustainable material possibilities. Characterization investigations for jackfruit seed bioplastics are an example. These investigations examine the special features of glycerol-plasticized bioplastics [12]. Bioplastic composite production and characterization have advanced. A good example is starch and empty fruit bunches supplemented with epoxidized oils. According to [13], the text's combination was meticulously designed and outlined. As a reinforcing component in starch-based bioplastic films, Chitosan has received interest due to its potential to improve mechanical characteristics and performance. Chitosan-reinforced starch-based bioplastics have been extensively studied for their mechanical parts. This research has illuminated these materials' applicability and durability [14]. It is essential to acknowledge that the utilization of sago starch for bioplastic production remains an area with limited research conducted thus far. Additional research is required to investigate the progress and potential of utilizing sago starch as a raw material for producing environmentally friendly bioplastics. Therefore, research to develop ecologically friendly bioplastics based on sago starch is still relevant.

## 2. Literature review and problem statement

Bioplastics have come to the forefront in recent years due to their promise to reduce the adverse environmental effects caused by traditional plastics made from petroleum. These renewable resource-based substitutes provide a greener alternative to conventional plastics manufacturing. The Tawaro sago palm (Metroxylon sp.) yields a starch that shows promise as a raw material for bioplastics. Traditional cuisines in Indonesia frequently use sago starch, which may be abundant in places like Palopo City in South Sulawesi Province [15]. However, its use in bioplastics can increase the resource's value while reducing plastic waste. Numerous important characteristics and properties of sago-based bioplastics have been investigated. The bioplastic features are affected by several factors, such as the amylose content, the moisture content, and the contaminants in sago starch.

The study in [2] emphasizes developing sustainable natural bioplastics. This strategic approach emphasizes the need to lessen our dependence on finite fossil fuels and address the environmental impacts of traditional plastics. The study addresses plastic pollution by studying biodegradable bioplastics. This family of materials has the advantage of spontaneously degrading, leaving small ecological footprints. Thus, biodegradable bioplastics may help fragile ecosystems from plastic trash. The study examines bioplastics' ability to meet food packaging's strict functional requirements. This multidimensional challenge requires good performance and durability. The study emphasizes bioplastics' potential to improve food safety and longevity by preserving food. Despite this hope, the study highlights careful verification. Researchers must determine if bioplastics can compete with conventional polymers in various dimensions. Shelf life, barrier properties, and structural robustness are essential. These studies will ensure that bioplastic-packaged food is safe and well-preserved from manufacture to consumption.

…oughly evaluates the bioplastic and …ectively evaluates the strengths and …sustainable materials research topic …spective. The review goes beyond …ider range of materials. Bioplastics, …nposites are included. The assess… …cycling landscape's complexity and …otential by evaluating this variety of materials. The text emphasizes the practical importance of understanding recycled bioplastics' real-world ramifications and prospective applications. However, one must examine how these materials interact with recycling processes to understand this topic. A more extensive investigation of how bioplastic blends and biocomposites affect recycling operations and recycled material quality and efficiency will greatly improve our understanding. Detailed examples of successful submissions will further enhance the review. These case studies could show how recycled bioplastics have been integrated into various sectors and prove their practicality. Furthermore, detailed market research should examine recycled bioplastics' current and future potential in numerous sectors. This research should evaluate market demand, pricing dynamics, and competition to inform industry stakeholders and policymakers. While emphasizing bioplastic recycling's economic viability, a cost-benefit analysis of different recycling methods is helpful. This could help find and promote the most cost-effective recycling techniques.



The review in [7] explores starch-based bioplastics with fiber and nanoparticles. Its main goal is to study these increased bioplastics' properties and biodegradability. This broad analysis examines starch-based bioplastics' mechanical, thermal, and barrier properties. This holistic approach recognizes the complexity of these materials and that their practical applications frequently depend on a careful balance of their properties. Notably, the review addresses biodegradation performance. Given the increased emphasis on sustainability and environmental responsibility, starch-based bioplastics' biodegradability is crucial. The review's attention to this essential aspect shows a holistic approach to assessing these products. Several factors could improve the review's impact and accessibility. First, knowing the audience can help customize material. Tailoring the review to researchers, policymakers, and industry experts' requirements and viewpoints may improve its relevance and usefulness. Quantitative data and comparative analysis across research projects can also improve comprehension and usability. Using such data, users can draw conclusions and make informed judgments on starch-based bioplastics. Testing conditions affect biodegradation efficacy, so consider these. Addressing these variables and exploring biodegradation evaluation methodologies in the review would help readers grasp the subject better.

The study [9] analyzes how glycerol and clay nanoparticles affect biodegradable films made from cassava starch. This research goal emphasizes a dedication to eco-friendly packaging materials. The careful selection of materials and components makes this research stand out. The systematic use of glycerol as a plasticizer and clay nanoparticles as a reinforcing agent shows a comprehensive strategy for studying biodegradable films. This purposeful choice enables extensive film property study and sets a precedent for sustainable materials with improved qualities. This study evaluates mechanical properties, particularly tensile strength and elongation at break. These characteristics largely determine the film's mechanical performance. Understanding these films' stress and strain behavior is crucial, especially for packaging, where durability and flexibility are crucial. A complete approach is needed for informative and replicable research. Everything from clay nanoparticle preparation to film casting should be covered. Documenting outcomes helps researchers reproduce them and uncover and fix inconsistencies. Statistical analysis improves study rigor. These evaluations estimate the relevance of tensile property differences between formulations. Statistical validation gives research objectivity and credibility.

In the extensive study [16], waste fatty acids are converted into marketable bioplastics and smoothly integrated into a dark-fermentative hydrogen production process. A multifaceted study addresses two major environmental issues: fatty acid waste management and sustainable bioplastics. One of the most remarkable parts of this work is its creative usage of Bacillus tequilensis for specific applications. This choice involves a targeted use of waste fatty acids for bioplastic synthesis. To understand why Bacillus tequilensis was chosen over other microbial strains, the study must explain why. Which traits or talents make this strain ideal for the job? This selection's rationale and future study directions could be illuminated by such insights. Besides bioplastic synthesis, the study emphasizes dark-fermentative hydrogen generation from a holistic and resource-efficient approach. The integrated method maximizes waste material utility and minimizes environmental effects. The study could provide real-world examples of bioplastics and dark-fermentative hydrogen generation's uses and benefits to make the findings more realistic and applicable. Displaying how these new techniques might be used in diverse sectors or applications may increase acceptance and influence.

The study [17] aims to evaluate the effects of bentonite on yam extensively starch-based biodegradable bioplastic films. This study's target is clear and serves a specific need-improving yam-starch-based biodegradable films for food packaging. One of this study's highlights is its purposeful use of yam starch for bioplastic synthesis. Yam starch, a renewable natural resource, shows a dedication to sustainability in materials selection. This choice supports the global push to use sustainable bioplastic materials and reduce environmental impact. The study's approach goes beyond bentonite inclusion. It examines bioplastic sheets' mechanical and barrier properties. This comprehensive study understands that bioplastic film performance in practical applications depends on a complex balancing of various properties. Contextualizing the study within the sustainability landscape would improve its effect and utility. The study can emphasize its importance by relating it to global environmental and food packaging concerns. Additionally, it would be insightful to study yam starch's particular properties and discuss why it was chosen as the major material.

Despite the promising prospects of sago-based bioplastics, there is a need for a comprehensive characterization of these materials to optimize their production and application. Existing research has focused on specific aspects, such as chemical composition, crystalline structure, and mechanical properties, but a holistic understanding is lacking. Researchers are studying polar polymers, including polysaccharides and proteins, as biodegradable plastic alternatives to synthetic polymers. The development of degradable polymers is a significant step forward and environmentally favorable. Because they are renewable, these polymers may be used efficiently [18]. Tawaro sago starch, from Palopo, is a polysaccharide [15]. However, polysaccharide-based bioplastics have temperature resistance and material elongation issues [19, 20]. Further study is needed to address these constraints.

Thus, this study follows the SNI standard [21], which ...n (XRD) to detect heavy metals ... and after their conversion into ...ets for packaging products. The ...plastics for UV resistance using ...on exposure. ASTM D822 mate- ...lso planned. The project also seeks ...s' fungus resistance by assessing ...cs using ASTM G21.



## 3. The aim and objectives of the study

The aim of the study is to identification the feasibility of utilizing sago starch (Metroxylon sp) from the Tawaro variety, sourced from Palopo City in South Sulawesi Province, Indonesia, as a primary material for environmentally friendly bioplastics.

To achieve this aim, the following objectives are accomplished:

– to identify the heavy metal content in sago starch and after processing it into bioplastic sheets using the X-ray Diffraction (XRD) method;

– to determine the mechanical properties of sago starch after its transformation into bioplastic sheets;

– to observe the proliferation of microorganisms on the surface of sago bioplastic specimens.

## 4. Materials and methods of experiment

### 4. 1. Object and hypothesis of the study

The object of the study is properties and characteristics of bioplastics made from Tawaro sago starch. This research aims to investigate these bioplastics' structural, mechanical, and environmental characteristics, specifically in relation to their potential use in environmentally friendly packaging. The study thoroughly examines the mechanical properties displayed by bioplastics made from sago. The analysis involves evaluating the subject's tensile strength, elongation at break, and modulus of elasticity under various conditions. The focus is examining how these mechanical attributes may change in response to external factors, specifically exposure to ultraviolet (UV) light.

The utilization of Tawaro sago starch in the production of bioplastics results in materials with advantageous structural, mechanical, and environmental characteristics. These properties render them well-suited for use in eco-friendly packaging applications. The bioplastics are anticipated to exhibit structural stability, improved mechanical strength, resistance to UV degradation, reduced vulnerability to microbial growth, and a biodegradable nature. As a result, they meet the requirements for sustainable packaging materials. The hypothesis proposes that Tawaro sago starch-based bioplastics could fulfill the demanding criteria of environmentally conscious packaging in today's world while providing beneficial characteristics in multiple aspects. The study seeks to evaluate and confirm this hypothesis by thoroughly analyzing these bioplastics.

The research assumes that bioplastics made from Tawaro sago starch demonstrate biodegradability and eco-friendliness. This foundational premise drives the exploration of their potential as environmentally sustainable materials for packaging. Moreover, it suggests that the structural integrity of bioplastics made from Tawaro sago starch remains intact even when subjected to external factors such as UV radiation. The foundational assumption is crucial for studying the mechanical characteristics and resistance to UV-induced degradation. In addition, the study is based on the premise that Tawaro sago starch is easily obtainable and can be used as a sustainable and renewable resource for the production of bioplastics. This assumption is crucial when assessing this resource's practicality and potential for growth.

The research may have been conducted in controlled environmental conditions to isolate specific factors, thereby reducing the influence of external elements on the properties of bioplastics. This approach facilitates a clearer understanding of the inherent characteristics of the materials. The study likely chose standardized testing conditions and procedures to make the characterization process more efficient. Although the simplification ensures consistency and facilitates result comparison, it may not fully reflect real-life scenarios. The investigation likely focused on short intervals of UV radiation exposure and microbial growth to expedite data collection. The simplification may fail to account for long-term degradation or the wider range of environmental impacts.

**4. 2. Material**

The Tawaro variety of sago trees, which are scientifically referred to as Metroxylon sp and can be found in the picture-perfect location of Palopo City, South Sulawesi Province, Indonesia, provided the source of the sago starch that was used in this pioneering research attempt. This starch served as the primary structural component. This specific sago starch was an excellent contender for creating bioplastic since it had an amazing amylose content of 36.49 % and a moisture level that was flawlessly dry at 0.0 %. The concept of precise hand layup was the methodology that was utilized in the process of producing these extraordinary specimens. A specific combination of materials was needed for this purpose. Eight grams of Tawaro sago starch, three milliliters of glycerol, and forty-six milliliters of an activator solution were expertly mixed. This activating solution was painstakingly prepared by carefully combining 2 % volume/weight acetic acid ($CH_3COOH$) with distilled water. The formulation was ingenious.

Fig. 1 illustrates the step-by-step process of bioplastic production, beginning with the primary raw material of sago and concluding with a series of thorough tests to evaluate the bioplastic's quality and performance. The first step of this complex process involves the production of the bioplastic material. The primary ingredients in this formulation are sago starch, acetic acid, glycerol, and pure water. The deliberate combination of these elements demonstrates a meticulous approach, establishing the groundwork for the following phases. The mentioned phase highlights the intentional adoption of sustainable and environmentally friendly materials in the production of bioplastics. This aligns with the principles of responsible and green manufacturing.

After the formulation stage, the bioplastic is subjected to a critical drying process. The utilization of an oven is a dependable technique for eliminating moisture, which guarantees that the bioplastic achieves the intended texture and strength. The drying phase plays a critical role in the production process, as it is crucial for successfully preparing the bioplastic material for further use and testing. After the completion of the oven process, the bioplastic is ready for a series of quality assessments. The tests are essential for assessing the bioplastic's performance and characteristics. The evaluation of the elastic modulus is one of the mentioned assessments. It offers insights into the material's elasticity and flexibility. XRD analysis is a technique that examines the crystalline structure of the bioplastic, providing insights into its molecular arrangement and properties. Moreover, the process of microbial growth testing involves a thorough examination of the bioplastic surface to identify any possible interactions with microorganisms. This aspect holds significant importance, particularly in applications such as food packaging.

The enchantment took place at a temperature of 70 degrees Celsius under strict control, where these components were continuously mixed with diligence until they reached a harmonic and consistent consistency. This impeccable combination of sago starch, glycerol, and the activator solution was the basis for a sago bioplastic specimen that would significantly contribute to the field. It was necessary to use a glass mold with an exact thickness of 0.6 millimeters to give this homogenous slurry a form that could be touched. The potential of an eco-friendly bioplastic was captured in this mold, which acted as a crucible for invention. After being meticulously positioned inside this mold, the material underwent a transformation process by being dried out for one hour at a temperature of one hundred and ten degrees Celsius. This crucial stage of the manufacturing process resulted in the construction the extraordinary sago bioplastic specimen, which paved the path for a sustainable and environmentally conscientious future.

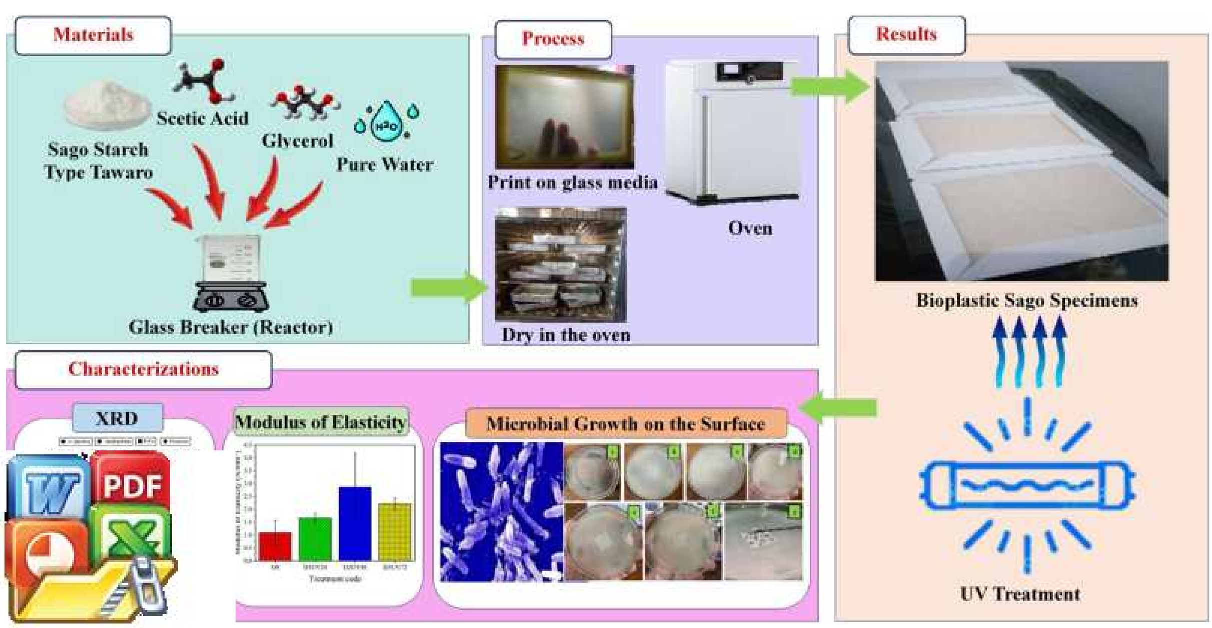





Fig. 1. The process of making and testing sago bioplastic material

#### 4. 3. Methods and sample testing

The application of the X-ray Diffraction (XRD) technology in our research played an essential part in the characterization and identification of heavy metal content within the sago starch, both before and after the transformative process into bioplastic sheets. This was the case both before and after the bioplastic sheets were formed. Because of our analytical method, it is possible to investigate the structural features of the material in great detail, which assisted in accurately determining its composition and purity.

After this, our inquiry assessed the bioplastic material's resilience to the potentially damaging effects of UV radiation exposure under the stringent requirements outlined in ASTM D5208. This standardized testing showed that our bioplastic sheets exceeded the criteria for durability, confirming that they are suitable for various applications in which they might be exposed to sunlight and other environmental stressors.

To assess the material's mechanical qualities, particularly its elongation capability, let's resort to the well-respected standards established by the ASTM D822 committee. As a result of these experiments, it is possible to quantify how well our sago bioplastic could endure stretching and deformation, which provided with vital insights into its flexibility and potential utility in practical applications.

To determine the bioplastic material's level of microbiological resilience, let's subject it to a series of tests that adhered to the standards set forth by the ASTM G21. These tests simulated the presence of pathogenic bacteria and fungi. This aspect of our research highlighted the significance of the material's physical characteristics and its capacity to preserve its integrity in the face of microbiological challenges. As a result, the material is an all-around and versatile solution that can be utilized in various contexts.

In a nutshell, the path taken in our research has been defined by a dedication to conducting exhaustive tests and adhering to standards that are considered standard in the industry. It has received valuable insights into the heavy metal content, UV resistance, mechanical characteristics, and microbiological resistance of sago bioplastic through utilizing the XRD method, ASTM D5208, ASTM D822, and ASTM G21 standards. This multifaceted strategy guarantees that our bioplastic products meet and surpass the requirements for quality, performance, and sustainability.

### 5. Results of the experiment using Tawaro environmentally friendly sago starch as a sago bioplastic

#### 5. 1. Results of X-ray diffraction (XRD) of ... plastic



... (XRD) analysis provided ... e structural composition ... mples and the subsequent ... is analysis revealed var... oduced throughout the transfor... depicts the diffractogram of the ... erein several peaks are observed, each corresponding to distinct crystalline phases. The presence of the α-amylose phase was seen, as evidenced by different peaks at 2θ angles of 15.32°, 17.08°, 17.84°, 22.92°, and 25.19°. The observed phase displayed clearly defined crystal planes identified as (020), (013), (121), (123), and (024). The compound possessed the chemical formula ($C_6H_8O_4$) and displayed an orthorhombic crystal structure, which closely matched the information obtained from The International Centre for Diffraction Data (ICDD) database entry #00-043-1858. The discovery mentioned above highlights the high purity and structural stability level exhibited by the α-amylose phase in Tawaro starch.

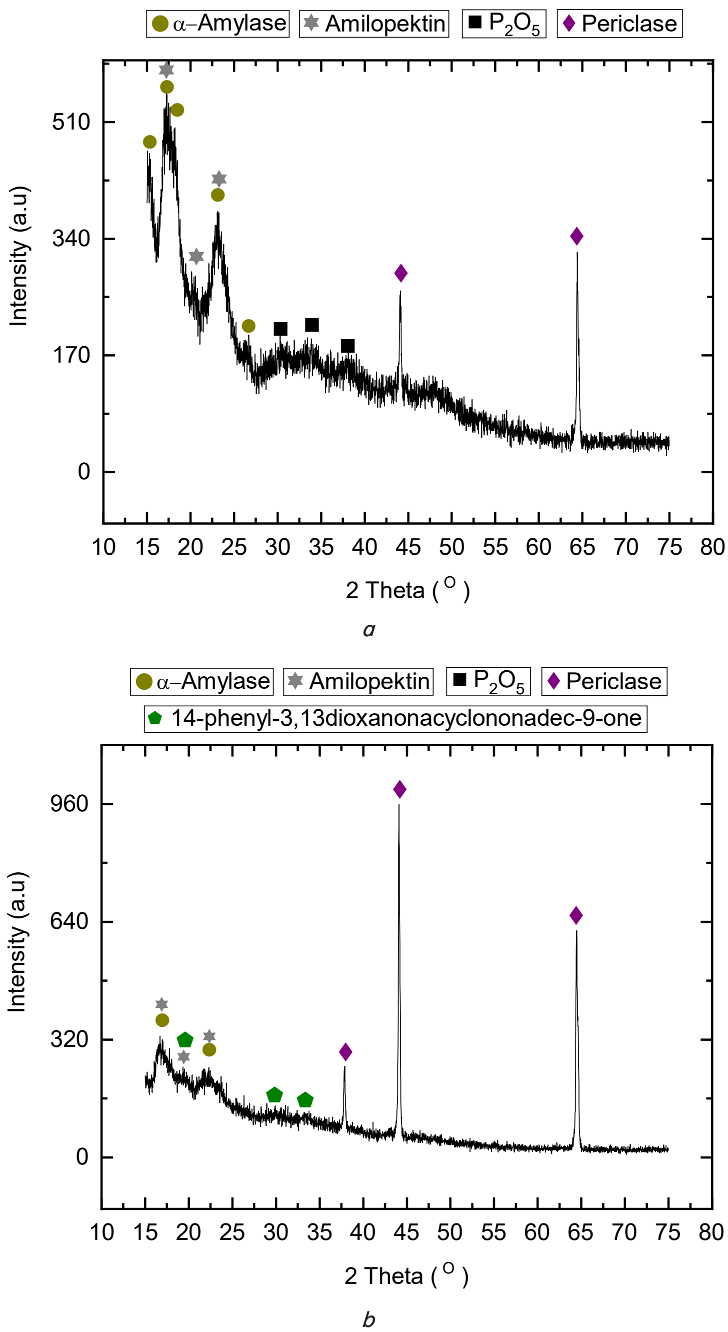



Fig. 2. Diffractogram of: *a* — Tawaro starch; *b* — bioplastic specimens

The Amylopectin phase, which exhibited peaks at 2θ angles of 15.32°, 19.56°, and 22.92°, was distinguished by its chemical formula ($C_6H_{10}O_5$), which closely matched the data obtained from the ICDD database entry #00-052-2248. This phase is considered notable. This particular phase plays a crucial role in the overall structure of starch, hence making significant contributions to its distinctive characteristics. Nevertheless, impurity phases were identified inside the Tawaro starch samples amidst the clearly characterized phases. The identification of these impurities was conducted with great attention to detail, and they were determined to be $P_2O_5$ and Periclase ($Mg_2O_4$) based on data obtained from the Crystallography Open Database (COD) entries #96-231-1014 and #96-901-3251, respectively. The existence of these contaminants has prompted thought-provoking inquiries regarding their source.

The analysis of data from the ICDD#00-043-1858 and ICDD#00-052-2248 databases, as presented in Fig. 2, *b*, has provided valuable insights into the structural properties of the Tawaro starch and bioplastic samples, enhancing our understanding of these materials. The databases played a crucial role in helping to identify and verify the crystalline phases present in our samples. Upon further investigation, it is worth noting that, in addition to the primary α-amylose and Amylopectin phases, there were noticeable impurity phases originating from Tawaro starch. The presence of impurities, specifically $P_2O_5$ and Periclase ($Mg_2O_4$), was easily identifiable. This observation aligns with the information obtained from the COD database entries #96-231-1014 and #96-901-3251, confirming these impurities' presence. The discovery highlighted the intricate relationship between environmental factors and the makeup of Tawaro starch, prompting the need for additional research on the causes and effects of these contaminants.

The discovery of the 14-phenyl-3, 13-dioxanonacyclo nonadec-9-1 ($C_{92}H_{80}O_{12}$) phase, observed at angles of 2θ 30.58° and 33.94°, is highly fascinating. The presence of this distinct phase was discovered to align with the data obtained from the COD entry #96-402-6080. The unique aspect of this discovery lies in its origin, as it emerged from the interactions between glycerol, acetic acid, and sago starch. The finding highlights the ever-changing nature of the bioplastic synthesis process. The combination of glycerol, acetic acid, and sago starch created a fascinating phase, which presents opportunities for further investigation into the underlying mechanisms that drive its formation. Comprehending these interactions is crucial for customizing the production process to optimize the characteristics and effectiveness of sago-based bioplastic materials for particular uses.

The presence of contaminants in Tawaro starch is hypothesized to originate from groundwater or the sago tree's pith. During the extraction process, it is plausible that these contaminants may be assimilated by the sago starch, ultimately becoming included in the makeup of the substance. The discovery presented in this study provides opportunities for additional research on the origins and consequences of these contaminants since they could potentially impact the characteristics and uses of bioplastic materials derived from sago. The X-ray diffraction (XRD) analysis provided valuable insights into the crystalline phases in the Tawaro ...ples. Additionally, it suggested a ...een environmental conditions and ...phasizing the need for additional ...uing study area.

**...nical properties of sago bioplastic**

... extensive selection of bioplastic ...icated and afterwards exposed to a range of Ultraviolet (UV) radiation treatments to evaluate their durability and efficacy across different environmental circumstances. Table 1 shows the code for the bioplastic samples used in this study based on exposure to ultraviolet radiation. To conduct a comprehensive assessment of the mechanical properties of the bioplastic specimens, let's utilize the Universal Testing Machine - Lloyd L10K Plus. This particular instrument is widely recognized for its exceptional precision and reliability in accurately measuring material properties. The utilization of this apparatus facilitated the execution of elongation experiments on individual specimens, yielding significant observations regarding their inherent flexibility, stretchability, and general mechanical soundness.



Table 1

Bioplastic sample code

| No. | Treatment code | Code meaning |
|---|---|---|
| 1 | D0 | Lacking any ultraviolet radiation |
| 2 | D1UV24 | Exposed to 24 hours of ultraviolet radiation |
| 3 | D2UV48 | Subjected to 48 hours of ultraviolet exposure |
| 4 | D3UV72 | Enduring an intensive 72 hours of ultraviolet Irradiation |

The analysis of the elastic modulus, as shown in Fig. 3, offers valuable insight into the material's rigidity and reaction to UV exposure. The purpose of this parameter is to analyze the relationship between the stiffness of the bioplastic sago sample and the duration of UV exposure. The consistent exposure to UV light leads to a noticeable increase in the elastic modulus, suggesting that the material undergoes a stiffening effect when exposed to UV radiation. The user's text suggests a correlation between UV exposure and changes in the mechanical properties of bioplastics. These changes may result in increased rigidity and reduced susceptibility to deformation.

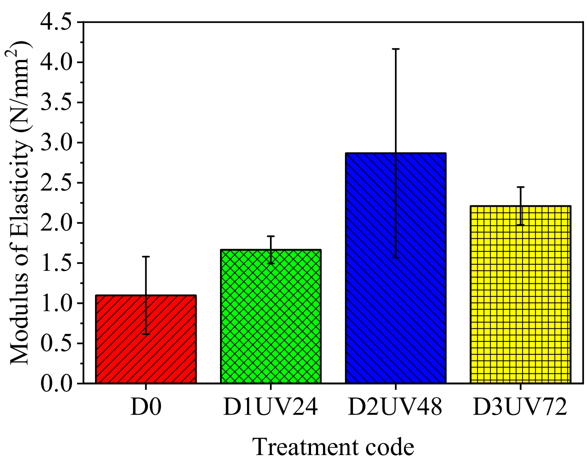



Fig. 3. Testing the modulus of elasticity on bioplastic before and after being treated with ultraviolet radiation

The study observed an impressive elastic modulus of 2.867 $N/mm^2$, the highest recorded. This high modulus was achieved after subjecting the material to 48 hours of UV light exposure. The significant increase in stiffness observed may be explained by the cumulative effects of UV-induced alterations in the material's structure, which enhance its mechanical integrity. In contrast, the samples not exposed to UV light demonstrated the lowest elastic modulus, measuring only 1.097 $N/mm^2$. The lower modulus suggests that the material is more flexible and pliable when in its original state, without exposure to UV radiation. The findings provide insights into the possible uses of sago-based bioplastics in situations that require stiffness and rigidity. The deliberate adjustment of UV exposure has the potential to customize the mechanical properties of a material to fulfill particular needs. In specific applications where maintaining structural integrity is crucial, extended exposure to UV radiation may be utilized to improve stiffness. Conversely, in other applications where flexibility is a priority, it may be preferable to limit UV exposure.

### 5. 3. Results of microbial growth on the surface of sago bioplastic

Monitoring sago bioplastic material surface microbial development is essential for product safety, stability, and quality. Testing helps meet regulatory requirements and guides product development. Testing microbial growth on bioplastics is careful and systematic to give reliable and valuable results. Controlled microbe application to the bioplastic product commences. This stage simulates real-world microbial infection, making it crucial.

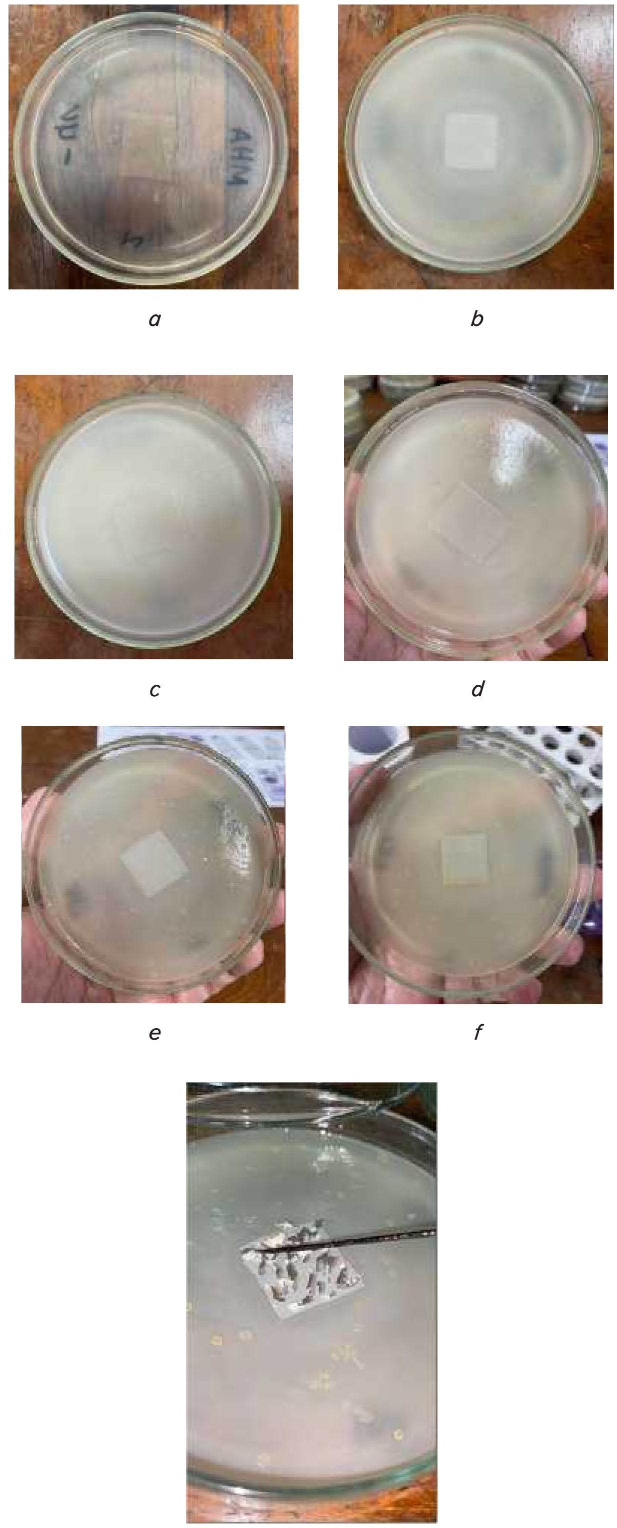
The microorganisms are applied, and the testing process precisely controls environmental conditions to track their growth over time. Test results are trustworthy and reproducible in a controlled environment. Temperature, humidity, and light exposure are carefully controlled to imitate product lifetime conditions. The microbiological monitoring data is invaluable. They show the product's microbial growth prevention efficiency. This information is crucial for determining the product's hygienic and structural integrity under different settings.

Assessing bacterial proliferation on bioplastics entailed a systematic and rigorous examination protocol to evaluate the material's vulnerability to microbial colonization. The research investigation examined Bacillus subtilis bacteria, yielding significant findings on the interaction between microorganisms and the bioplastic material. The experimental procedure was initiated by introducing Bacillus subtilis bacteria onto Muller Hinton Agar (MHA) media, a commonly used bacterial cultivation and proliferation medium. The precise attachment of small bioplastic samples, with dimensions of 1.5×2 cm, was carried out on the agar media surface, as depicted in Fig. 4, *a*. The experimental arrangement emulated a situation where the bioplastic material might encounter possible microbial pollutants.

The incubation phase was initiated during the subsequent 24-hour period, facilitating the interaction between the bacteria and the bioplastic surface. The following observations done on the next day confirmed the presence of bacterial proliferation on the bioplastic sheet. The observed effect was consistent over three iterations of the experiment, indicating the material's inclination to facilitate bacterial colonization. The salient feature of this finding was the ı of bacterial proliferation across tic sheet, which closely resembled ial colonies expanding in the im- te, as illustrated in Fig. 4, *b*. The ed a comparable hue on both the nding plate, suggesting a strong activity. This finding underscores material to bacterial colonization.



During the investigation, as the observation period extended to 48 hours, it was observed that there was a significant increase in bacterial growth on the surface of the bioplastic sheet, as depicted in Fig. 4, *c*. The observed phenomenon of the bacterial colonies exhibiting a progressive increase in



*a* *b* *c* *d* *e* *f* *g*

Fig. 4. Antimicrobial testing on samples of sago bioplastic: *a* – initial conditions; after incubation for *b* – 24 hours; *c* – 48 hours; *d* – 72 hours; *e* – 96 hours; *f* – 120 hours; *g* – 168 hours

thickness indicates the material's heightened vulnerability to extended periods of microbial presence.

The progression of bacterial growth observed over extended intervals, from 72 hours to 120 hours, unveils valuable insights into the bioplastic material's interaction with microorganisms and its susceptibility to microbial colonization. At the 72-hour mark, as depicted in Fig. 4, *d*, a continuation of the trend seen in earlier observations is evident. Bacterial colonies on the bioplastic sheet have grown thicker, and the size of the bioplastic attached to the agar surface appears to have reduced. This suggests an ongoing microbial activity and a potential impact on the structural integrity of the bioplastic.

A notable development emerges as the observation period extends to 96 hours, as seen in Fig. 4, *e*. In addition to the thickening of bacterial colonies, an intriguing occurrence occurs bubbles or foam formation on the bioplastic sheet. This phenomenon could indicate various processes, such as bacterial metabolic activity or the release of gases due to microbial interactions with the bioplastic surface. It underscores the complexity of microbial behavior on the material. By the 120-hour mark, shown in Fig. 4, *f*, further changes come to light. Additional bacterial growth is observed on the agar media and the surface of the bioplastic plate. This phenomenon might be attributed to other bacteria that were initially attached to the media during earlier observations. This observation underscores microbial communities' dynamic and ever-evolving nature and interactions within the testing environment. The seventh day of observation, as depicted in Fig. 4, *g*, marked a significant milestone in the bacterial testing of the bioplastic material. It clearly illustrated the transformative effects of prolonged microbial exposure on the material's properties and integrity.

## 6. Discussion of the experiment using Tawaro environmentally friendly sago starch as a sago bioplastic

Phosphorus pentoxide, or $P_2O_5$, is an element that exists in multiple crystallized forms or polymorphs. These forms are metastable states. Phosphorus pentoxide is utilized in numerous applications, such as serving as a desiccant and dehydrating agent and producing phosphoric acid. The presence of $P_2O_5$ in Tawaro sago starch could be attributed to the extraction process or environmental factors. It is crucial to recognize that $P_2O_5$ is different from heavy metals like Mercury (Hg), Lead (Pb), Cadmium (Cd), and Chromium ($Cr_{6+}$), which are widely recognized as environmental pollutants and can pose health hazards if present in excessive quantities. Magnesium sulfate ($Mg_2O_4$), commonly referred to as Epsom salt, is a compound with a wide range of external and internal applications [22]. Magnesium sulfate is widely utilized in bath salts due to its calming and healing attributes.

Additionally, it is employed in agriculture as a supplement for plant nutrition, providing magnesium and sulfur. The presence of it in this context could potentially be linked to soil or processing conditions. It is important to note that ...vy metals. In addition, it is essen-... ents oxygen (O), carbon (C), and ... al role as constituents of the com-... , *b*). These elements are essential ... itter and can be found extensively ... orld. The statement suggests that ... ssified as heavy metals. The pres-... ounds like $P_2O_5$ and $Mg_2O_4$ in



Tawaro sago starch does not necessarily indicate contamination by heavy metals linked to environmental pollution. The differentiation between different types of sago starch is crucial to guarantee its safety and appropriateness for various uses.

The mention of the SNI (Indonesian National Standard) standard implies that Tawaro sago starch fulfills the requirements to serve as a viable bioplastic foundation for food packaging. The statement supports the worldwide movement towards sustainable and eco-friendly packaging options, emphasizing the preference for natural materials over synthetic ones [23]. The use of raw materials in food packaging has become increasingly popular due to the increasing demand for packaging options that are environmentally friendly and sustainable [17, 24].

The analysis of mechanical properties testing performed on sago bioplastic material sheets (Metroxylon SP) has provided valuable insights into how the material reacts to UV exposure. The results provide a detailed understanding of the impact of UV treatment on the elasticity modulus of the sheet. After conducting a thorough analysis of the obtained results, it is evident that applying UV exposure treatment can modify and improve the elongation properties of the sheet material when exposed to external forces. It is important to highlight that there is a significant exception observed in the case of specimen D3UV72. In this particular instance, extended exposure to UV light seems to result in a decline in the material's mechanical properties. This suggests that there is a point at which prolonged UV exposure may start to have fewer positive effects or even negative effects on the material's performance. Using a UV light source, a high-frequency light wave with a 100–280 nm wavelength and an energy of 375 kJ/mol. Exposure to UV radiation can change the molecular bonds in the sample [25].

The study reveals an interesting finding in specimen D2UV48, as the mechanical properties demonstrate a noteworthy improvement. The elastic modulus experienced a significant increase from 1,097 $N/mm^2$ to 2,867 $N/mm^2$, indicating a remarkable 161 % growth, as illustrated in Fig. 5. The discovery highlights the complex connection between UV exposure and the mechanical characteristics of sago bioplastic samples. The period of UV exposure lasting between 24 to 42 hours is considered a critical window, as it significantly improves the material's mechanical performance. The increased mechanical properties observed can be explained by the chemical changes that occur due to UV exposure. Oxygen, which is likely introduced through photochemical reactions, can potentially cause changes in the chemical composition and cross-linking of the sample surface. The suggested modifications can potentially strengthen the substance, improving its structural soundness.

Extended UV exposure, as seen in specimen D3UV72 (2.211 $N/mm^2$), provides valuable insights into the behavior of sago bioplastics throughout time. Extended UV exposure slows the lengthening of these bioplastic specimens, indicating a more progressive mechanical property change. UV-induced biodegradation of bioplastics is linked to this phenomenon. Oxidation drives biodegradation. UV radiation causes chemical reactions in sago bioplastics, polymerizing polymer chains. UV-generated free radicals catalyze these processes. UV light-induced chlorine-hydrogen interactions are crucial to this chain reaction. The interaction between elements gradually transforms bioplastic material, changing its mechanical characteristics.

Note that the decrease in elongation from D2UV48 to D3UV72 is safe. The SNI standard [21] requires tensile elongation at break to be less than 5 % after 250 hours of UV irradiation. The variations in elongation found in these specimens are well within acceptable boundaries, showing that the material is mechanically adequate for its intended applications even after extensive UV exposure. Biodegradability is important in situations where cost-effective disposal is a requirement after use [26]. Sago bioplastics are environmentally friendly alternatives to traditional plastics, which promotes sustainability and responsible material use.

Sago bioplastic's antimicrobial qualities, particularly its capacity to inhibit bacteria and fungal development, are assessed by microbial growth testing on its surface. This study uses Bacillus subtilis as the test bacteria. Bacillus subtilis is a gram-positive rod bacterium that measures 2–3 nanometers long and 0.7–0.8 nanometers wide. These bacteria is important in the nutrient cycle because it is saprophytic and thrives on decaying organic materials. Its ability to produce a variety of enzymes makes it useful in many industrial applications [16, 27]. Industry uses Bacillus subtilis to make proteases, amylases, antibiotics, and compounds. Bacillus subtilis is experienced in environmental cleanup, especially chromium removal. This bacterium detoxifies or sequesters heavy metals alone or in groups [28]. Its ability to reduce heavy metal contamination highlights its versatility and environmental importance.

During the 96-hour bacterial test of the bioplastic sheet, it was observed that bubbles or foam formed (Fig. 4, *e*). Multiple factors contribute to this phenomenon, which can be attributed to the characteristics of bioplastic materials and their interactions with bacteria. These factors include the production of gas by bacteria, the release of gas from the material, the metabolic activity of bacteria, chemical interactions, material deformation, and variations in pressure and temperature. The same idea was conveyed by the source referenced as [29]. The presence of bubbles or foam in bacterial tests conducted on bioplastic materials should be interpreted with caution, as its significance can vary depending on the specific objectives of the test and the desired properties of the material.

Bacterial testing on bioplastic material containing sago starch indicated optimum bacterial growth on the whole surface of the plate, with no growth inhibitors that could prevent Bacillus subtilis bacteria from growing. Bioplastic plates contain sago starch, which bacteria use to build colonies. Bacteria may decompose bioplastics, making them eco-friendly. After piercing and raising, the material became brittle (easily torn) on the seventh day (Fig. 4, g) due to increased bacterial activity. According to SNI criteria [21], product surface microbial growth is >60 % for one week. Fig. 4, *b* shows that 100 % of bacteria filled the sago bioplastic specimen in two days. Because bioplastics are natural starches with protein, young bacteria proliferate by defending themselves.

The research could encounter limitations in terms of the conversion of sago starch into bioplastics. This process may … ment and expertise, which could … practicality for small-scale oper… ined regions. A thorough evalua… sed bioplastics, encompassing raw … rocessing, is necessary. The poten… bioplastics could be attributed to … onventional plastics. Various fac… c region, climate, and cultivation practices, influence sago starch quality and characteristics. The variability in material properties can challenge maintaining consistency during bioplastic production.



Several disadvantages related to the study can be observed alongside potential approaches for mitigating them in future research. One of these disadvantages is the diversity in sago starch characteristics resulting from geographical and agricultural disparities, which can impact the uniformity of the material. In order to effectively tackle this issue, future research endeavors could entail establishing partnerships with specialists in sago farming to enhance the quality of starch and formulate uniform procedures. The issue of variability in the rates of biodegradation of sago-based bioplastics can be effectively mitigated by implementing formulation optimization techniques and conducting standardized biodegradation testing across diverse environmental conditions. This approach ensures the attainment of consistent and predictable degradation patterns. Reducing costs associated with sago-based bioplastics can be achieved by implementing process optimization techniques and undertaking scale-up initiatives. Subsequent investigations may prioritize enhancing production efficiency and exploring sourcing and processing technologies that are economically advantageous. To mitigate this drawback, forthcoming research endeavors may undertake more extensive life cycle analyses, wherein sago-based bioplastics are compared to a broader spectrum of conventional plastics and alternative bioplastic materials. This approach would yield a more precise evaluation of the environmental implications associated with sago-based bioplastics.

The study's development encompasses multiple stages and avenues for further research and progress. One such direction is to improve the bioplastic formulation to enhance its material properties, including tensile strength, flexibility, and barrier properties. To achieve the desired characteristics, adjusting the ratios of sago starch, glycerol, and activator solution may be necessary. Conduct research on novel processing techniques to optimize the conversion of sago starch into bioplastics, focusing on methods that enhance efficiency and streamline the overall production process. One potential avenue for improvement and expansion is the exploration of innovative approaches, such as extrusion or 3D printing, which have the potential to enhance efficiency and scalability. The objective is to establish a consistent set of sago starch properties by addressing the variability caused by geographical and cultivation variations. Collaboration with sago cultivators is necessary to establish uniform quality standards. Research sustainable sago cultivation practices that reduce environmental impact, such as implementing agroforestry or organic farming techniques. Evaluate the environmental impact of expanding sago cultivation.

The study will likely face numerous difficulties and challenges in different areas, including the variation in sago starch properties caused by geographical factors and cultivation practices. The variability in sourcing and the need for consistent raw material quality may present challenges. Converting sago starch into bioplastics can be challenging due to the requirement of specialized equipment and expertise. This may result in processing difficulties, scalability issues, or the necessity for expensive modifications. Developing an optimized bioplastic formulation that balances material properties can be complex and intricate. A significant challenge is to balance factors such as starch content, plasticizer ratio, and activator solution composition. Conducting biodegradation studies requires careful attention to experimental setups and extended observation periods to assess the effects of different environmental conditions accurately. The process of standardizing these tests presents certain difficulties.

## 7. Conclusions

1. The absence of heavy metals within the composition was discovered by carefully investigating the XRD (X-ray diffraction) features of Tawaro-type sago bioplastic material, which is both promising and environmentally benign. This research further establishes sago-based bioplastics as a more environmentally friendly and sustainable alternative to petroleum-based plastics. A finding of this nature has far-reaching ramifications, especially in environmentally friendly packaging materials and other fields where preventing heavy metal contamination is critical.

2. Sago bioplastic's modulus of elasticity changed significantly when exposed to UV radiation. Under ultraviolet exposure for 48 hours, modulus of elasticity levels increased significantly from 1,097 N/mm$^2$ to 2,867 N/mm$^2$. UV light is responsible for this 161 % rise, demonstrating its tremendous effect on the substance. A complex chemical alteration in the bioplastic's chemical structure under ultraviolet exposure causes this metamorphosis. UV light modifies polymer chains by reactions. Changing the material's structure strengthens it, increasing modulus of elasticity.

3. Microbes on sago bioplastic evolve rapidly. Suitable temperature and humidity allow microbial colonies to grow quickly on bioplastics. Microbial development must be assessed and managed for diverse applications since organic materials like sago bioplastic are susceptible to microbial activity. For several reasons, understanding sago bioplastic microbial growth speed is vital.

## Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

## Financing

The study was performed without financial support.

## Data availability

Data will be made available on reasonable request.

## Acknowledgments

The author expresses gratitude to the sago processing area in Mancani Village, Telluwanua District, Palopo City, South Sulawesi Province, Indonesia, for providing the raw materials used in this research.

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# LAMPIRAN

**Seminar Internasional**
**Microstructure and Mechanical Properties of Sago Starch Bioplastics (Metroxylon sp) as Biodegradable Plastics**

**ICITAMEE 2022th**
**The 4 International Conference on Information Technology, Advanced Mechanical and Electrical Engineering (ICITAMEE)**
**Univeristas Muhammadiyah Yogyakarta 9 – 10 Agustus 2023.**
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**Email: icitamee@umy.ac.id**

**KARAKTERISASI PATI SAGU *(Metroxylon SP)* DALAM MENGEMBANGKAN MATERIAL BIOPLASTIK**

**CHARACTERIZATION OF SAGO (Metroxylon SP) STARCH IN DEVELOPING BIOPLASTIC MATERIALS**

**BUDIAWAN SULAEMAN**
**D043181001**

**PROGRAM STUDI DOKTOR ILMU TEKNIK MESIN**
**DEPARTEMEN TEKNIK MESIN**
**FAKULTAS TEKNIK**
**UNIVERSITAS HASANUDDIN**
**GOWA**
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**Microstructural and Mechanical Properties of Sago Starch Bioplastics (Metroxylon sp) as Biodegradable Plastics**

in The 4th 2023 International Conference on
Information Technology, Advanced Mechanical and Electrical Engineering (ICITAMEE 2023)

held from 9-10 August 2023
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# Microstructure and Mechanical Properties of Sago Starch Bioplastics (*Metroxylon sp*) as Biodegradable Plastics

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**Abstract.** Bioplastic materials, also known as biodegradable materials made from plant starch, have become one of the alternatives to prevent the accumulation of non-biodegradable plastics. Sago starch material (*Metroxylon sp*) has been developed for the production of bioplastics. The microstructural properties of *Tawaro* sago starch (STA) and *Tawaroduri* sago starch (STB) have been characterized, and it has been found that STA sago starch is superior as a base material for bioplastic production due to its amylose content of 36.49%. The XRD diffractogram revealed the formation of the α-amylose phase, and the elongation of the sago starch (STA) amylose polymer chains (C-O) was confirmed by the absorption band in the range of 1200 – 990 $cm^{-1}$ for (C-O-C) and (C-O-H) in the sago starch glucosidic ring, with higher intensity compared to *Tawaroduri* starch (STB) at absorption bands 958 $cm^{-1}$, 860 $cm^{-1}$, 771 $cm^{-1}$, and 715 $cm^{-1}$. Sago starch (STA) was modified using Heat Moisture Treatment (HMT) technique at a temperature of 100℃ with different time variations, and the hand layup method was used to produce four bioplastic specimens. Sago starch (STA) with 0.0% moisture content in specimen D showed a tensile strength value of 0.254 MPa and a strain of 0.247 MPa. The tensile strength increased due to the HMT treatment of sago starch. However, the strain value of specimen D was still relatively rigid. This occurred because the low moisture content in the starch granules was evenly distributed, leading to increased liquid absorption capacity and better distribution of other elements.

## INTRODUCTION

Sago (*Metroxylon sp*) is known as one of the commodities that grow abundantly in Indonesia, particularly in Luwu Regency and Palopo City, covering an area of 1334.9 hectares. Based on investigations by Barahima, sago (*Metroxylon sp*) in Palopo City consists of two types, *Tawaro* and *Tawaroduri*, with a harvest age of around 5-10 years [1]. From field observations, there are still many unused sago trees that fall (become neglected) due to exceeding their harvest age. Sago (*Metroxylon sp*) has great potential as a bioplastic material due to its availability, characteristics, and high amylose content [2]. Starch with a high amylose content can enhance mechanical and thermal properties, produce homogeneous bioplastics, and provide strong adhesion [3], [4].

…as focused on Heat Moisture Treatment (HMT) to modify the physicochemical properties of …midity, temperatures of 100-120°C for 2 hours, and achieving uniform moisture content of 10%. …ed to the amylose chain is higher in pea starch, resulting in increased interactions between starch …crystallite perfection [5]. Eduardo also reported that the HMT method affected the modification … (*Musa paradisiaca L.*), resulting in an increased elastic modulus of 12.38 MPa, tensile strength …tion of 6.0%, and no significant change in solubility [6]. Based on the aforementioned research findings, this study aims to analyze sago starch (*Metroxylon sp*) using HMT to enhance its physicochemical properties. The research on sago (*Metroxylon sp*) as a bioplastic material is expected to improve its mechanical properties, light exposure, moisture, and heat resistance without causing severe damage, and make it water-resistant (hydrophobic) for further development into packaging products.

## MATERIALS AND METHOD

The extraction of sago starch (*Metroxylon sp*) was performed on two types, *Tawaro* sago (STA) and *Tawaroduri* sago (STB), sourced from Mancani Village, Telluwanua District, Palopo City, South Sulawesi Province, Indonesia. Microstructural property testing of the starch was conducted to select the sago starch with the best quality. The testing included the calculation of amylose and amylopectin content, X-Ray Diffraction (XRD), Fourier Transform Infra-Red (FTIR), and Scanning Electron Microscopy (SEM). The sago starch with the best quality based on microstructural testing was subjected to the Heat Moisture Treatment (HMT) stage at a temperature of 100°C for varying durations of 2 hours, 4 hours, and 5 hours.

The hand layup method was used in the production of bioplastic specimens from the sago starch that had undergone the HMT process. The preparation of the bioplastic specimens involved combining 8 grams of sago starch, 3 mL of glycerol, and a 46 mL solution of 2% v/v activator (acetic acid ($CH_3COOH$) and distilled water). The mixture paste of all ingredients was homogenously stirred at a temperature of 70°C. The paste was poured onto glass media and heated for 1 hour at a temperature of 100°C to form the bioplastic specimens. This method resulted in 4 bioplastic specimens, namely specimens A, B, C, and D, with variations in the HMT duration of the sago starch.

## RESULT AND DISCUSSION

### Amylose and Amylopectin Content of Sago Starch

The extraction process of sago starch from the sago pith resulted in two types of starch, namely *Tawaro* starch (STA) and *Tawaroduri* starch (STB). After being processed into starch, these two types of starch have their own distinct characteristics. *Tawaro* starch is white and clean, while *Tawaroduri* starch has a slightly reddish color (Fig. 1a and 1b).


**FIGURE 1.** (a) Sagu *Tawaro* starch (STA) and (b) Sagu *Tawaroduri* starch (STB)

The average amylose content of *Tawaro* sago starch is 36.49%, while *Tawaroduri* sago starch has an average amylose content of 36.42%. These amylose contents are higher compared to the findings of Polnaya, who reported an amylose content of 35.13% for Ihur sago starch from Central Maluku [7]. Du reported an amylose content of sago starch from Papua reaching 24.07% [8]. The amylose content of 28% was reported for sago starch from SIM Company in Penang Island, Malaysia [9].

### Microstructure of Sago Starch

:terization results obtained diffractograms from the samples of *Tawaro* starch (STA) and TB), which show the phases formed by each peak in Figure 2c.

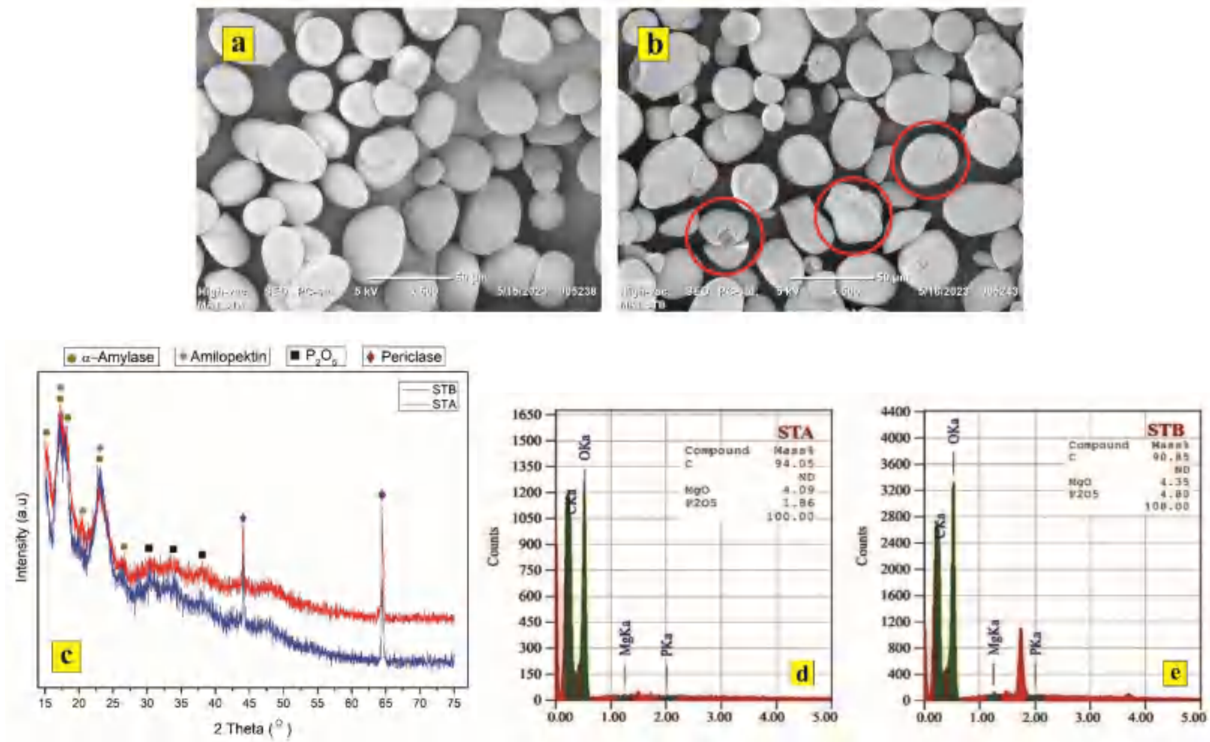


**FIGURE 2.** (a) SEM image of starch (STA), (b) SEM image of starch (STB), (c) Difractogram of sago starch, (d) EDS of STA, and (e) EDS of STB

There are several peaks observed in the *Tawaro* starch (STA) and *Tawaroduri* starch (STB) samples, which were identified as four phases: α-amylose phase at 2θ angles of 15.32°, 17.08°, 17.84°, 22.92°, and 25.19° with crystal planes (020), (013), (121), (123), and (024) having a chemical formula of $(C_6H_8O_4)n$ and an orthorhombic crystal [10] structure as recorded in the ICDD#00-043-1858 database. The amylopectin phase was observed at 2θ angles of 15.32°, 19.56°, and 22.92° with a chemical formula of $(C_6H_{10}O_5)n$, in accordance with the ICDD#00-052-2248 database [11]. In addition to these two phases, contaminants $P_2O_5$ and Periclase $(Mg_2O_4)$ were also identified in *Tawaro* starch (STA) and *Tawaroduri* starch (STB) based on the COD#96-231-1014 and COD#96-901-3251 databases, respectively. These contaminants in *Tawaro* (STA) and *Tawaroduri* (STB) starches are likely due to the use of groundwater or contaminants already present in the sago plants during the sago starch extraction process. Furthermore, the composition of impurities in STB sago starch is greater than STA as seen in Fig. 2(d) and 2(e). The $P_2O_5$ composition in STA is only 1.86%, while in STB, it is 4.80%. This can affect the physical characteristics of sago starch, which can be observed in *Tawaroduri* starch (STB), which exhibits a reddish color due to the presence of phenolic compounds caused by the interaction between $Mg_2O_4$ and *Tawaroduri* starch (STB), the relative higher content of $P_2O_5$, and genetic factors in sago plants [12]. The presence of phenolic compounds in sago starch (STB) affects the appearance of both sago starch samples. STA and STB sago starches show granules with various shapes, ranging from round to elongated (oval) and oval with notches. The SEM results in Fig. 2(a) show that STA sago starch granules tend to have an oval shape with smooth and intact surfaces. On the other hand, STB sago starch in Fig. 2(b) displays more abstract granule shapes with surface defects [3]. This is caused by the higher water content in the STB sample, which can be seen in the broader absorption band of -OH groups at 3572 $cm^{-1}$ compared to the absorption band of STA sago starch, resulting in granule expansion, polymer leakage from the granules [8], and ultimately changing the granule

...of STA sago starch granules shows absorption at the wavenumber of 1652 $cm^{-1}$, corresponding ...etching bond, supported by the absorptions at wavenumbers 1240 $cm^{-1}$, 1161 $cm^{-1}$, 1056 $cm^{-1}$, ...C-O ether stretching bonds [14], as depicted in Fig. 3. The absorption of the C=O (carbonyl) ...o starch is likely due to the presence of tightly bound water molecules within the starch molecule ...identifies that *Tawaro* material (STA) contains a higher amount of amylose compared to

*Tawaroduri* material (STB), as indicated by the absorption bands in the fingerprint region at the range of 1200 - 990 $cm^{-1}$, which strengthens the characteristics of C-O stretching in C-O-C and C-O-H in the glycosidic ring of sago starch [8], [16], [17].

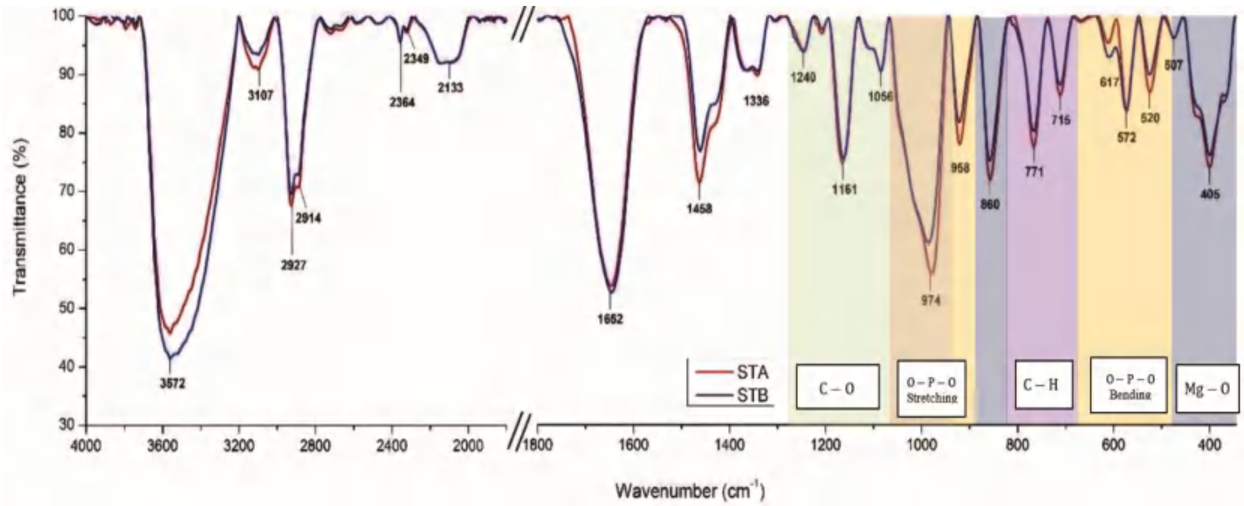


**FIGURE 3.** The FT-IR spectra of *Tawaro* starch (STA) and *Tawaroduri* starch (STB)

Based on the microstructural testing of *Tawaro* starch (STA) and *Tawaroduri* starch (STB), it appears that the content of amylose and amylopectin is quite similar between the two starches. High amylose and low amylopectin content can enhance the mechanical and thermal properties of bioplastics, as supported by the long linear chain of amylose and the intact granule structure acting as reinforcement material [6], [13]. Some previous researchers have also reported that high amylose content results in homogenous bioplastics with stronger shear resistance, characterized by high hardness and firm elasticity [3]. However, STB sago starch contains phenolic compounds that damage the granule shape. A damaged granule shape can decrease the quality of tensile strength when this sago starch is processed into bioplastics [13]. This is why we chose to use STA sago starch in bioplastic production.

## Microstructure of Sago Starch (STA) Bioplastic Specimens

*Tawaro* starch (STA) was selected to be processed into bioplastic. The results of HMT (Heat Moisture Treatment) of *Tawaro* starch (STA) can be seen in Table 1, which shows the reduction in moisture content during the HMT process.

**TABLE 1.** Data HMT of Sago Starch (STA) as the base material for bioplastics

| No. | HMT Duration (hours) | Moisture Content (%) | Description |
|---|---|---|---|
| 1. | 0 | 34.90 | Specimen A |
| 2. | 2 | 11.32 | Specimen B |
| 3. | 4 | 7.10 | Specimen C |
| 4. | 5 | 0.00 | Specimen D |

The *Tawaro* starch (STA) that has undergone HMT was made into 4 bioplastic specimens, which were then characterized to observe the changes in microstructure due to variations in HMT duration. The XRD results of the bioplastic specimens show that the α-amylose phase is still visible at angles 2θ 17.01° and 21.85° for specimens A and D, and the amylopectin phase is detected at angles 2θ 17.01°, 19.49°, and 21.85° [18], corresponding to the ICDD#00-043-1858 and ICDD#00-052-2248 databases. In addition to these two phases, different phases are formed e to the interaction between glycerol, acetic acid, and *Tawaro* starch, as shown in Fig. 4.

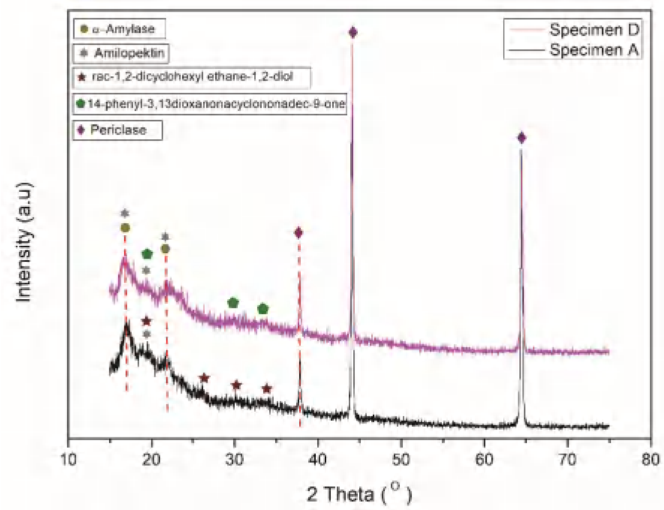


**FIGURE 4.** Difractogram of bioplastic specimens A and D.

Specimen A with a moisture content of 34.90% and specimen D with a moisture content of 0% in Fig. 5 and Table 2, have similar intensity for each absorption band, except for the absorption band at 1032 $cm^{-1}$, which represents the (C-O) functional group affecting the formation of chemical chains. This is supported by the difference in phases formed due to the interaction between starch, glycerol, and acetic acid. Additionally, specimens B and C exhibit acidification in the broadening of the absorption band of the -OH group, indicating that *Tawaro* starch (STA) undergoing HMT for 2 and 4 hours undergoes gelatinization or a change from a solid form to a gel-like form, as previously conducted [6]. This results in the accumulation of the -OH group into the / starch (STA), causing imperfect interaction between the -OH group contained in starch and glycerol and acetic acid compounds due to the -OH groups already strongly bonded to the *Tawaro* starch (STA), as indicated by the absorption band at 1032 $cm^{-1}$ for the (C-O) functional group, which plays a role in binding glycerol to *Tawaro* starch (STA).

**TABLE 2.** FT-IR spectrum data of the bioplastic specimens.

| **Gugus Fungsi** | **Wave number ($cm^{-1}$)** | | | |
|---|---|---|---|---|
| | **Spesimen A** | **Spesimen B** | **Spesimen C** | **Spesimen D** |
| O-H stretching | 3446.79 | 3448.72 | 3566.38 | 3450.65 |
| C-H ($sp^3$) stretching | 2927.94 | 2929.87 | 2927.94 | 2924.09 |
| C = O stretching | 1649.14 | 1649.14 | 1647.21 | 1649.14 |
| $-CH_2-$ bending | 1460.11 | 1460.11 | 1460.11 | 1462.04 |
| C-O *stretching* | 1029.99 | 1026.13 | 1024.2 | 1028.06 |

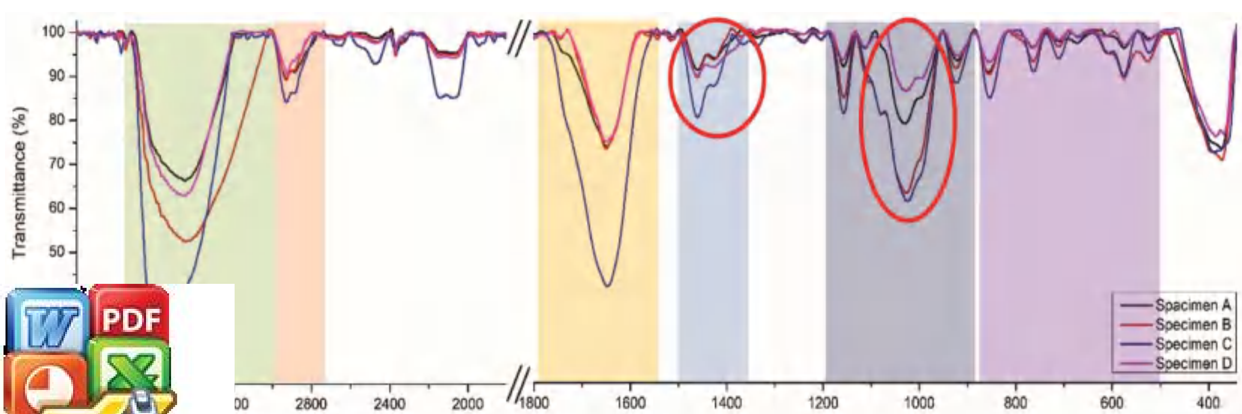




**FIGURE 5.** FT-IR spectrum of the bioplastic specimens.

The comparison of tensile strength data in Fig. 6 for the HMT treatment on starch materials shows that the values are almost the same as the untreated specimen. However, specimen D, which has a moisture content of 0.0% and a tensile strength value of 0.254 MPa, shows an increase in strength due to the HMT treatment and is still superior to the other specimens [19]. The testing results also show a strain value of 0.247 and an elasticity value of 1.101 MPa, indicating that specimen D is the stiffest bioplastic compared to the other specimens. From Figure 6, it is also evident that the HMT treatment on STA sago starch tends to increase or enhance the tensile strength value [15]. This occurs due to the varying moisture levels contained within the starch granules, which affects the absorption of liquids and other elements during the gelatinization process [20]. This process is demonstrated in the FTIR spectrum, showing changes in the absorption of specific wavebands, especially the -OH and C-O functional groups that play a role in forming linear bonds [3], enhancing crystallinity, and improving the tensile strength of the bioplastic specimens [19].

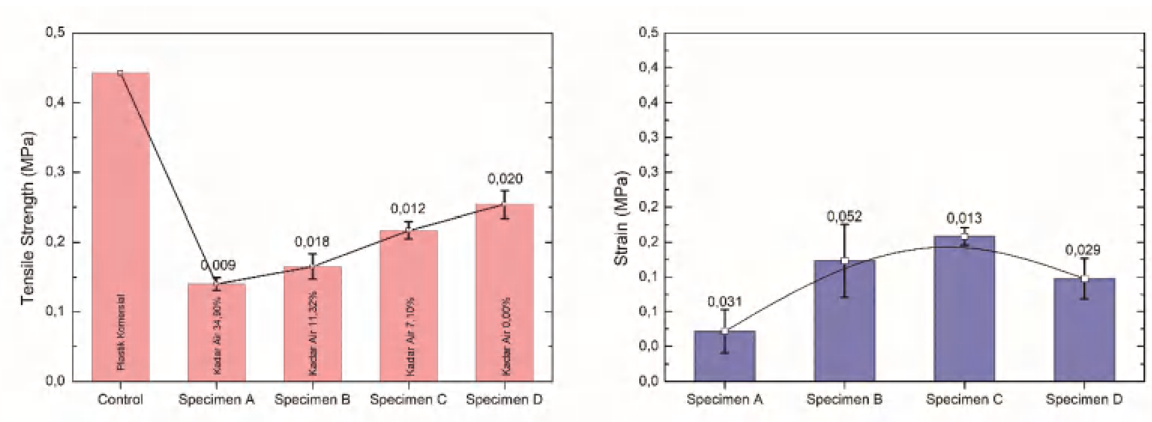


**FIGURE 6.** Tensile strength and strain of bioplastic specimens.

## CONCLUSION

Sagu *Tawaro* starch (STA) is considered the highest quality starch without flavonoid compounds, with an amylose content of 36.49%. This starch exhibits linear protruding α-amylose chains and uniform particle shapes based on microstructural characterization. Due to its high quality, *Tawaro* sago starch (STA) is used as the main material in the production of bioplastic specimens. Bioplastic specimens made from *Tawaro* sago starch (STA) that have undergone the HMT process at a temperature of 100°C for varying durations show reduced moisture content. The control starch specimens have moisture content of 34.9% (Sample A), 11.32% (Sample B), 7.10% (Sample C), and 0.0% (Sample D). Among the bioplastic specimens, Sample D performs the best, with a tensile strength value of 0.296 MPa, as evidenced by its well-mixed (homogeneous) microstructure. Sample D also exhibits a high elasticity value of 2.045 MPa compared to the other samples. However, the tensile strength value of Sample D has not yet reached the standard of commercial plastic. Therefore, further research is required concerning the appropriate composition ratio of sago starch, glycerol, and acetic acid to improve the bioplastic's properties.

## ACKNOWLEDGMENTS

The author would like to thank the sago processing area in Mancani Village, Telluwanua District, Palopo City, South Sulawesi Province, Indonesia, for supplying sago in this research.

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