EXCELLENCE IN AFRICA

100 PHDS FOR AFRICA

PhD Proposal

Applicant name	FOKAM FOKAM MAURANE GAELLE
Title	Elaboration, characterization and study of the behavior of a BioSource composite material : using natural resin as matrix and banana leaf fiber as reinforcement agent.
Home institution	National Advanced School of Engineering Yaounde (ENSPY)
Supervisor at home institution	Supervisor: Pr. KENMEUGNE Bienvenu Co-Supervisor of Thesis: Dr. FOKAM BOPDA Christian.
Possible EPFL co-supervisor **(Please do not contact this person)**	Pr. ANSERMET Jean-Philippe

PhD Proposal

1. Background and purpose of the study

Please briefly describe the background of your proposed research, its novelty, and its overall objectives

The agricultural sector is vital for Cameroon as it employs around 50% of the working population. Apart from agro-industrial plantations (CDC, PHP, etc.), banana cultivation is carried out by small family farms which gather together in cooperatives.

According to FAOSTAT, Cameroon produced around 1,203,440 tons of bananas in 2018. Very often, after harvesting the bunch of bananas, the trunk, leaves and stalk are usually thrown out into the wild as waste. The aim of this thesis project is to provide a market value to this banana waste, for products that can be used locally. Our application is to promote local resources by providing an additional outlet for farmers faced with fluctuations in the prices of food products on national and international markets.

This thesis project is part of a favorable national context. In 2020, Cameroon adopted a new vision of growth during the National Development Strategy Council 2020-2030 (SND30). The aforementioned objectives are maintained with a priority to supply the national market with products stamped "made in Cameroon".

Thus, the fibers from agricultural waste from the banana tree in Cameroon (particularly fibers from the leaf) will be used for the development of a new bio-composite material with natural resin for the manufacture of useful objects (such as: plates, bowls, cups, etc.) obtained by thermoforming.

Recent research authors are mostly interested in fibers gotten from the pseudo-trunk of banana as per Bhuvaneswari et al., (2017), Nataraj et al., (2018), Guna et al. (2018). Apart from Chengoué et al, (2020), very few are the relevant studies on banana fibers gotten from Cameroon's soil.

The General objective is to contribute to the economic growth of farmers by recycling certain food waste for the manufacture of thermoformed objects while respecting the precepts of sustainable development

2. Research questions/hypotheses
Please articulate your research questions, explaining the problems and issues that will be explored and why they are worth exploring

Main Research Question: What are the qualities of the bio-composite material / objects made from banana leaf fibers and natural resin?
Main scientific sub-questions addressed

- What is the best method of extracting fibers from the banana leaf?

This will involve conducting a comparative study on the different extraction processes (mechanical, chemical retting, natural retting, cooking with water, etc.) of fibers from banana leaves and their impact on the physical/mechanical properties and the extraction efficiency.

- What are the physicochemical and mechanical properties of banana fibers compared to known natural fibers?

This will be a multi-staged physical fiber characterization study. This characterization will be physicochemical (content of cellulose, hemicellulose, extractable compounds, lignin, density, water, adsorption rate), mechanical (modulus of elasticity, tensile strength, elongation at break) and thermal (thermal conductivity, thermal stability, flammability). These results will make it possible to consider other possible domains of application suitable for the fibers studied.

- What is the compatible organic plant resin in terms of matrix / banana fiber cohesion?

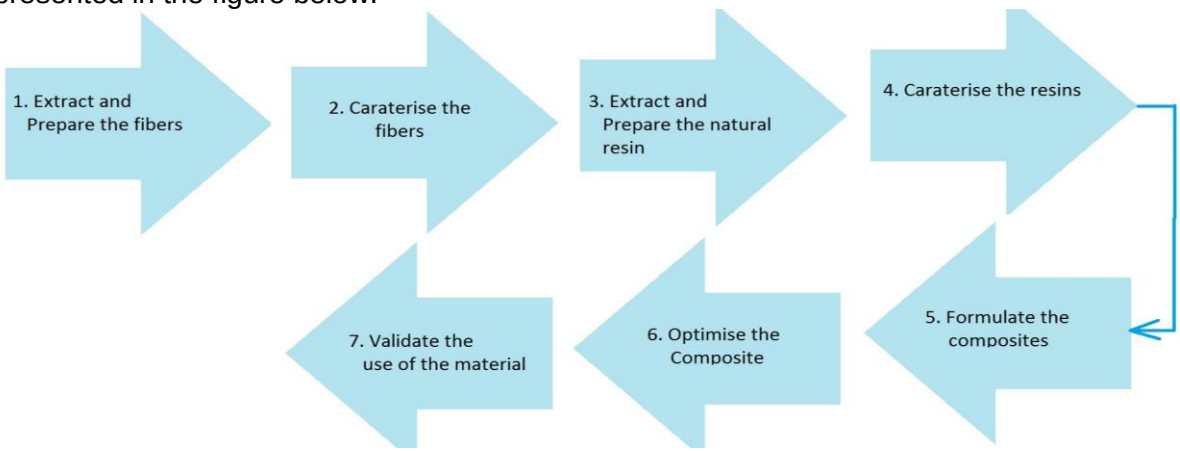
Here, we will be interested in determining the most compatible plant resin and providing properties other than the fibers of the banana leaf. An important step in the extraction and characterization of the different resins.

- What mixture in proportion of resin and fiber gives better properties of the bio-composite material? Which fiber format (long, short) gives better properties?

In response to these questions, various experimental protocols will be deployed in order to determine the physical characteristics (density, porosity, absorption rate, biodegradability, permeability to water vapor, etc.) and mechanical (Young's modulus, ultimate resistance). , ultimate elongation, impact resistance…).

3. Research Method
Please outline the research approach (theoretical framework) and the research methods appropriate for the proposed research

The research method will be mainly experimental. The experimental design approach will be used to control and optimize the tests. The different stages of our research approach are presented in the figure below.



To carry out this work and achieve the objectives mentioned above, we will follow the framework below:

- **State of the art on banana fibers**
- **Chemical, Physical and Mechanical characterization of the fiber**
  - Extraction of fibers (banana leaves fibers);
  - Preparations of the different test specimens;
  - Observation of the morphology at different scales of the banana leaf fiber (Scanning Electron Microscope: SEM)
  - Determination of density, kinematics of water absorption and desorption
  - Chemical characterization.
    - ATG: Study of mass losses at different temperatures,
    - DTG: Fiber degradation temperature (useful for configuring the thermoforming process),
    - FTIR: Type of chemical bond between micro fibrils Density, absorption and desorption kinetics;
- **Resin characterization**
  - Extraction of resin from plant essences
  - Viscosity (Rheometers)
  - Determination of gel time, DSC method;
  - Determination of the structure of molecules:
  - **RMN^{13}C**: confirms whether the structure of the molecule contained in the resin is exactly what we are looking for.
  - Determination of the structural formula of the resin (mass spectrum)
  - Dimensional variations of the resin as a function of temperature: Thermomechanical analysis (TMA)

Implementation and characterization of the thermoformed material

- Fiber preparation and formulations
- Shaping of composite panels
- Determination of the behavior and mechanical characteristics (tensile tests, 3-point bending, resilience, etc.)
- Dynamic mechanical behavior (resilience, Charpy test, etc.)

- Determination of density,
- Thermal conductivity of the panels.
- Panel sound conductivity test
- Mold rate: assess the amount of water the material may contain when exposed to the open air.
- Fire resistance test: evaluate the time for which the material is completely calcined according to the amount of heat supplied by a furnace
- Study of fiber / resin cohesion (FTIR)

4. Timeline and milestones
Please describe the various stages and corresponding timeline for developing and implementing the research, including the writing of your thesis

2020 to 2021: Literature review and identification of banana collection site and preparation of fiber and resin samples
2021 to 2022 Characterization, chemical, physico-mechanical of the components
2022 to 2023: Development and characterization of the bio-composite material.
2023 to 2024: Final writing and publication, Defense process

5. Collaboration
Please highlight the added value of joint supervision by your prospective EPFL co-supervisor. The PhD proposal must describe the envisaged collaboration with EPFL. The research goals must be aligned with the objectives of EXAF

A jointly supervised thesis offers the doctoral student the opportunity to benefit from the means (equipment, supervision, etc.) of the two institutions involved in the training of the candidate. EPFL is a large institution that is organized into platforms (electron microscopy, NMR, characterization of materials). The EPFL co-supervisor will facilitate my integration into his university, and will be able to direct me to local resources useful for the success of my research.
In addition, the supervision by an EPFL co-supervisor will allow me to benefit from the expertise of a teacher-researcher working in a world-renowned scientific environment with practical knowledge on the creation of startups. We hope to discover scientific opportunities and outlets not yet envisioned in the current state of our understanding.

This joint supervision with EPFL is also the opportunity to benefit from a different approach, based on very powerful means of investigation, and to face an atmosphere of high-level scientific research.
In this thesis project, the collaboration with EPFL will take place during the following activities;

- Active joint supervision between the two institutions, through a clearly identified co-supervisor within EPFL (in our case, Professor ANSERMET Jean-Philippe).
- Preparation for travel and stay in Switzerland for the doctoral student and / or local supervisors (administrative documents, accommodation, campus access cards, etc.)
- Establishment of an experimental program (characterization of bases and mechanical tests).

- Carrying out experiments in different EPFL platforms or centers, as well as standard measurements with the instruments available for practical work in the physics and chemistry sections,
- Access to the EPFL library
- Participation in scientific conferences
- Writing of the thesis

EPFL will play a critical role in the success of this research because I could find the following characterization equipment there:

- A tensile machine to perform the mechanical characterizations of the fiber and the composite material;
- A scanning electron microscope that can quickly provide information on the morphology and chemical composition of the fiber;
- A device allowing me to perform the various analyzes (ATG, DTG, DSC and FTIR) of the fiber, the resin, and the composite material;
- Equipment allowing the chemical composition of the fiber to be carried out (ethanol, hydrochloric acid, deaf, hydrogen peroxide, sodium chloride, etc.);
- An apparatus for performing the following different analyzes: **RMN^{13}C**, Gel-time, Maldi-tof and TMA;
- An apparatus for performing three-point bending on the samples;
- A hot isostatic press allowing me to perform the processing, thermal conductivity and center rate of the composite material;

6 Ethics
6.1 Please state if the proposed research involves the use of local genetic resources of plant, animal, bacterial, or other origin, and, if so, how benefits will be shared
6.2 Please explain if the proposed research will benefit local communities (e.g. through capacity building, access to healthcare, education, etc.)

My proposed research topic involves the use of local plant-based resources: banana leaves and resins from local wood species.

The proposed research project falls directly within the framework of local economic development. Indeed, it is about offering other economic opportunities to farmers (especially banana producers) by helping to give a market value to the waste products of agriculture.

This research topic is first of all a feasibility study on the use of waste from agricultural products in the implementation of a new material (reinforced with fibers from its waste) and its use in the manufacture of everyday objects by thermoforming. The demonstrated performance of objects obtained by this new material will contribute to the emergence of new economic activity. It will require having a sustainable production chain for banana fibers from agricultural waste (industrial or artisanal).

7. List of bibliographic references for all preceding sections

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[2] Chengoué Mbouyap A., T. Tchotang , C. Bopda Fokam , B. Kenmeugne, (2020) Influence of extractions techniques on the physico-mechanical properties of banana pseudo-stem fibers J. Mater. Environ. Sci., 2020, 11(7), pp. 1121-1128;

[3] Guna V.K., G. Murugesan, B.H. Basavarajaiah, M. Ilangovan, S. Olivera, V. Krishna, Karthick R., Adithya K., Hariharaprasath C., Abhisheck (2018). Evaluation of mechanical behavior of banana fiber reinforced hybrid epoxy composites. Materials Todays: Proceedings 5 (2018) 12814-12820

[4] Nataraj D., S. Sakkara, Meenakshi HN, Narendra R., 2018. Properties and applications of citric acid crosslinked banana fibre-wheat gluten films 0926-6690/ 2018 Elsevier

[5] Venkateshwaran N, Elayaperumal A. Banana Fiber Reinforced Polymer Composites - A Review. Journal of Reinforced Plastics and Composites. 2010;29(15):2387-2396. https://doi.org/10.1177/0731684409360578

[6] Nicollin A.. Développement de matériaux composites écologiques à base de résines de tannins et de renforts de fibres végétales. Ph.D . Université de Lorraine, 2014. Français. ⟨NNT : 2014LORR0086⟩. ⟨tel-01750809⟩

[7] Segovia C., Sauget A., Besserer A., Kueny R., Pizzib A.,(2016) “Evaluating mold growth in tannin-resin and flax fiber biocomposites”, Industrial Crops and Products Volume 83, May 2016, Pages 438-443

[8] Wang S, Kaneko D., Kan K., Jin X., Kaneko T., Syntheses of hyperbranched liquid-crystalline biopolymers with strong adhesion from phenolic phytomonomers, Pure and Applied Chemistry | Volume 84: Issue 12 (2012). https://doi.org/10.1351/PAC-CON-12-05-12