

(続紙 1)

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論文題目	Environmental and Economic Sustainability Assessment of 4F (Food, Feed, Fuel and Fertilizer) towards Industrial Ecology Coffee (IEC) (Case study on a pilot plant at Andungsari Coffee Group-Bondowoso-Indonesia) インダストリアル・エコロジー・コーヒー (IEC) の確立に向けた 4F (食料、飼料、燃料、肥料) の環境的・経済的持続可能性評価 (インドネシアのアンドゥンサリ・コーヒー・グループの事例)		

(論文内容の要旨)

This research aims to identify the environmental, economic and quality implications of multiple coffee production processes.

The thesis consists of 9 chapters, starting with Chapter 1 Introduction and Chapter 2 Background to coffee production, and finishing with Chapter 9 Conclusions. The remaining 6 chapters represent the results of 7 sub-studies which consider different coffee processes and potential waste valorisation, including the production of biogas and alternative food products.

Chapter 3 presents the results of a study applying lifecycle assessment (LCA) to consider the main “wet” methods of processing coffee (full wash and semi-wash). Chapter 4 then considers the environmental impacts of dry methods to upgrade coffee quality (natural, anaerobic, lactic acid, hydro-honey, carbonic maceration, inoculant, mossto, wine). Chapter 5 provides an evaluation of the economic potential, including options for renewable energy that utilize wastewater for biomass production, in comparison to conventional fossil-fuel based energy. Chapter 6 then presented the quality assessment of some of the processed coffee, using cupping test results. Chapter 7 and Chapter 8 consider Industrial Ecology approaches for valorization of waste. Chapter 7 considered the production of “coffee tea” cascara, as well as modelling the roasting process energy consumption and emissions. Chapter 8 focused on the production of biogas from waste streams.

The main questions to be answered in this study were:

1. What is the environmental and economic impact on upstream to downstream coffee production from wet and dry methods when evaluated using Life Cycle Assessment (LCA) and Life Cycle Costing (LCC)?
2. To what extent does increasing the use of by-products in coffee processing also produce quality coffee with lower environmental impact?

This research employed a combination of multiple methods. Primary data were collected from a pilot plant in Indonesia. Experimental data for 10 different processes for processing coffee cherries to coffee products were obtained, as well as the mass and energy inputs from the farm through to coffee products. Biogas production was also undertaken and data obtained. For analysing the environmental impacts, lifecycle assessment (LCA) was the primary method used. The primary data were supplemented with secondary data from existing databases, which were analyzed using SimaPro software. Economic analysis on the basis of lifecycle costing (LCC) was undertaken using data obtained through

interviews and market surveys. Coffee quality was also tested using standard coffee quality tests undertaken by qualified coffee evaluators.

By applying industrial ecology principles through the integration of coffee plantation–coffee industry–and livestock, the study explored ways to enhance the sustainability of coffee production. For instance, wastewater to biogas, the valorisation of coffee by-products, such as coffee cherry skin, into value-added products like cascara was investigated. This not only reduced waste but also created additional revenue streams for farmers. Furthermore, implementing integrated farming systems combining coffee cultivation with other agricultural activities improved resource efficiency and reduced environmental impacts.

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(論文審査の結果の要旨)

The thesis presents a multi-method evaluation of the environmental, economic and quality aspects of coffee production, using primary data from a case study pilot plant in Indonesia. This data was used to undertake lifecycle assessment (LCA) to determine the environmental impact of alternative coffee processing methods. Quality of the coffee produced was also evaluated, and economic performance of alternative processing configurations with waste valorization estimated. No known previous studies have comprehensively evaluated coffee from farm to ground coffee across this wide variety of processes and with the inclusion of quality evaluation and industrial ecology approaches.

The unique and novel contributions of this study include:

1. This study used a combination of methods to evaluate environmental impacts and economic potential of 10 different coffee processing methods. Typical studies only evaluate one or two processes at most. Here the study considered standard wet processes (Full Wash and Semi-Wash); and dry processes used where water is more scarce (Natural process), as well as more-novel dry processes that could be used to upgrade coffee quality (Anaerobic, Lactic Acid, Hydro-Honey, Carbonic Maceration, Inoculant, Mossto, Wine).
2. Industrial Ecology principles were applied to reduce environmental impacts by waste valorization in the form of biogas production from wastewater and processing of coffee husk or coffee cherry skin to produce coffee tea “cascara” as a by-product. In particular, the consideration of cascara is quite unique in literature.
3. In this study the quality of the coffee product was assessed, in addition to the environmental and economic considerations – which is very rare in the literature.

よって、本論文は博士(エネルギー科学)の学位論文として価値あるものと認める。また、令和6年9月27日実施した論文内容とそれに関連した試問の結果合格と認めた。

論文内容の要旨、審査の結果の要旨及び学位論文の全文は、本学学術情報リポジトリに掲載し、公表とする。ただし、特許申請、雑誌掲載等の関係により、要旨を学位授与後即日公表することに支障がある場合は、以下に公表可能とする日付を記入すること。

要旨公開可能日：