The Efficiency of Naturally Derived Pigments from Microorganisms, Fungi, and Plants in Dyeing Fabric

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Introduction

Picture 1: Monascus red dyed strips

Natural pigments

- Also known as biopigments, natural colorants or micropigments (fungi, bacteria)

- Reference all pigments created by living organisms

- Used since ancient times but decreased in popularity

- Have started to resurface

Perspective Application

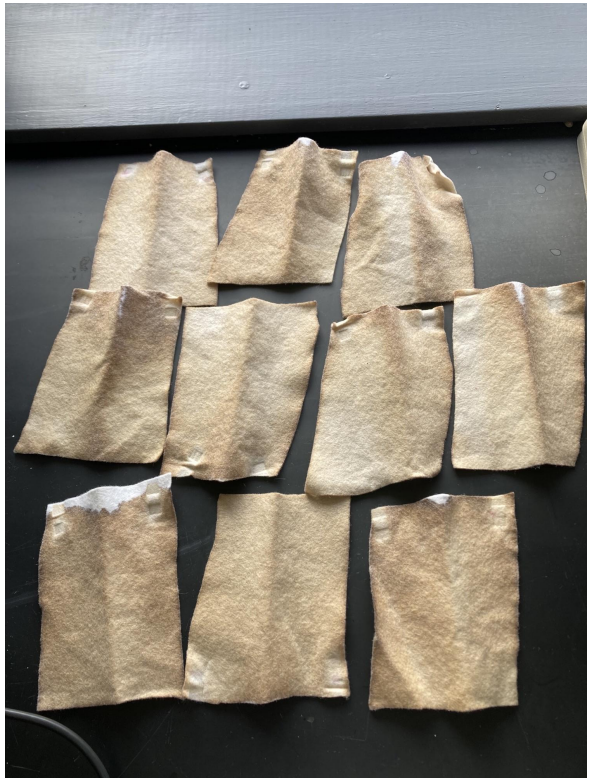
- Create a sustainable alternative
    - Waste
    -Unrenewable resources

- Limit the impacts of Synthetics
    -Pollution
    -Other

- Increase cost effectiveness

- Meet social demand

Picture 2: Textiles dye waste water; https://arviatechnology.com/case-studies/case-study-removal-of-chemical-dye-from-textile-wastewater/



Picture 3: *Quercus robur* dyed strips

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Background

Literature Review

Dyeing History/ Dyeing Process:

- A Brief History Of Colour, The Environmental Impact Of Synthetic Dyes And Removal By Using Laccases. (Ardila-Leal et al., 2021)

- Global Communities, Biotechnology, and Sustainable Design- Natural/ Bio Dyes in Textiles (Carvalho & Santos, 2015)

Literature Review

Plants:
- Extraction of Natural Dyes for Textile Dyeing from Coloured Plant Wastes Released from the Food and Beverage Industry (Bechtold et al., 2005) -
- Preparation of Biomass Pigments and Dyeing Based on Bioconversion (Gong et al., 2018)
- Textiles Coloured With Natural Dyes Of Vegetal Origin (Dolca, 2018)

Bacteria:
- Microbial Pigment as an Alternative to Synthetic Dye (Jha et al., 2017)
- Microbial Pigments as an Alternative to Synthetic Dyes and Food Additive: a Brief Review of Recent Studies (Aman et al., 2022)
- Bacterial Secondary Metabolites as Biopigments for Textile Dyeing (Kramar & Kostic, 2022)

Fungi:
- Colorfastness of Extracted Wood-staining Fungal Pigments on Fabrics: a New Potential fo Textile Dyes (Hinsch et al., 2015)
- Production of Fungal Pigments: Molecular Processes and Their Applications (Lin & Xu, 2022)

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Research Questions

Picture 4: Lawsone dyed wool segments after spectrophotometer test

RQ1

Can microbial and other natural pigments be used to dye textiles based on quantity yield produced, and quality of saturation?

H_0: Microbial, fungal, and natural pigments cannot be used to dye a textile based on yield of pigment, and quality of saturation based on absorbance value and transmittance percentage .

RQ2

What biopigments produce the most yield of pigment during application when dyeing textiles?

H_0: The microbial pigments will not produce a bigger yield of pigment compared to the other natural alternatives by milligrams/milliliter.

RQ3
Which biopigment has the best color output?

H_0: The plant pigments will not produce the best color output compared the other biopigments based of absorbance value and transmittance percentage.

Picture 5: *Allium cepa* Peel Dye bath

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Research Methods

Pigments

Fungi: Xylindein (*Chlorociboria aeruginosa*); Draconin red (*Scytalidium cuboideum*)

Alter. Fungi: p-Benzoquinone; Lawsone

Bacteria: Monascus (*Monascus sanguineus);* Melanin *(Aspergilus carbonarius)*

Alter. Bacteria: Red Yeast Rice; Synthetic Melanin

Plant: Oak Leaves (variation); Onions (*Allium cepa*)

Control/Comparison: Synthetic Red dye

Dye

Dye Bath/ Incubation: Water & 95% Ethanol, 60 mins, Uptake for 30 secs
Drying: 24+ hours

Fabric

100% Wool strips
10 strips per dye
50 ¼ inch strips for color analysis

Color tests

Absorbance Value (ABS) Transmittance Percentage (T%)
Optical Observation (Averages compared)

Yield

Based on ratio of weight to volume of solvent (mg/mL)
Averages compared

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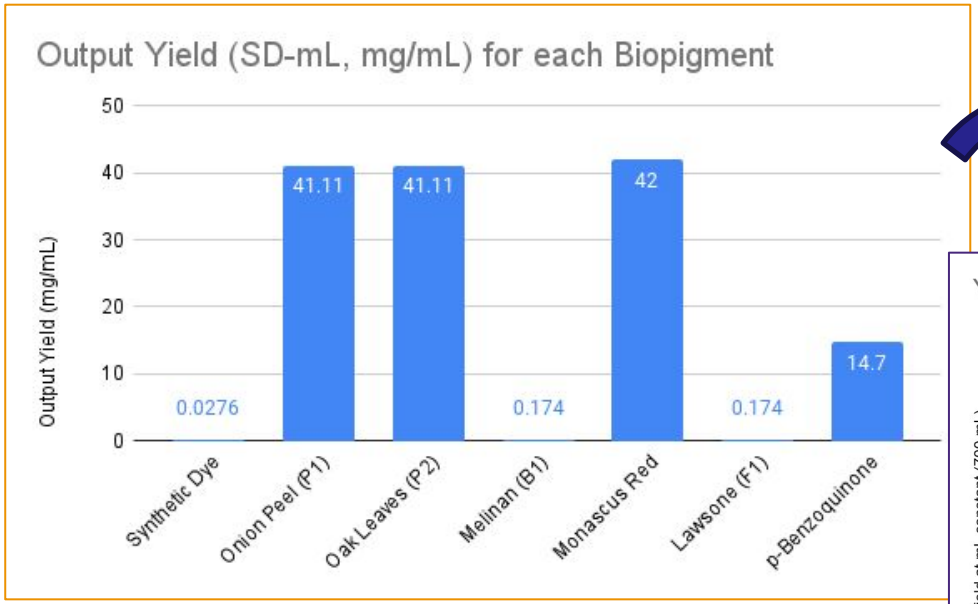
Results

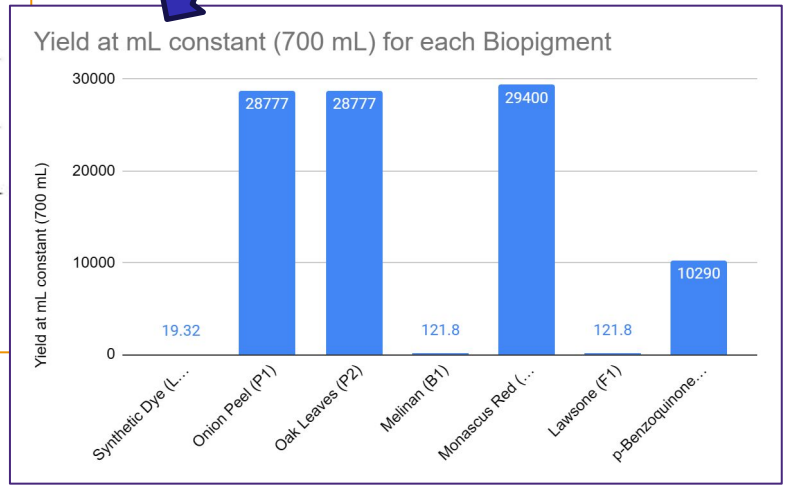
Picture 6: (top) Onion Peel dyed wool strips, (Bottom) Synthetic dyed wool strips

Visible Color

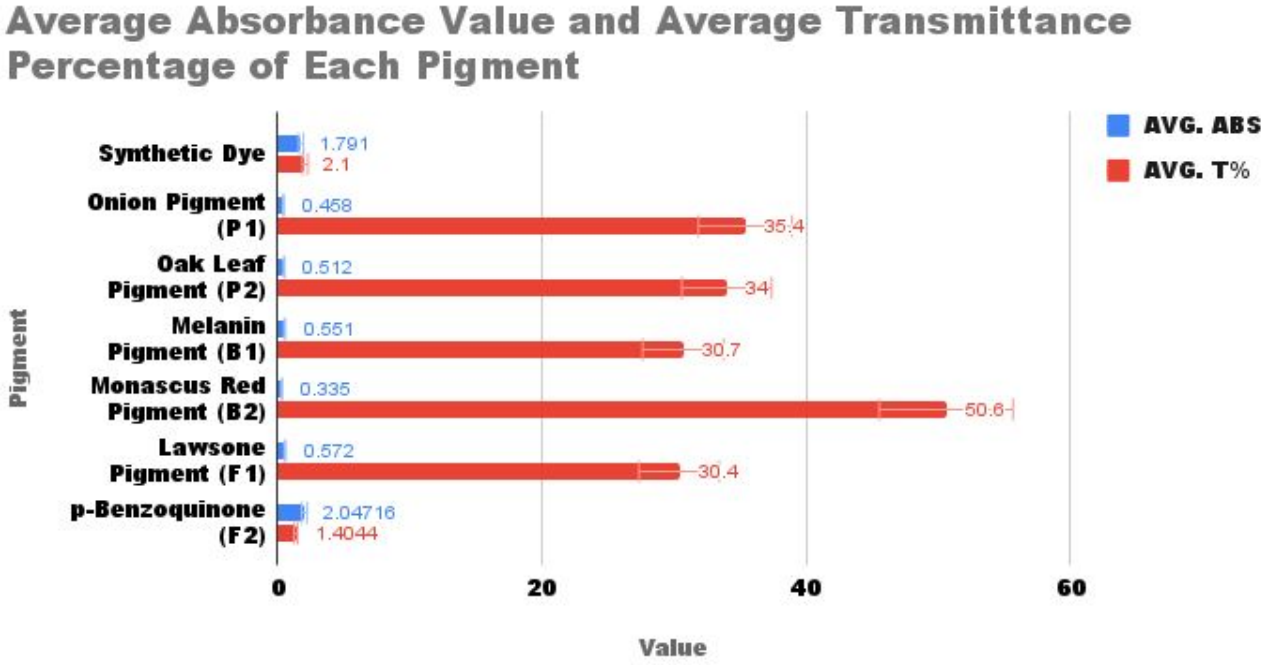
	Visible Color on Fabric
Synthetic Dye (Liquid)	Red
Onion Peel (P1)	Yellow/Tan
Oak Leaves (P2)	Brown/Tan
Melinan (B1)	Black
Monascus Red (B2)	Light Red
Lawsone (F1)	Orange/Yellow
p-Benzoquinone (F2)	Brown/Tan

Output Yield in (mg/mL)





Average ABS and T% per Pigment



ANOVA Test Results

ANOVA table (Type II)

Hover over the cells for formulas and calculation.

Source	DF	Sum of Square (SS)	Mean Square (MS)	F Statistic (df_1,df_2)	P-value
Factor A - rows (A)	6	45707.066	7617.844	120.773 (6,686)	< 2.2e-16
Factor B - columns (B)	1	112788.729	112788.729	1788.155 (1,686)	< 2.2e-16
Interaction AB	6	53068.959	8844.827	140.226 (6,686)	< 2.2e-16
Error	686	43269.772	63.075		
Total	**699**	**254834.526**	**364.57**		

Chi-Squared test and paired t-test Results

Chi-Squared Test of Association:

- x^2 = 58.854
- P-value= 0.000128

Paired T-test:

- P-value= .0001
- Df = 349

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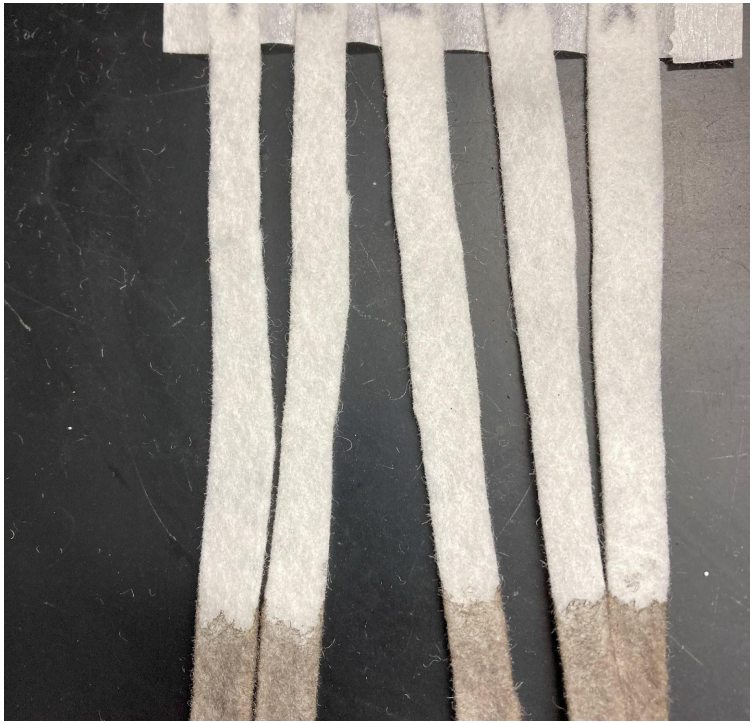
Discussion



Picture 7:Melanin dyed wool strip after spectrophotometer test

Errors and Research Against Hypotheses

Production yield:

- No pigment production or fermentation of B1, F1, or F2 pigment
- Human error of Strain

Color Analysis:

- Highest ABS and lowest T% were fungal alternatives

Quantity Yield:

- F1 one of the lowest ratio (.174)

Research Supporting Hypotheses

Bio pigments can dye fabric:

- Change in ABS and T% from plain wool
- All yield outputs produced color
- (Ardila-Leal et al., 2021, Rice, 1974, Kramer & Kostic, 2022, & Shirata et al., 2000)

Significance was determined:

- ANOVA, chi-squared, t-test all less then .05

Color Analysis:

- Lawsone= highest ABS and lowest T%
- (Che & Yang, 2022)

Yield Output:

- B1 one of the lowest ratios (.174)
- (Rana et al., 2021).

Future Prospects

- Knowledge of more species

- Mixtures of Biopigments to create new colors

- Bio waste as a source

Conclusion

https://www.pngarts.com/explore/133498

https://www.tiedyeyoursummer.com/Technique/heart-tie-dye-technique

Thank you for listening!!

Questions?

https://www.pngall.com/color-png/download/60480

Citations

Aman, M. M., Hossein, A., Saeed, M., Hosseini, S. M., & Dufossé Laurent. (2022). Microbial pigments as an alternative to synthetic dyes and food additives: a brief review of recent studies. Bioprocess and Biosystems Engineering, 45(1), 1-12. https://doi.org/10.1007/s00449-021-02621-8

Ardila-Leal, L. D., Poutou-Piñales, R. A., Pedroza-Rodríguez, A. M., & Quevedo-Hidalgo, B. E. (2021). A brief history of colour, the environmental impact of synthetic dyes and removal by using laccases. *Molecules*, *26*(13), 3813. https://doi.org/10.3390/molecules26133813

Bechtold, T., Mussak, R., Mahmud‐Ali, A., Ganglberger, E., & Geissler, S. (2005). Extraction of natural dyes for textile dyeing from coloured plant wastes released from the food and Beverage Industry. *Journal of the Science of Food and Agriculture*, *86*(2), 233–242. https://doi.org/10.1002/jsfa.2360

Bonev, B., & Cartwright-Jones, C. (2003). Lawsone. Henna Page. https://www.hennapage.com/henna/encyclopedia/lawsonia/

Bronze-Uhle, E. S., Piacenti-Silva, M., Paulin, J. V., Battocchio, C., & Graeff, C. F. de O. (2015, August 29). Synthesis of water-soluble melanin. arXiv.org. https://arxiv.org/abs/1508.07457

Carvalho, C., & Santos, G. (2015). Global Communities, biotechnology and sustainable design – natural / bio dyes in textiles. *Procedia Manufacturing*, *3*, 6557–6564. https://doi.org/10.1016/j.promfg.2015.07.956

Che, J., & Yang, X. (2022, October 11). A recent (2009–2021) perspective on sustainable color and textile coloration using natural plant resources. Heliyon. https://www.sciencedirect.com/science/article/pii/S2405844022022678

Citations

Dolca, C. (2018). TEXTILES COLOURED WITH NATURAL DYES OF VEGETAL ORIGIN. *Scientific Bulletin Series D : Mining, Mineral Processing, Non-Ferrous Metallurgy, Geology and Environmental Engineering, 32*(2), 81-89. http://library.keystone.edu:2048/login?url=https://www-proquest-com.keystone.kohacatalog.com:2443/scholarly-journals/textiles-coloured-with-natural-dyes-vegetal/docview/2186993250/se-2\

Dufossé, L., Padhan, B., Lim, G. B., Martínez, J. M., Mussagy, C. U., Macıas-Sánchez, M., Macías-Sánchez, M., Pasquet, V., Guillard, C. L., Castro-Puyana, M., Gilbert-López, B., Molino, A., Pinheiro, N., Morcelli, A., Khoo, K. S., Liu, C., Parniakov, O., Bernaerts, T. M., Herrero, M., … Mohammed, E. (2023, June 8). Microbial pigments: Eco-friendly extraction techniques and some industrial applications. Journal of Molecular Structure. https://www.sciencedirect.com/science/article/abs/pii/S0022286023010517

Gong, J., Wang, F., Ren, Y., Li, Z., Zhang, J., & Li, Q. (2018). Preparation of biomass pigments and dyeing based on bioconversion. *Journal of Cleaner Production*, *182*, 301–312. https://doi.org/10.1016/j.jclepro.2018.01.219

Hinsch, E. M., Weber, G., Chen, H.-L., & Robinson, S. C. (2015). Colorfastness of Extracted Wood-staining Fungal Pigments on Fabrics: a new potential for textile dyes. *JTATM: Journal of Textile and Apparel, Technology and Management* , *9*(3), 1–11. https://jtatm.textiles.ncsu.edu/index.php/JTATM/article/view/8018/4094

Jha, J., Meenu, K., Sinha, P., & Priyargini. (2017). Microbial Pigment as an Alternative to Synthetic Dyes. *IRIS- Journal for Young Scientists*, *7*, 50–58. https://patnawomenscollege.in/upload/IRIS%20Vol.%20VII/Details/iris-t9.pdf

Kramar, A., & Kostic, M. M. (2022). Bacterial Secondary Metabolites as Biopigments for Textile Dyeing. *Textiles*, *2*, 252–264. https://doi.org/https://doi.org/10.3390/textiles2020013

Citations

Jha, J., Meenu, K., Sinha, P., & Priyargini. (2017). Microbial Pigment as an Alternative to Synthetic Dyes. *IRIS- Journal for Young Scientists*, *7*, 50–58. https://patnawomenscollege.in/upload/IRIS%20Vol.%20VII/Details/iris-t9.pdf

Kramar, A., & Kostic, M. M. (2022). Bacterial Secondary Metabolites as Biopigments for Textile Dyeing. *Textiles*, *2*, 252–264. https://doi.org/https://doi.org/10.3390/textiles2020013

Lin, L., & Xu, J. (2022). Production of Fungal Pigments: Molecular Processes and their Applications. *Journal of Fungi*, *9*(1), 1–25. https://doi.org/10.3390/jof9010044

MedKoo BioSciences. (2020, February). Lawson Safety Data Sheet. Product Data Sheet. https://www.medkoo.com/uploads/product/Lawsone/product_insert/ProductData-Lawsone.pdf

Prabhu, K. H., & Bhute, A. S. (2012). Plant based natural dyes and mordants: A Review. Scholars Research Library. https://www.scholarsresearchlibrary.com/articles/plant-based-natural-dyes-and-mordnats-a- review.pdf

Shirata, A., Tsukamoto, T., Yasui, H., & Hata, H. (2000, April). Isolation of bacteria producing bluish-purple pigment and use ... ResearchGate. https://www.researchgate.net/publication/283814437_Isolation_of_bacteria_producing_bluish-purple_pigment_and_use_for_dyeing

Sigma-Aldrich. (2024, March 4). p-Benzoquinone Safety Data Sheet. Safety Data Sheet. https://www.sigmaaldrich.com/US/en/life-science/safety\

Rana, B., Bhattacharyya, M., Patni, B., Arya, M., & Joshi, G. K. (2021, February 8). The realm of microbial pigments in the food color market. Frontiers. https://www.frontiersin.org/articles/10.3389/fsufs.2021.603892/full

Rice, M. C. (1974). Let's Try Mushrooms for Color. Thresh Publications.