RGC Ref. No.:
UGC/FDS16/E01/20
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

The development of polylactide green composites with coffee grounds and tea leaf powder waste

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Ir Dr LI Jimmy Chi-ho / Assistant Professor	Department of Construction and Quality Management, School of Science and Technology, Hong Kong Metropolitan University
Co-Investigator	Ir Dr TANG Fanny Wai-fan / Assistant Professor	Department of Construction and Quality Management, School of Science and Technology, Hong Kong Metropolitan University
Co-Investigator	Dr CHIU Winnie Wai-hang / Lecturer	Department of Construction and Quality Management, School of Science and Technology, Hong Kong Metropolitan University
Co-Investigator	Ir Dr MAK Shu-lun /Principal Lecturer.	Youth College (Kwai Chung), Vocational Training Council

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	1 January 2021	1 January 2021	

Project Completion Date	30 June 2023	31 December 2023	11 May 2022
Duration *(in month)*	30	36	11 May 2022
Deadline for Submission of Completion Report	30 June 2024	31 December 2024	11 May 2022

4.4 Please attach photo(s) of acknowledgement of RGC-funded facilities / equipment.

Injection machine

Injection mould – Spoon

Injection mould - Tension strength testing specimen.

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. **Study** the feasibility of developing low cost new green composite materials and apply in injection molding and 3D printing as well as displaying better uses of waste materials
2. **Investigate** the effects of pretreatments on mechanical; chemical properties and environmental resistance of spent coffee ground, tea leaf powder wastes and PLA materials by determining the optimal composition of different green materials
3. **Evaluate** the strength, biodegradability and productivity of the new green composite materials
4. **Investigate** the effects of pretreatments on properties of new green composites
5. **Compare** and analyse the mechanical strength of the moulded products

5.2 Realisation of the objectives

The first objective of developing new green composite materials using various waste materials and bioplastics is the main focus, with research on plastic wastes and bamboo used for the production of wall tiles being discussed, and exploring the feasibility of utilising plastic waste materials and bamboo fibers as eco-friendly alternatives to traditional composite materials. A different approach to the use of spent coffee grounds and tea leaf powder as filler materials in polylactic acid (PLA) for 3D printing applications is also researched. The optimal composition of these green materials for use in 3D printing and evaluate their mechanical properties is determined. Further evaluation on eco-friendly PLA/natural fiber composite filaments for 3D printing is carried out, using natural fiber as a reinforcing material in PLA to improve the mechanical properties of the final product, with the strength parameters of the new green composite materials being assessed, showing promising results.

Regarding the second objective, the investigation of the optimal composition of different green materials for 3D printing applications by the new filament made of PLA and coffee and tea waste fibre mixture. The effects of varying the amounts of spent coffee grounds, tea leaf powder, and PLA on the mechanical properties are being investigated.

For the third objective, the strength of the new green composite materials, ranging from bamboo and plastic mixture to the PLA-spent-coffee-grounds being investigated for their material properties and prospective applications, along with the biodegradability of the PLA-coffee composite.

The effects of pretreatment are discussed in the study of the extraction of coffee grounds oil extraction, with the effects of reduced oil in coffee grounds and the reinforcement properties on the PLA plastic being investigated.

The final objective of comparing the mechanical strength of the 3D printed products with different compositions of green materials is also addressed for the PLA-biofibre composites. The mechanical properties of the 3D printed products made from different compositions of spent coffee grounds, tea leaf powder, and raw PLA are being compared, with the mechanical strength of the 3D printed products made from different compositions of natural fiber and PLA also being evaluated and assessed.

5.3 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. Study the feasibility of developing low cost new green composite materials and apply in injection molding and 3D printing as well as displaying better uses of waste materials	✓	100%
2. Investigate the effects of pretreatments on mechanical; chemical properties and environmental resistance of spent coffee ground, tea leaf powder wastes and PLA materials by determining the optimal composition of different green materials	✓	100%
3. Evaluate the strength, biodegradability and productivity of the new green composite materials	✓	100%
4. Investigate the effects of pretreatments on properties of new green composites	✓	100%
5. Compare and analyse the mechanical strength of the moulded products	✓	100%

6. Research Outcome

6.1 Major findings and research outcome

The high consumption of polymeric materials has led to the significant issue of plastic waste disposal, prompting the need to prioritize plastic waste recycling as a critical research topic. Similarly, the widespread use of bamboo scaffolding in China's construction industry has resulted in a considerable amount of bamboo waste. Therefore, investigating the recycling and reuse potential of bamboo waste. Also, the rise of caffeinated drinks in the form of coffee has led to the rise in spent coffee grounds, providing materials for the production, especially in recycling the plant fibres in the processed coffee grounds for improving properties of PLA plastic, a common biodegradable plastic that is commonly used in 3D printing.

The studies in the project found that recycled plastic wastes and bamboo could meet the requirements for manufacturing wall tiles. In addition, recycling spent coffee grounds as well as spent tea leaves for reinforcing PLA plastic can produce desirable and distinguishable improvement of the 3D printing material over the pure PLA counterpart. The effects of pretreatments on the mechanical and chemical properties of spent coffee grounds and PLA materials are investigated, with the mechanical, chemical, and thermal properties being assessed, along with promising strength and biodegradability being found on the materials.

The processes of processing the plant fibres for reinforcing plastics are also researched and improved, be it through the thermal treatment, or the oil-extraction pretreatment of coffee grounds. The research discovered ways to improve the material quality of the plant waste materials, as well as preliminary research into optimizing the processing processes on an industrial scale.

The new materials are being compared with existing materials and is found the mechanical properties are superior to the basic counterpart, however at an increased cost to varying degrees.

6.2 Potential for further development of the research and the proposed course of action

The research has demonstrated the feasibility of recycling plastic waste, bamboo waste, and spent coffee grounds for producing reinforced plastics. However, the processes need to be scaled up to an industrial level to make a significant impact on waste reduction and resource conservation. Further research into refining the processing and developing cost-effective methods for large-scale production is needed with industrial cooperation.

While the new materials have shown improved properties over their basic counterparts, there is still room for further improvement. For example, the thermal stability of the PLA-coffee ground composites could potentially be enhanced by incorporating additives, such as nanoparticles or compatibilizers. In addition, the oil-extraction pretreatment of coffee grounds could be optimized to maximize the quantity of the extracted oil, for the improved pretreatment of the plant fibres for use.

And finally to fully assess the environmental impact of the new materials, a life cycle analysis (LCA) should be conducted to evaluate their carbon footprint, energy consumption, and water usage. This would help to identify the potential environmental hotspots in the production process and provide guidance for further improvement.

7. Layman's Summary

The research project aimed to develop low-cost, eco-friendly composite materials for use in injection molding and 3D printing, utilizing waste materials such as plastic, bamboo, spent coffee grounds, and tea leaf powder. The study found that recycled plastic wastes and bamboo could meet the requirements for manufacturing wall tiles, while spent coffee grounds and tea leaves could be used to reinforce polylactic acid (PLA) plastic, a biodegradable plastic commonly used in 3D printing. The optimal composition of these green materials was investigated, and the effects of pretreatments on their mechanical, chemical, and thermal properties were assessed. The new materials were found to have promising strength and biodegradability, and the processes for processing plant fibers for reinforcing plastics were improved. The mechanical properties of the new materials were compared with existing materials and found to be superior, albeit at an increased cost. The research also explored ways to optimize the processing processes on an industrial scale. Overall, the study demonstrated the feasibility of utilizing waste materials to create eco-friendly composite materials with potential applications in various industries.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				**Author(s)** *(denote the corresponding author with an asterisk*)*	**Title and Journal / Book** *(with the volume, pages and other necessary publishing details specified)*	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2023				S. L. Mak*, M. Y. T. Wu, W. Y, Chak, W. K. Kwong. W. F. Tang, C. H. Li and C. C. Lee	A Review of the Feasibility of producing Polylactic acid (PLA) Polymers using Spent Coffee Ground *Sustainability*	No	Yes [Attachment 1]	Yes	Yes
2022				S. L. Mak*, W. F. Tang, C. H. Li, C. C. Lee, M. Y. Wu, W. Y, Chak and W. K. Kwong	Spent Coffee Ground based polymeric materials for 3D printing, *Chapter 7, 3D Printing Revolution and Sustainable Product Development, Taylor and Francis, USA*	No	Yes [Attachment 2]	Yes	Yes

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered
(Please attach a copy of each conference abstract)

Month / Year / Place	**Title**	**Conference Name**	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
December 2021, Singapore	A Study on Recycling the Plastic Wastes with Bamboo on Making Wall Tiles	The 2021 International Conference on Industrial Engineering and Engineering Management, IEEE	2022	No	Yes	Yes

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning
(Please elaborate)

No

11. Student(s) Trained
(Please attach a copy of the title page of the thesis)

Name	**Degree Registered for**	**Date of Registration**	**Date of Thesis Submission / Graduation**
Nil			

12. Other Impact
(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

No

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
No. of outputs arising directly from this research project	1	1	1	0	Type	No.
					0	0

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
Nil	