LOCALNUTLEG project is part of the PRIMA programme supported by the European Union's Horizon 2020 research and innovation programme

ECONOMIC AND TECHNOLOGY ANALYSIS FOR THE SCALING-UP PROCESSES

DELIVERABLE 2.6

PulpIng

Developing of Pumpkin Pulp Formulation using a Sustainable Integrated Strategy

Index

Document Information

Deliverable Number	2.6
Deliverable name	Economic and technology analysis for the scaling-up processes
Contributing WP	WP2: Sustainable recovery of compounds with preserving capacity from pumpkin by-products
Contractual delivery date	M18, February 2022
Actual delivery date	M26, October 2022
Requested delivery date	February 2023
Dissemination level	Public
Responsible partner	IPB
Reviewers	All partners
Version	1

1. Executive Summary

PulpIng project aims at the development of a differentiated and added-value pumpkin fruit pulp with natural food preservatives rather than synthetic counterparts and, at the same time, create a product to prioritize low environmental impact. This report constitutes the deliverable D2.6 – "Economic and technology analysis for the scaling-up processes". Eco-friendly and easy-to-perform methodologies based on innovative technologies such as microwave and ultrasound will be applied in the extraction of bioactive compounds. Once the procedures are defined at the laboratory scale it is important to study and identify the strategies that allow to implement its scale up. This report then focuses on the study and analysis of the scaling up processes to be applied in the PulpIng project.

1.1. PulpIng in context

PulpIng is an innovation action which brings together 9 partners from 6 countries:

PulpIng aims at the stimulation of a value chain with innovative processes that goes throughout all developing stages of pumpkin fruit pulp formulation functionalized with a natural-based preservative extracted from pumpkin by-products. For this purpose, the project consortium is driven by the interest of all R&D, SME and industry partners, towards the generation a food value-chain based on developing a novel pumpkin fruit pulp product, incorporating pumpkin by-product extracts with preserving capacity, thus promoting the sustainable development of these ecosystems.

In fact, the aim is to improve the pumpkin production in northern Africa through technology transfer from research into established local enterprises. In line with sustainable development and the "idea to application" strategy, pumpkin production will be improved by establishing the best agronomic conditions, extraction of preserving compounds from pumpkin by-products, use of these compounds to preserve fruit pulps, and finally studying their properties along shelf-life and enhanced shelf-life.

The objective of the PulpIng project is to stimulate a value chain with innovative processes that goes throughout all developing stages of pumpkin fruit pulp formulation functionalised with a natural-based preservative extracted from pumpkin by-products. Given the concept of the project, whereby each partner will generate its own data, from the establishment of agronomic conditions for pumpkin production (WP1) to life-cycle assessment of pumpkin (WP6), structured databases will be built and shared by all partners to optimise exploitation. So, PulpIng will produce high quality integrated datasets in the areas of: biology, agronomy, phytochemistry, food technology, chemistry, food and processing engineering, including access to scientific papers and studies based on pumpkin-based products, development of new food preservatives, ground-breaking foodstuff, sustainable processes and innovating knowledge exchange. For this reason, a default PulpIng data management approach is described in this document, which applies to all datasets that the project will generate. However, deviations from the default approach will be needed for some datasets, due to reasons such as confidentially of data or embargo periods related to IPR or scientific publication.

2. Economic and technology analysis of scaling-up processes

2.1. Goal and Scope

The goal of the present study consists of performing an analysis on the strategies for scaling up the processes for the extraction of preservative compounds from the by-products of pumpkin that were previously studied and optimized at the laboratory scale. The intended audience of this work thus constitutes the: scientific community; food and other industrial sectors; relevant market stakeholders, including regulatory agencies.

3. Factors to be considered on scaling-up

In order to achieve a successful scale-up, it is vital to identify the fundamental aspects of the process, which includes the innovation by itself, the user organization adopting and applying such innovation, the environment and the resource team developing opportunities for diffusion. On the other hand, failures in scaling-up proceedings are normally related to inappropriate features of innovation design, various environments of usage (social, economic or political) and preferences of potential users.

When considering the scaling-up of a process-driven sustainable technology, there are factors that must taken in consideration:

- Commercialization plan and market advantage. In the implementation of the scaling-up process, there is the possibility that some elements of the commercialization strategy (like unit costs and capital requirements) might change. Therefore, prior to scaling-up, it is vital to have an accurate knowledge of the potential customers, of their willingness to acquire your technology as well as of the market strategies that will promote the commercial trades with the identified potential consumers.

- Flow, equipment and materials of the process at the desired scale. When going forward with scaling a process or methodology, it is necessary to have a deep understanding of such process. Such knowledge normally takes form through a flow diagram where all the steps of the process are considered and the possible scales achieved, as well as various specificities such as material balances, physical variables used (temperature, pressure, etc.) and equipment capacity that will enable the process to be successful. Such extensive and detailed flow diagram is a valuable tool to determine the scalability of the process as well as to which potential clients and markets will be ideal.

- Functioning of the process as an integrated system. In order to ensure the success of the scaling-up process, it is essential that all the different operations and steps of the process so therefore one must take in consideration the inputs and outputs of the process, their scaling in concert and managing the outputs of the process on a market standpoint. To understand the process as an integrated system it is important to determine in what way the input/output ratio relates to different scales and, on other hand, to consider an effective harvest and delivering of the process outputs to be commercially available on the market.

- Financial model of the process. One of the stages of implementing a scale-up is to determine its operation in the economic level, which requires establishing a financial model. For this purpose, is important to perform a Techno-Economic Analysis that combines all the detailed process information such as financial costs, risks, benefits and ambiguities in order to develop a projection of how the unit economics might change as different technical aspects of the process development. The Techno-Economic Analysis then ensures that the financial projections are closely linked to the actual technical details of the process.

- Extensive planning towards an effective scale-up and commercialization plan. The successful scale-up of a given process or technology requires an extensive planning, research and preparation. With a deep knowledge of the different parameters involved in the implementation of the scale-up it is possible to de-risk the investments to be performed in such a capital-intensive operation. Through the close understanding of the process, it will bring more changes to the work in a larger scale and also in its integration into the defined financial model.

3.1 Techno-Economic analysis

Techno-Economic Analysis (TEA) is among the tools used to determine the technical and economic performance of various production processes. TEA has been performed for various to evaluate the feasibility of process technologies using process simulators commercially available such as Aspen Plus. The techno-economic analysis of a given process performs a critical examination on the overall investment and profit resulting directly and indirectly from the production process.

TEA is performed using a methodology that consists of holistic analyses to be completed consecutively (process design, process modeling, equipment sizing, capital cost estimation and cash flow analysis). In fact, TEA is an essential assessment tool to understand cost standards and potential economic feasibility of technologies, being widely used in the evaluation of systems across different industries, with major focus on the production phase. TEA can play a major role in optimizing process design and quantifying the final product selling price, supporting the decision-making process on R&D and investment decisions from both technological and economic perspectives. Therefore, TEA is essential for the evaluation of the feasibility of upscaling or industrializing various processes and technologies, with applications in various sectors, one of them being the bioactive compounds.

The technologies applied in the extraction of compounds of bioactive activity or other function from natural sources are often classified as conventional and emerging technologies. Emerging extraction technologies used in the bioactive recovery from plant materials include microwave-assisted extraction, ultrasound-assisted extraction, pulsed electric field processing, high-pressure processing and also supercritical and subcritical fluid extractions. Such emerging technologies have been associated with higher bioactive yields, less solvent consumption and less use of time and energy when compared with conventional technologies like heat-assisted extraction, however it is relevant to note that many of these technologies present various scale-up issues and often require large investments.

The economic analysis separates what are fixed and variable costs. Fixed costs are normally composed of three different items: (i) costs derived from the construction of the general equipment, (ii) costs of the analytical equipment (to measure physical properties such as pH, temperature, etc.), and (iii) auxiliary services (electric or hydraulic installations, power supply, pumps and compressors, etc.). On the other hand, variable costs are related to the cost of labor, feedstock as well as analytical and auxiliary services, that must be assessed in three different stages (start-up, operation and dismantling). In order to perform an economic profile with the total costs of each scale of the process, it is necessary to link the total costs to a determined time unit, which is normally of one year. There are also two relevant factors that must be considered. One is to determine an average amortization period of the fixed capital and another is the definition of a number of tests to be performed in the time unit considered.

Concerning a sustainable design, scale-up needs to consider not only technical and economic aspects but also potential environmental impacts while developing new technologies and processes. In that framework, TEA can be integrated with life cycle assessment (LCA) allowing to understand the trade-off between economic and environmental performance, being used in the early stages of technology development to evaluate techno-economic feasibility and future environmental performance. The integration of TEA and LCA can also reduce inconsistencies between system boundaries, functional units and other assumptions, taking advantage of LCA's systematic approach to assess the life cycle environmental impacts associated with a product. Such LCA properties are already being used in the WP6 of project PulpIng to address the sustainable production of a pumpkin fruit pulp, thus providing a valuable source of data and expertise.

3.2 Risk assessment

In order to obtain a sustainable process performance on a scale-up, it is fundamental to develop a framework for techno-economic and environmental analysis through the use of risk assessment in the early stages of design. Therefore, the existence of potential alternatives within the design must be analyzed following a series of targets: (a) quantification of the economic risk in the process; (b) conduct a financial evaluation of environmental impact categories under potential uncertainties; (c) quantification of the potential environmental risks; (d) measurement of the existing eco-friendly alternatives; (e) produce a joint risk assessment matrix to support the decision-making process with quantitative and qualitative assessment of sustainable features.

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