



### PPP-final report

PPP projects which are under supervision of the "Topsectoren" must file a final report concerning the total project period. This form is used to report the content of the project. There is a separate form for the financial reporting.


**The final report will be published on the TKI / topsector website. Therefore, please ensure that there is no confidential information in the final report.**

### General information

PPP-number	AF-17102b
Title	Exploration of electrochemical and integrated bi-catalytic chemo-enzymatic routes for starch modification
Theme	Biobased materials
Implementing institute	WFBR
Project leader research (name + e-mail address)	Carmen Boeriu, carmen.boeriu@wur.nl
Coordinator (on behalf of private partners)	Piet Buwalda
Project-website address	-
Start date	1.09.2017
Final date	31.12.2019

### Approval by the coordinator of the consortium

The final report must be discussed with the coordinator of the consortium. The "TKI's" appreciate additional comments concerning the final report.

Assessment of the report by the coordinator on behalf of the consortium:	<input checked="" type="checkbox"/> Approved <input type="checkbox"/> Not approved	 M.C. LAUS
Additional comments concerning the final report:		u-3-2020

### Consortium

Mention any changes in the composition of the project partners:	-
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### Summary of the project

Problem definition	The well-established starch industry faces the need to develop and implement greener technologies, to reduce the environmental footprint of current processes. Oxidation processes, in particular, generate high volumes of salt side streams that need to be treated in a downstream processing and subsequently discarded, which significantly increases the costs. Moreover, there is a continuous search in industry for new starch structures with enhanced functional properties for either food or non-food applications. Therefore new modification routes need to be explored. In this context, this project focused on novel green routes for starch modification, essentially salt-
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	<p>free, based on electrochemical and biocatalytic transformation. The project is multidisciplinary and addresses the following major topics:</p> <ul style="list-style-type: none"> <li>- The use of electrochemical conversion to regenerate oxidative reagents used for carbohydrate oxidation, which opens the window for production of oxidized carbohydrate ingredients at reasonable cost.</li> <li>- The use of industrial starch-acting enzymes for the modification of non-native starch materials, to tailor the product properties.</li> </ul> <p>These new technological routes for modification of carbohydrates, in particular starch, open the opportunity for the development of new classes of products. Moreover, both routes open new pathways in starch modification and can be easily implemented in industry.</p>
Project goals	<ul style="list-style-type: none"> <li>- Develop clean oxidation technologies based on electrochemistry for derivatisation of starch and oligomeric carbohydrates</li> <li>- Develop novel enzymatic technologies for modification of starch derivatives</li> <li>- Develop analytical tools to characterise the derivatised starch products and validate the efficiency of the derivatisation</li> <li>- Investigate properties of the starch derivatives obtained</li> <li>- Establish the technical viability of the technologies developed</li> </ul>

<b>Results</b>	
Planned results in the original project plan	<ul style="list-style-type: none"> <li>- Insight into the use of electrochemistry with regard to oxidative carbohydrate modification</li> <li>- Optimised conditions for electrochemical-based starch oxidation</li> <li>- Determine properties of oxidised starch products</li> <li>- Insight into the enzymatic modification of starch derivatives and the effects on starch properties</li> <li>- Optimised enzymatic technology for starch modification</li> <li>- Validated technologies and products at multigram preparative scale</li> <li>- Data on the properties and potential application of the novel starch derivatives produced by the technologies developed</li> <li>- Adequate analytical tools for characterisation of derivatised starch</li> </ul>
Achieved results	<ul style="list-style-type: none"> <li>- Optimised conditions for <i>in-situ</i> oxidation of (i) starch and (ii) carbohydrate oligosaccharides, with electrochemical regeneration of the oxidant co-substrate, have been determined.</li> <li>- The novel electrochemical-based technology developed for starch oxidation was proven to be efficient, and shows potential for reduction of salt side streams, allowing the recirculation of effluents.</li> <li>- Preparative experiments larger lab scale allowed production of representative samples for characterisation.</li> <li>- Starch was successfully oxidised via electrochemistry; isolated products matched the specifications of existing commercial products (as shown by partner AVEBE).</li> <li>- TEMPO-mediated electrochemical oxidation of carbohydrate oligosaccharides at optimal conditions obtained products with a DS of 1 (as determined by HILIC-MS) and with minimal chain degradation.</li> <li>- A novel enzymatic technology has been developed and optimised for derivatisation of a broad range of starch derivatives.</li> <li>- The enzymatic starch modification process has been proved to be highly efficient and reproducible, and easy to scale up.</li> <li>- Novel starch products with defined substitution pattern and molecular architecture have been obtained after enzymatic modification.</li> <li>- Reactions have been scaled up at AVEBE. A range of enzymatically-modified starch derivatives have been obtained in sufficient amount for application testing. A number of products showed useful functionality in various applications tests.</li> </ul>

	- Potential for IP application for the technologies and products developed has been assessed.
Explanation of changes relative to the project plan	There were no changes relative to the project plan. In the first and second year of the project, research focused on the development of the target technologies, optimisation of process conditions, development of analytical tools for product characterisation. In the third year, the technologies have been further developed and scaled up at preparative scale, production of sufficient amounts of products for characterisation and application studies, and process validation.

**What was the added value created by the project for:**

Participating "Knowledge Institutes" (scientific, new technologies, collaboration)	This project further increased our expertise in: <ul style="list-style-type: none"> <li>- Starch derivatisation and specific technics to modify starch using clean and non-invasive technologies</li> <li>- Selective electrocatalytic and biocatalytic conversion of carbohydrates</li> <li>- Advanced analytical techniques for the analysis of polysaccharides derivatives, and in particular for characterisation of starch and its derivatives</li> </ul>
Participating private partners (practical application of the results, within which period of time?)	<ul style="list-style-type: none"> <li>- New insights in the application of clean technologies for starch derivatisation</li> <li>- New environmental friendly technologies for starch derivatisation</li> <li>- New starch derivatives and applications</li> </ul>
Society (social, environment, economy)	<ul style="list-style-type: none"> <li>- Sustainable processes, with low environmental impact</li> <li>- Reduced need for chemical reagents and lowered side streams generation</li> <li>- New possibilities for starch derivatives with potential application in various food products, e.g., astringency reduction in fruit juices, texturiser for confectioneries</li> </ul>
Possibly other stakeholders (spin-offs)	- Technologies developed can also be applied in other industrial sectors and for other polysaccharides

**Follow-up**

Did the PPP result in one or more patents (first filings)?	Two patent applications are currently under discussion.
Are there any follow-up projects planned? If yes, explain. (Contract research resulting from this project, additional funding, or new PPP projects)	Yes, a new PPS project to advance the technologies developed has been granted in the TKI-AF 2019 call and will start in 2020 (project title: Electrochemical and enzymatic routes for starch modification; project number LWV19132 & LWV19107).

**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.)

Scientific articles:

None: no dissemination of results during the project, in relation to IP

External reports:

None: project results are confidential pending IP filing

Articles in professional journals/magazines:

None: project results are confidential pending IP filing

(Poster) presentations at workshops, seminars or symposia.

None: project results are confidential pending IP filing

TV/ radio / social media / newspaper:

None: project results are confidential pending IP filing

Remaining deliverables (techniques, devices, methods, etc.):

None