| General information | |
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| PPP-number | TKI-AF-16104 |
| Title | Cocoashell biorefinery towards marketable bioproducts |
| Theme | Circulair |
| Implementing institute | Wageningen Food & Biobased Research |
| Project leader research (name + e-mail address) | Dr. Richard Gosselink (richard.gosselink@wur.nl) |
| Coordinator (on behalf of private partners) | Mrs. Anne Mertens-Hoyng, Cargill Cocoa & Chocolate, Schiphol |
| Project-website address | https://topsectoragrifood.nl/project/cocoashell-biorefinery-towards-marketable-bioproducts/<br><br>A teamsite hosted by WFBR was used. |
| Start date | 1 March 2017 |
| Final date | 30 June 2019 |

| **Approval by the coordinator of the consortium**<br>The final report must be discussed with the coordinator of the consortium. The "TKI's" appreciate additional comments concerning the final report. | |
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| Assessment of the report by the coordinator on behalf of the consortium: | ■ Approved<br>□ Not approved |
| Additional comments concerning the final report: | |

| Consortium | |
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| Mention any changes in the composition of the project partners: | Not applicable |

| Summary of the project | |
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| Problem definition | Cocoashells are a substantial sidestream of the cocoa and chocolate industry present in the Netherlands. Cocoashells are currently used in low added value applications like coverings for garden pathways, and as energy pellets. Fractionation of the main components of the shells could lead to more added value for this by-product. For this, a novel value chain will be built for the fractionation of underutilised cocoashells in an extractables fraction for flavor/food application (Cargill), a fibre fraction for added value innovative fibre application (Schut Paper) and a lignin-like fraction for the development of biobased carpet tile backings (Interface). |
| Project goals | Objective of this project is to increase the added value of cocoashell by refining the cocoashell into an extractables fraction, a cellulose fibre and a lignin fraction. |

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| **Results** | |
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| Planned results in the original project plan | Detailed characterised cocoashells<br>Development of a Lab-scale optimised cost-effective separation process with reduced carbon footprint<br>Scaled-up fractionation process to obtain relevant quantities of the cocoa shell fractions for application tests<br>Lab-scale analysis of floor tiles backing based on lignin from cocoa shell<br>Lab-scale analysis of specialty fibre products with fibres from cocoa shell<br>Scaled-up production process for specialty fibres<br>Scaled-up production series of floor tiles backing with lignin from cocoa shell<br>Evaluation of extractives and potential application building on lab-scale analysis<br>Prototype of specialty fibres products<br>Prototype of carpet tile lignin based backing<br>Report on techno-economic and environmental evaluation of cocoashell fractionation and products derived of |
| Achieved results | A biorefinery concept has been developed at a scale starting with 25 kg of cocoa shells.<br>To preserve the quality and properties of the water soluble cocoa ingredients, a mild hot water extraction was developed to extract about 30wt% of mass from the cocoa shells. This fraction is of high interest for Cargill to use in their food chain. Extraction of individual components was discussed, but needs more specific research.<br>Fractionation of the remaining shells after hot water extraction was performed by soda pulping under conditions which are milder then used in the pulping industry. However, the proteins present in the starting cocoa shells stayed in both the fibre as lignin fractions causing dewatering and processing issues. Removal of proteins by enzymes solved this issue and the resulting fibre fraction was suitable to blend with cellulose pulp to produce a specialty paper with acceptable dewatering characteristics. The cocoa shell fibres do not contribute to the paper strength, due to the morphology of the material, but add a special decorative feature to the specialty paper. A nice prototype of a cocoa shell based paper was produced.<br>The lignin-like cocoa shell fraction was difficult to purify on large scale and this lignin was not suited to use as polymer additive in a carpet tile backing. Alternatively, modified Kraft lignin in bitumen did not reach the properties of polymer modified bitumen. In the project a small scale prototype of carpet tile backings was prepared but lignin functioned only as a filler.<br><br>The preliminary techno-economic analysis showed the following results, with the current numbers based on a continuously operating factory of 10 Kton dry matter cocoa shell per year:<br>- Total costs of raw materials are 2.9 m€/year.<br>- The total revenue is 16,85 M€/year. This includes the disposal costs of the liquid residue stream, estimated at 0.3 M€/year.<br>- The fixed capital investment is estimated at 12.3 M€.<br>- The annual production costs are estimated at 10.3 M€/year.<br>Based on the current estimates, the cocoa shell biorefinery factory would be highly profitable.<br><br>Overall, positive prospects were found for fractionation of cocoa shell into its main component fractions, water extractives, fibre and lignin (polyphenol). Special emphasis should be paid to the efficient removal of proteins at large scale. Therefore a proof-of-principle has been obtained at labscale, but scaling to larger scale remained difficult. |

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| Explanation of changes relative to the project plan | We anticipated a delay in the development of the biorefinery concept mainly due to the complex composition of cocoashells and the necessity to remove the recalcitrant proteins from the shells. More work has been performed to focus on the removal of proteins via an environmental sound step using enzymes. To perform the upscaling and techno-economic analysis of the biorefinery process to tens of kg's an extension of the project was needed till 30 June 2019.<br>Scaling the fractionation process to larger scale was not possible due to issues of effective removal of proteins on 25 kg scale.<br>It was not possible to produce a purified lignin fraction from cocoa shells at larger scale. |

| **What was the added value created by the project for:** | |
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| Participating "Knowledge Institutes" (scientific, new technologies, collaboration) | WBFR: developed knowledge on composition of complex cocoa shells, individual fractions, components and the polyphenol fraction. Application of a novel process for extracting proteins from cocoa shells. A successful cooperation with 3 industrial partners in 3 different application areas. |
| Participating private partners (practical application of the results, within which period of time?) | Cargill is happy with this collaboration and the results obtained. Cargill will discuss internally how to proceed.<br>Schut Paper is satisfied about the learnings gained from this project, but have no concrete plans to continue this research.<br>Interface did not succeed in finding a functional substitute for the bitumen or rubber and will continue the search for alternative materials for their carpet tile products. Cocoashell lignin will be excluded from this, but lignin in general could still be valuable. |
| Society (social, environment, economy) | In this project a sound environmental friendly process has been developed on kg scale. Overall, positive prospects were found for fractionation of cocoa shell into its main component fractions, water extractives, fibre and lignin (polyphenol). |
| Possibly other stakeholders (spin-offs) | No concrete plan were discussed within the consortium. |

| **Follow-up** | |
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| Did the PPP result in one or more patents (first filings)? | No |
| Are there any follow-up projects planned? If yes, explain. (Contract research resulting from this project, additional funding, or new PPP projects) | A PhD proposal has been submitted in January 2020 within WUR to further study the complex structure and the effect of polyphenols fraction on fractionation of cocoa shells. |

| **Deliverables/products during the entire course of the PPP** (provide the titles and/or a brief description of the products/deliverables or a link to a website. |
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| Scientific articles:<br><br>The results of this project did not lead to a scientific article. |
| External reports:<br><br>An extensive confidential report has been written including the methods, techniques, and results. |

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| Articles in professional journals/magazines:<br><br>Not submitted. |
| (Poster) presentations at workshops, seminars or symposia.<br><br>On February 8th 2018, the project goals and achievements were presented by Richard Gosselink for the TKI AF committee in Wageningen. |
| TV/ radio / social media / newspaper:<br><br>Not applicable. |
| Remaining deliverables (techniques, devices, methods, etc.):<br><br>An extensive confidential report has been written including the methods, techniques, and results. |

https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksprojecten-LNV/Expertisegebieden/kennisonline/Cocoashell-biorefinery-1.htm