Federal Ministry
of Food
and Agriculture

PHD PROGRAM OF BMEL

CoffeeChar: *Valorization of by-products from wet coffee processing: waste to carbon-rich material using hydrothermal carbonization to improve the sustainability of the coffee value chain in Vietnam.*

country/countries	Germany and Vietnam
funding agency	Federal Ministry of Food and Agriculture – BMEL
project management	Federal Office for Agriculture and Food – BLE
project coordinator	Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Potsdam.
project partner(s)	Germany: • Industrial Network: Bayerischer Bauernverband, Maschinen- und Betriebshilfsring Rhön-Grabfeld, Agrokraft GmbH und Artec GmbH. • University: Technical University of Dresden (TUD)

	Vietnam: • University: Van Lang University, HCM City (VLU) • Industrial partner: Phuoc An Coffee One Member Limited Company, Dak Lak province. (PA) • Company: GreenMessage-Water and Environment Limited Company, HCM City. (GM)
project budget	192.231,52 €
project duration	01/09/2019 – 30/09/2023 (with extension)
key words	coffee value chain, hydrothermal carbonization, wet-processing, coffee by-products, sustainability, hydrochar.
background	Coffee beverages play an important role in society and their consumption continues to grow worldwide. As coffee demand grows, so do expectations of product quality and sustainability. This poses particular challenges for coffee producers and is leading to changes in the way coffee is grown and processed around the world. These changes need to be managed in a way that ensures a fair income for coffee farmers. The same is true in Vietnam, the world's leading producer of robusta coffee. To enhance Vietnam's competitiveness, the government has initiated policies to move towards more certified sustainable coffee production and shift coffee berry processing from dry to wet methods. This shift may disrupt traditional recycling pathways for coffee by-products between the field and processing. Coffee by-products are generated throughout the coffee value chain, with similar amounts coming from primary processing (dry and wet methods) of coffee berries into green coffee beans (e.g. hulls, wet outer skins, silver skins and parchment) and from secondary processing of coffee beans into coffee beverages (spent coffee grounds – SCG). Incorrect disposal of the by-products can cause adverse environmental impacts, besides wasting their potential as a renewable energy source that can be utilized for drying or roasting coffee beans or as a soil amendment to recycle carbon and nutrients to the soil.
objective	The purpose of this project was to investigate the feasibility of integrating the HTC process into the coffee processing sector in Vietnam to valorize wet solid by-products to improve the sustainability of the value chain by:

	1) reducing the need for fossil fuel, 2) recycling carbon and nutrients to the soil, 3) avoiding GHG and odor emissions from improper disposal of the wet solid wastes, and 4) improving the wastewater effluent quality from coffee-processing plants.
results	The results of the project were published in three peer-reviewed papers: 1. Farru, G., Dang, C. H., Schultze, M., Kern, J., Cappai, G., & Libra, J. A. (2022). Benefits and Limitations of Using Hydrochars from Organic Residues as Replacement for Peat on Growing Media. Horticulturae, 8(4), 325. Online: https://doi.org/10.3390/horticulturae8040325 2. Dang, H.; Farru, G.; Glaser, C.; Fischer, M.; Libra, J.A. (2023): Enhancing the Fuel Properties of Spent Coffee Grounds through Hydrothermal Carbonization: Output Prediction and Post-Treatment Approaches. Sustainability. (1): p. 338. Online: https://doi.org/10.3390/su16010338 3. Dang, H.; Cappai, G.; Chung, J.; Jeong, C.; Kulli, B.; Marchelli, F.; Ro, K.; Román, S. (2024): Research Needs and Pathways to Advance Hydrothermal Carbonization Technology. Agronomy. (2): p. 247. Online: https://doi.org/10.3390/agronomy14020247 The major results are summarized here according to the overall project objectives. • *Current status of coffee by-product generation and disposal in the Vietnamese coffee value chain* The total amount of coffee by-products in each stage of the coffee value chain were estimated from national production statistics combined with information gathered from interviews with coffee farmers and coffee processors in the study region. Dry coffee processing is the most common method for local farmers in five coffee growing provinces in Vietnam (81% of respondents from 120 farmers). Most (60 %) are using coffee by-products for producing compost for their own farms, but 26% dispose of the coffee by-products on their farms without reuse.

- *Valorization of coffee by-products using HTC and post-processing treatments: Lab-scale experiments*

Lab-scale experiments showed that HTC can significantly improve the energetic properties of coffee by-products, e.g. the calorific value increased 32% for coffee processing by-products and 46 % for SCG, making them suitable for use as a substitute for fossil fuel. Models for the HTC outputs (solid yield, calorific value, energy yield) were developed and compared to published models. The models based on operating conditions and/or the composition of the feedstock predicted the three outputs with low error. Post-processing steps enhanced the properties of the hydrochars for potential applications. Agglomeration processes improved the handling and transportation of the fine-particle SCG-hydrochars as fuel or as soil amendments. Operation of the HTC process in the alkaline range (pH 7-13) with the processing by-products produced humic acids, which are recognized as important components in soil health and fertility. Germination tests with SCG and its hydrochar highlighted hydrochar´s potential to replace at least 5% of peat in growing media. The inhibitory effects of SCG were significantly decreased after hydrothermal and post-treatment (washing and drying).

- *Integration of a HTC system in coffee processing systems: Design of management schemes and HTC process combinations for fuel and soil applications*

Process combinations for the integration of a HTC system in 1) a wet processing system for coffee berries, as well as in 2) a spent coffee ground recycling scheme were developed with key stakeholders in Vietnam (Figure 1). The overall consensus of these stakeholders is that installing HTC can improve the sustainability of the coffee value chain in Vietnam In order to extrapolate this knowledge to other world regions, an information base made up of experimental data and procedures for estimating material flows was developed that can be used to evaluate the potential use of HTC-systems in other coffee producing regions.

- *Dissemination*

A network with national and international scientists/experts in the field of HTC, coffee processing, and/or by-product valorization in the coffee value chain in general was built up via conferences, workshops, publications and research visits.

recommendations	A key next step is the construction of an HTC demonstration plant in a coffee berry processing facility. Interviews with key stakeholders in five different coffee-producing provinces in Vietnam revealed a high potential for the integration of HTC in processing cooperatives producing high quality coffee. To support the current trend of farmer-cooperative collaboration in the wet processing of organic coffee, there is a need for the sustainable use of wet coffee by-products as renewable energy for coffee drying or as soil amendments for coffee plantations. The use of an HTC system can increase sustainable production, reduce or improve environmental impact and secure the income of those involved. Therefore, a follow-up study should be carried out to develop a technical design for integrating HTC into coffee berry processing processes for dry and wet coffee by-products. The steps would include scaling the material flows of feedstocks and products for various levels of production -from cooperatives to large scale processors, along with estimating potential CO_2-emission reductions from the replacement of fossil fuels in coffee drying facilities and chemical fertilizers in soil amendments. Furthermore, pilot or lab-scale studies should be performed on co-treating coffee by-products and other agricultural residues in these coffee regions. This can expand the HTC operations over the whole year while providing more products for energy and soil improvement for coffee farm cultivation. The information base that was started in this project should be continued within Vietnam and expanded to other coffee producing regions. Continuing the surveys with refined questionnaires about coffee processing methods and supply chains across various provinces will help maintain its relevance. An international collaborative project to evaluate the potential use of HTC-systems in other coffee producing regions is recommended to develop estimates of how our project results can be extrapolated to other regions.

photos

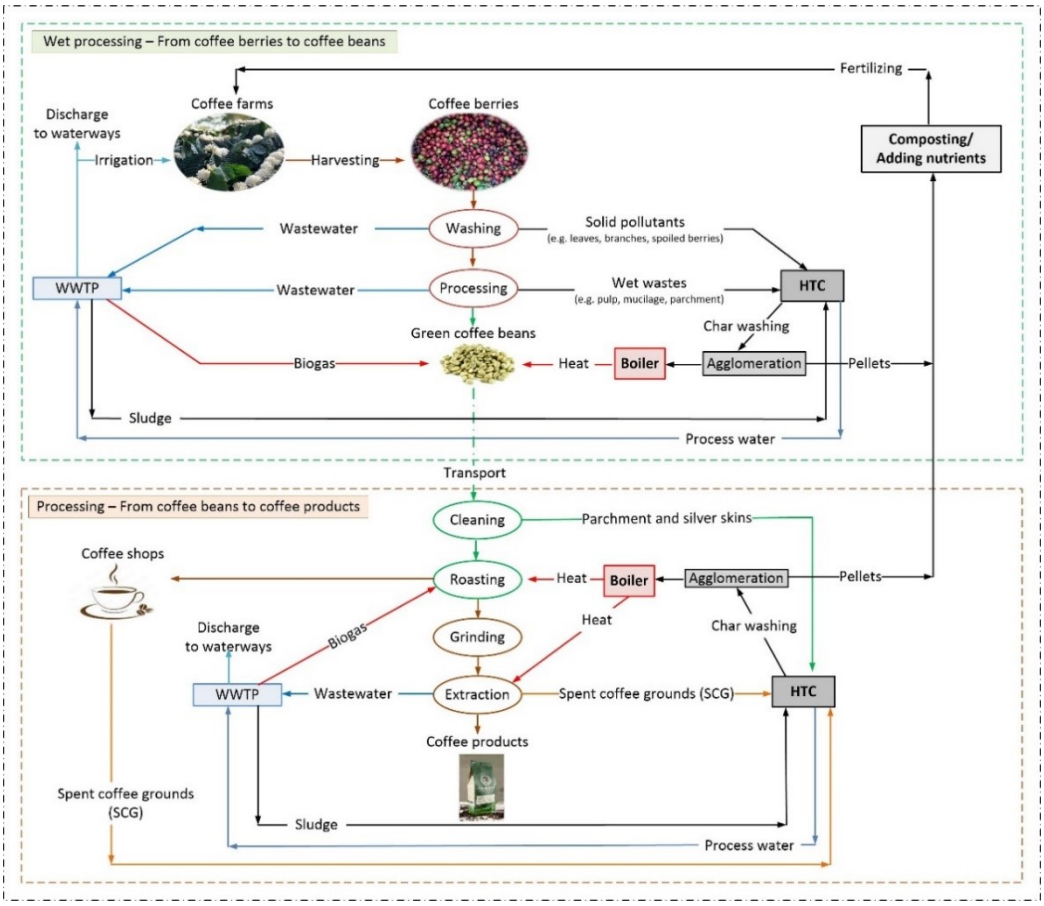

Figure 1. Conceptual design of HTC integration into the coffee value chain for treating coffee berry processing by-products and SCG (own design).

Figure 2. The secondary processing coffee chain with HTC integration – from green coffee beans to coffee char pellets.