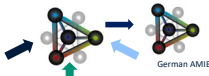
Fully Biobased Fibers

Naveen Kumar Balakrishnan
Polymer Engineering Group
Prof. Dr–Ing. habil. Dipl.–Wirt. Ing. G.H. (Gunnar) Seide
05.09.2023

Maastricht University

1

Aachen-Maastricht Institute for Biobased Materials



German AMIBM e.V.

Maastricht University
- 17,454 Students (2016)[1]
  - >50% foreign students
- 491 Professors[1]
- 342 PhD Candidates[1]
- 404.53 Million € (2016)[1]

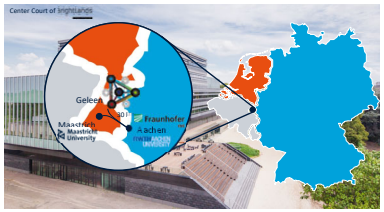
Fraunhofer
- 527 Employees[2]
- 52.8 Million €[2]
- >190 Publications (2017)[2]

RWTH Aachen University
- 45,377 Students (2017)[3]
  - 7,165 Graduates
- 547 Professors[3]
- 4,436 PhD Candidates[4]
- 948 Million €[3]

1: Facts & Figures UM 2016, 2017/18
2: Fraunhofer IME Annual report
3: RWTH key Data 2017;
4: Datenblatt Studierende WS17/18

Maastricht University 2

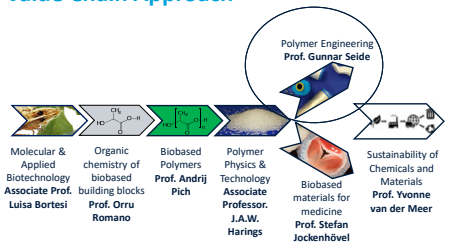
2



Maastricht University 3

3

Value Chain Approach



Maastricht University

4

Melt Spinning Filament Infrastructure

Lab scale	Pilot scale	Technical scale
		
• Batch processing (4-5 g) • Winding speed 150 m/min	• Twin-screw compounder with spinning possibility (KETSE 2040) • Continuous (1 kg/h) • Winding speed 1500 m/min	• Continuous (now up to 3.5 kg/h) • Bico-option is ordered and expected to come in September 2023 • Throughput with bico: upto 10 kg/hr) • Winding speed 4200 m/min

Maastricht University

5

Melt Spinning Staple fibre infrastructure

IFGAsota

- Upto 10000 filaments simultaneously
- Production speed between 40-270 kg/h
- Temperatures upto 330 °C
- High speed crimper
- Fixing (segmented hot/cold air) channel

Maastricht University 6

6

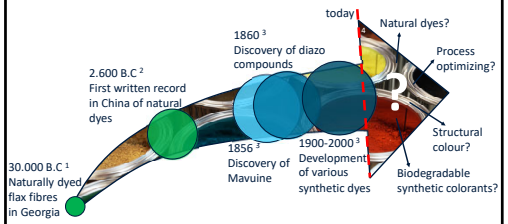
Introduction

- European Textile Industry: €162 Billion
  - Man-made fibers: €80.9 million tons in 2020
  - PET is a major player €48 million tons
  - Huge dependence of fossil-based resources
  - Focus on biobased polymers
- Colorants – one of the most commonly used additives
  - Market of €98 Billion by 2030
  - Majority of dyes used are fossil-based
  - Some azo based dyes are even toxic, and mutagenic
  - Can be applied through bath/dope dyeing

Maastricht University

7

State of the art

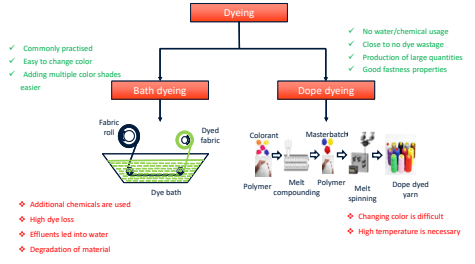


1: Kvavadze, E. et al.: 30,000 Years Old Wild Flax Fibers: Science: 2009
2: http://www.quiltthistory.com/dye.htm
3: Bien HS., et al.: "Anthraquinone Dyes and Intermediates": Ullmann's Encyclopedia of Industrial Chemistry, 2005
4: http://www.naturfarben-gottsdorf.de/

Maastricht University

8

State of the art



Maastricht University

9

Problem Statement

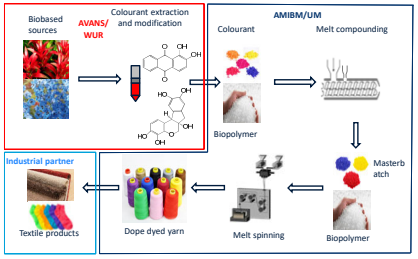
- Textile industry is heavily dependent on fossil-based resources
  - Both polymer and colorants come from this
  - Some of the colorants used are toxic
- Bath dyeing is very commonly used
  - Dye loss is a problem
  - Effluents pollute water resources

Goal: Develop PLA based textiles with biobased colorants

Maastricht University

10

Biobased colorants for dope dyeing

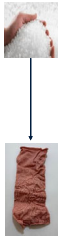


Maastricht University

11

Materials and Methods

- Polylactic acid (PLA)
  - Grade L130 from Total|Corbion
- Madder root extract-MR (Red colour)
  - Contains anthraquinones
  - Root of Rubia tinctorum L. was ground
  - Extracted using Ethanol
- Curcuma Longa extract (Curcumin)



Maastricht University

Derksen, G.C.H., Holthaan, F.L.V., Willemen, H.M., Krul, C. A. M., Franssen, M. C. R., van Beek, T. A.; Development of a process for obtaining non-mutagenic madder root (Rubia tinctorum) extract for textile dyeing, Industrial Crops & Products; V. 164, 2021

12

Materials and Methods

Bath dyeing

1. Melt spinning → PLA granules
2. Texturizing → PLA yarn
3. Knitting → Texturized yarn
4. Bath dyeing → Knitted fabric → Dyed fabric

Dope dyeing

1. Compounding → PLA granules + dye
2. Melt spinning → Dyed masterbatch
3. Texturizing → Dyed yarn
4. Knitting → Texturized yarn → Knitted fabric

Maastricht University 13

13

Bath dyeing

1. Melt spinning → PLA granules
2. Texturizing → PLA fibres
3. Knitting → Texturized yarn
4. Bath dyeing → Knitted Fabric → Dyed fabric

Maastricht University 14

14

1. Melt spinning

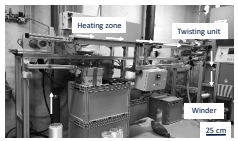
- FET melt spinning line
- 210 °C
- **Winding speed of 2500 m/min**
- Fineness of 268 dtex

Maastricht University 15

15

2. Texturizing

- False twist texturizing
- Heated to 145 °C
- Winding speed of 200 m/min
- Fineness of 210 dtex



3. Knitting

- Circular knitting machine

Maastricht University 16

16

4. Dyeing

- Performed on a Datacolar Ahiba IR
- Pre-rinsed in sodium bicarbonate solution
- Mordanting with aluminium sulfate and tartaric acid
- Dyed with 5% of madder extract at 98 °C
- pH of dye bath was 7
- A fabric to liquor ratio of 1:10 was used
- Washed with tap water

Maastricht University 17

17

Dope Dyeing

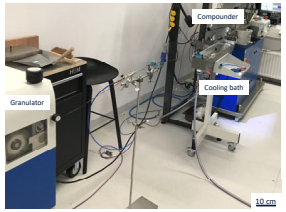
1. Compounding → PLA granules + dye
2. Melt spinning → Dyed masterbatch
3. Texturizing → Dyed yarn
4. Knitting → Texturized yarn → Knitted fabric

Maastricht University 18

18

1. Compounding

- Performed using a Brabender KETSE 20-40 twin-screw extruder
- Temperature of 210 °C

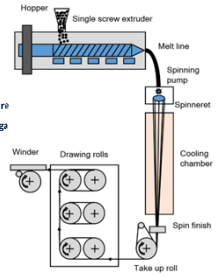


Maastricht University 19

19

2. Melt spinning

- FET melt spinning line
- 210 °C
- **Winding speed of 500 m/min for Madder Root**
- **Winding speed of 2500 m/min for pure PLA and PLA dyed with Curcuma Longa**

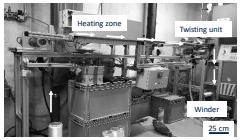


Maastricht University 20

20

3. Texturizing

- False twist texturizing
- Heated to 145 °C
- Winding speed of 200 m/min
- Fineness of 210 dtex
- Possible only with Curcuma Longa



4. Knitting

- Circular knitting machine

Maastricht University 21

21

Results and Discussion

Investigation

1. Mechanical properties
2. Gel Permeation Chromatography

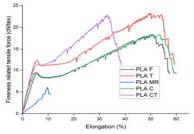
Maastricht University 22

22

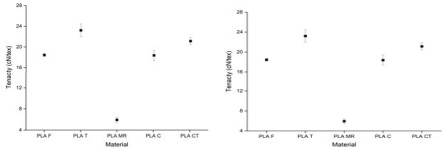
Results and discussion

Mechanical Properties

- ZwickLine Z2.5 low-force tensile machine
- DIN EN ISO 1973, testing length of 200 mm and testing speed of 200 m/min



Dope Dyeing with MR leads to loss in mechanical properties



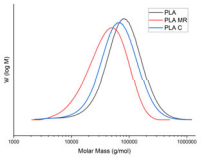
Maastricht University 23

23

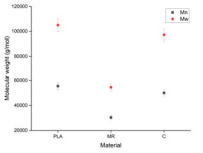
Results and discussion

Gel Permeation Chromatography (GPC)

- Hexaflurorisopropanol GPC was used
- Reduction in molecular weight means degradation



Dope dyeing with Madder root extract leads to degradation



Maastricht University 24

24

Conclusion & Outlook

- Knitted PLA ✓
- Bath dyeing of PLA with madder root extract ✓
- Dope dyeing is of PLA with madder root extract X
  - Degradation and loss of mechanical properties
  - Burnt brown colour
- Dope dyeing of PLA with Curcuma Longa ✓

- Other chemicals (Sugar) present in the extract need to be removed before dope dyeing
- Supercritical CO_2 dyeing can be a better alternative to use the extract

25

Acknowledgement

- This research is a part of the Beautifully biobased fibres project funded by the NWO
- Members of the Polymer Engineering Group and AVANS Hogeschool

26

Thank you for your kind attention

27

28