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EVALUATION OF SCALING UP PROCESSES

DELIVERABLE 2.5

PulpIng

Developing of Pumpkin Pulp Formulation using a Sustainable Integrated Strategy

Index

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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 D2.5 – "Evaluation of 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 of a food value-chain based on developing a novel pumpkin fruit pulp product, incorporating pumpkin by-product extracts with preserving capability, thus promoting the sustainable development of these ecosystems.

In fact, the aim of the project 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, extracting compounds with preserving capabilities from pumpkin by-products, using such 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 the value chain of pumpkin production with the introduction of novel processes that encompass all development stages and by functionalising the pulp with natural preservatives extracted from pumpkin by-products. According to the project concept, each partner is expected to produce complete datasets that range from the definition of agronomic conditions (WP1) to life-cycle assessment (WP6). This data is stored in structured databases for use by the project partners for exploitation optimization. PulpIng has been producing high quality integrated datasets in the areas of biology, agronomy, phytochemistry, food technology, chemistry, food and processing engineering which include access to scientific papers and studies on pumpkin-based products as well as on the development of new food preservatives, ground-breaking foodstuff, sustainable processes, and innovative knowledge exchange. The default PulpIng data management approach, to be applied to all datasets of the project, is described in this document. However, deviations from this default approach will be needed for some datasets, due to issues as confidentially of data or embargo periods related to IPR or scientific publication.

2. Scaling up processes

2.1. Goal and Scope

The goal of the present study consists of defining 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 laboratory scale. The intended audience of this report comprises the scientific community; food and other industrial sectors; relevant market stakeholders, including regulatory agencies and rural development agencies.

3. Strategies for process scaling-up

The definition of strategies for process scaling-up towards the extraction of preservative compounds from pumpkin by-products relies on a number of conceptual design approaches and tools. It is useful to create a general block diagram of the process and, by performing mass and energy balances, to establish the streams of the process namely in what concerns composition, temperature and pressure. At a later stage, energy integration should be carefully considered, as it can have a tremendous effect not only on the economical but also on the environmental viability of the project. Another important instrument to take advantage of, in a context of designing the industrial process line, is the so-called process flow diagram (PFD), which is a schematic representation of the complete process. It details, under systematic rules, all the process units, streams, associated control elements, and even some auxiliary equipment, evidencing the existing interactions, raw-materials, products, and energy needs apart from giving information on the operating conditions.

All the mentioned tools are essential to establish a techno-economic analysis in order to assess the economic viability of the project. Such analysis should also take into account a previous prospection of the market to ensure that the planned production of the study is appropriate from a selling point of view. If the analysis reveals economic unfeasibility, a decision should be taken: either to repeat the study considering possible technical alternatives or to reject the investment proposal.

3.1 Challenges and perspectives

Considering food related processes, the scaling up from the laboratory to the industry is always accompanied by a series of problems and requirements. Heat transfer, during cooking and cooling, and mixing in tanks or containers are among the most common steps that are used in the industry, being easily carried out in the laboratory but then requiring complex equipment when transferring to the industrial scale. Both steps depend largely on the ratio of surface area and volume, but there are other factors that can also play a decisive role, namely the geometry of the vases, the agitator´s rate and shape since they affect the relative velocity of the phases

The need to use different materials is also a major challenge for the scaling up transition, considering its potential influence in the physical properties of the product. On the other hand, the effect of the size of the sample must be taken into consideration due to its impact on the different process parameters involved in the manufacturing process.

In order to overcome a significant set of problems and challenges, the principle of similarity should be used in conjunction with mathematical models, which is closely related to the relationships between physical systems of different sizes and shapes, therefore essential for scaling up. This does not mean that it is enough to merely rely upon geometry, agitator´s design and radial velocity or other mechanical measurements. The probability of success is higher if the scaleup is made based on the mass and heat transfer coefficients. Also, apparently inoffensive issues (such as the location of the feed in a vessel or the positioning of an agitator) can easily turn what would be a successful project into an unsuccessful one.

In order to achieve the most possibly successful scaling-up process in a food industry, it is vital to apply an extensive methodological approach that cover the three major pathways: (a) review of existing processes, (b) process efficiency, intensification and control, (c) best practices for localized application of technologies.

(a) Review of existing food engineering processes.

There are numerous publications describing a variety of food engineering processes, where a major example are the Top 20 listing of the Royal Society (https://royalsociety.org/news/2012/top-20-food-innovations/). The food manufacturing review (Campbell-Platt, 2011), the forward look (De Vries et al., 2009) and the classical approach proposed by Windhab (Fischer & Windhab, 2011) are other examples of relevant publications on food engineering processes.

(b) Process efficiency, intensification and control

In order to determine the competitiveness of the small scale technologies and methodologies, it is important to research on their efficiency, reliability and resilience in a processing environment. For this matter can be proposed two approaches. One is through process intensification, by increasing the functionalities of single equipment in parallel, reduce manufacturing space, production facilities and costs, and also by improving efficiency in terms of energy, water, and so reducing the environmental impact. Another approach is by process control, which consists of improving different process steps using feedback controls receiving data from online monitoring tools. Process control also allows to enable formalized processing steps that are steered remotely, where the main bottleneck of this approach is the relevance and applicability of the sensors used rather than the quality and diversity of the existing algorithms.

(c) Best practices for localized application technologies

Once food processes are very diverse, the most successful practices for small-scale applications are directed to immediately after harvest and at-home preparations. Such applications can then span from single-food sectors such as micro-breweries, single resources with multiple output products for different industrial sectors or even multiple resources for multiple-output products.

3.2 Conceptual design approach

A good design is one of the major points to build scalability into process development in the food industry. The use of optimized platforms comes as an advantage as these are well understood and scalable. Also important is actual manufacturing experience as carrying out a process on a large scale builds up manufacturing understanding which, in combination with reliable small-scale data derived using statistically designed experiments, allowing for an effective control strategy to be developed. The result is a good process robustness and consistency that ultimately supports the establishment of a design space. The involvement of partner Decorgel is relevant due to their extensive experience in the food sector, to their knowledge in the processing of food samples and also to their industrial sensitivity of the industrial processes.

There are software packages available that can assist in the tasks referred above, namely in the establishment of a schematic representation of the production line, the computations from mass and energy balances and sometimes even sensitivity analysis and/or the base for a techno-economic analysis. These are chemical processes simulators, such as ASPEN Plus (proprietary) or DWSIM (open source software). Both have advantages and disadvantages, but their use might be considered.

Some useful tools for process characterization are failure mode and effects analysis (FMEA), design of experiment (DoE) and lab models, as well as experimental studies at lab-, pilot-, and full-scale. The use of risk-assessment tools such as FMEA is an important part of process characterization to focus efforts where required.

4. References

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