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1st year report; the Sunniva project

Sustainable food production through quality optimized raw-material production and processing technologies for premium quality vegetable products and generated by-products

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Report

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Summary:

The SUNNIVA project aims to increase the overall sustainability of vegetable processing by providing valorisation strategies to reduce waste and limiting environmental impact, while improving the nutritional properties of vegetable food products. Results obtained during the first project year indicate that; (i) The waste and by-product fractions of cabbage, tomato and black salsify have a great potential to be better utilized in the food processing chain and to serve as valuable sources for health beneficial phytochemicals (HBPC), and (ii) that tomato and grape seed press cakes have an interesting plant nutritional (NPK) profile, which makes them suitable candidates as raw material in soil amendments. Further, raw materials from tomato and cabbage, in terms of cultivars and morphological parts, has been assessed for HBPC and nutritional value as an effect of N-fertilization and processing. Experimental data for deriving numerical thermal models for agitated and static retort are obtained. Mapping of the most important underutilized vegetable biomass streams in partnering countries are under way. The development of non-destructive tools for rapid HBPC measurements in cabbage and tomato is promising, but some more calibration/validation of the method is necessary. One year into the 3-year project, we conclude that progress has been satisfactory.

Summary/recommendation in Norwegian:

SUNNIVA tar sikte på å utvikle et bærekraftig system fra produksjon til konsumering, via hele matvarekjeden for tomat og *Brassica.* Prosjektet vil øke forbrukernes tilgang til trygg, sunn og enkel mat gjennom nye behandlingsteknikker, og bedre utnyttelse av råvaren, biprodukter og avfall. Resultater fra prosjektet viser at restråstoff fra kål, tomat og skorsonnerot ikke blir optimalt utnyttet i prosesskjeden, og kan være en verdifull kilde til helsefremmende fytokjemikalier. Presskake fra tomat har en svært interessant næringssaltprofil, som gjør den til en god kandidat som råmateriale i jordforbedringsprodukter. Effekt av kultivar, gjødsling og prosessering på næringsinnhold i kål er evaluert.

Preface

We aim at the development of a sustainable food system from production to consumption, addressing the entire food supply chain for the vegetables tomato and *Brassica* (white cabbage, cauliflower and broccoli), and their derived products. The project will increase consumers' access to safe, healthy and convenient food through novel processing techniques, and improve utilization of raw material, by-products and waste, for which valorisation strategies will be developed.

Brassica and tomatoes represent a major part of the human diet. They are consumed world-wide and are renowned for their health beneficial effects. In Europe, tomatoes and Brassica are among the most important vegetables cultivated; the areas for Brassica and tomato production cover 400 000 and 250 000 hectares, respectively, yielding 6 and 15 million tons/year.

Preservation of health-beneficial phytochemicals (HBPC) is central in the vegetable processing part of the project. It is technologically challenging to preserve the nutritional and sensory quality of vegetables in processed foods, e.g. provide for acceptable texture, colour and health-promoting compounds. Process optimization by modelling, via knowing the temperature distribution of the products during processing, will contribute to preserve HBPC and thus food quality.

Tomato and Brassica have a high intrinsic health-promoting value and technologies will be developed to preserve the high HBPC level in the derived food products while also developing novel products with beneficial nutritional and sensory attributes. The initial properties of the vegetable raw material before processing is a limiting factor for the quality of the food products derived thereof.

Optimal harvest time and post-harvest elicitor treatments will further increase HBPC in the raw material. We will also explore the use of well-balanced organic N-fertilizer, based on unused vegetable biomass, and enhanced with bio-control microorganisms. Promoting plant health and growth will result in benefits for the consumer, and for the plant (higher phytochemical content is associated with higher disease resistance). This convergence of benefits includes lower cost and reduced environmental pollution. Non-destructive, high throughput optical indices will be used to monitor phytochemicals, reducing the use of toxic chemicals for wet chemistry analysis.

The global volume of vegetable food wastage, not including agricultural waste, is estimated to 400 million tons/year. Valorization of unused biomass after processing thus enhances food production sustainability and contributes to a lower ecological impact. We will reduce waste in the food supply chain using two strategies. First, processing and stabilization for recycling into the food chain will be investigated through the use of the novel technologies such as e.g. spiral press filtering and refractance window drying. Second, the value of unused vegetable biomass as component in the production of organic fertilizer will be evaluated.

The development of innovative processing technologies is essential for improving competitiveness and economic growth for the European food industry. The novel food processing technologies microwave heating and agitated retorting will be utilized to demonstrate the potential for combining savings in energy and water consumption. The project aims for 25% savings in energy expenses, and 40-60% reduction in water consumption, compared to conventional processing.

Table of Contents

1 Introduction

The project entitled 'Sustainable food production through quality optimized raw-material production and processing technologies for premium quality vegetable products and generated by-products' [Acronym: SUNNIVA] is in the FP7 SusFood Era-net programme. Sunniva is a 3-year project with official starting date April 14th, 2014. The Sunniva consortium consists of 11 research institutes and 6 industrial partners representing 7 European countries as shown in Table 1.

Table 1 Partners of the Sunniva consortium

	Beneficiaries	*Short name*	*Country*
1	Nofima AS – Norwegian Institute of Food, Fisheries and Aquaculture Research	Nofima	Norway
2	Bioforsk - Norwegian Institute of Agricultural and Environmental Research	Bioforsk	Norway
3	Gdansk University of Technology	GUT	Poland
4	Consiglio Nazionale delle Ricerche – Istituto di Fisica Applicata "Nello Carrara"	CNR-IFAC	Italy
5	ILVO – Institute for Fisheries and Agricultural Research	ILVO	Belgium
6	University of Ankara	UoA	Turkey
7	De Ceuster Meststoffen N.V.	DCM	Belgium
8	INRA – the French National Institute for Agricultural Research	INRA	France
9	Mondragon GOI Eskola Politeknikoa, S. COOP	MGEP	Spain
10	KU Leuven	KUL	Belgium
11	InHort Research Intitute of Horticulture	InHort	Poland
12	Alata Horticultural Research Institute	ALATA	Turkey
13[§]	Noliko N.V.	Noliko	Belgium
14	Enbio Technology	Enbio	Poland
15	Fjordland AS	Fjordland	Norway
16	Meat Company Nowak	Nowak	Poland
17	Fjordkjøkken AS	Fjordkjøkken	Norway

[§] The original industrial partner HEVAD (Belgium) left the consortium in November 2014 and was replaced by Noliko which was accepted as a partner by IWT in January 2015 and formally joined the consortium in April 2015.

The work packages are interconnected as outlined in Figure 1.

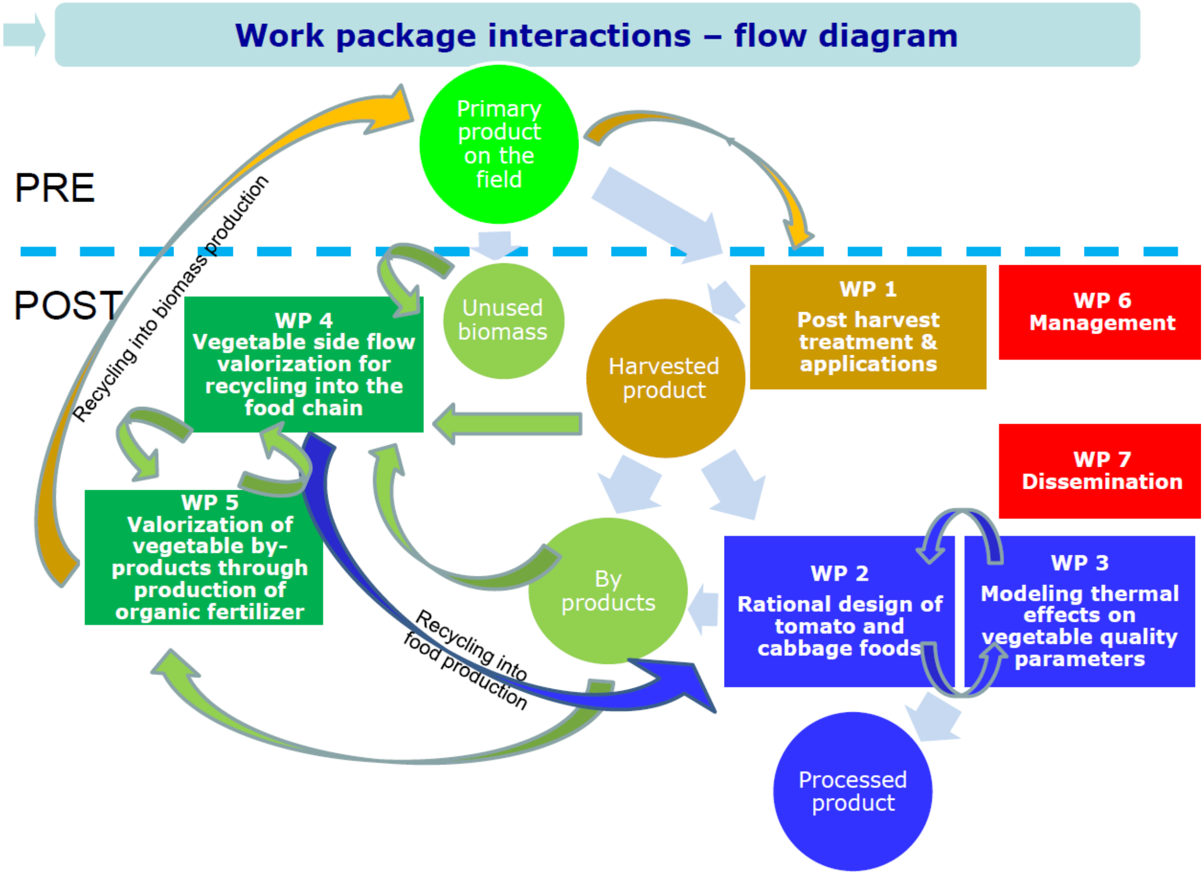


Figure 1 Work package interactions

2 Activities

There have been performed 3 physical whole consortium meetings:

1. Kick-off meeting in Leuven (hosted by KUL, Belgium) 18-19 February 2014
2. Meeting in Gdansk (hosted by GUT, Poland) 22-23 September 2014
3. Meeting in Gent (hosted by ILVO, Belgium) 27-28 April 2015

Additional internal WP meetings have been held via Skype when needed.

2.1 WP1 – Post harvest treatments and applications; optimizing harvest time and improving quality of processing raw material and waste fractions for side streams in *Brassica* and tomatoes

2.1.1 Active partners WP1

Bioforsk (leader Ingunn Vågen), InHort, CNR-IFAC.

2.1.2 Aims WP1

Investigate and develop methods to induce added value to vegetable raw material postharvest through selection of raw material and improving concentration and composition of health beneficial phytochemicals (HBPC) in *Brassica* and tomatoes

1. Inducing added health value of vegetable raw material for food by-products

   a. Identify initial properties of different fractions of raw materials and their waste fractions
   b. Determination and comparison of optimum harvest time for tomatoes based on i) current practices for industry and fresh consumption purposes, and ii) om maximum content of HBPC
   c. Improving concentration and composition of PC in vegetable raw material and side stream fractions by post-harvest elicitor applications

2. Develop non-destructive optical tools to estimate *in situ* flavonols and chlorophyll of *Brassica* and lycopene content of tomatoes to facilitate more frequent and inexpensive monitoring of PC content of vegetable raw material. These tools will be used in objectives 1.b and 1.c. The tools will also be valuable for sorting raw material into quality classes for specific purposes or as guidance in elicitor treatments.

2.1.3 Activities WP1

Field trials on both tomatoes (fresh-market and processing cv's) and white cabbage (cv's Transam and Typhoon) were carried out in spring/summer of 2014 at InHort, and in summer 2014 on commercial green-house fresh-market tomatoes in west-Norway in collaboration with Bioforsk. The purpose of these trials was primarily to obtain calibration data for development of non-destructive optical tools. Second, the response of varying mineral N-fertilizer dosage and storage was observed for yield and parameters related to quality and nutritive status, and also the effect of ripening stage on content of HBPC.

2.1.4 Highlighted results WP1

Tomato

A LED reflectance sensor was optimized for tomato measurements. The sensor was calibrated against lycopene content of whole tomatoes of 3 different cultivars: Calista, Volna and Juanita. Samples for the 'Dometica' round tomatoes should be re-analyzed. There is a cv-dependence of the PLS models defined to predict lycopene, therefore the model for one cv applied to another gives erroneous predictions. The model of prediction works well for Calista processing tomatoes, less well for Volna and Juanita fresh-market tomatoes. This could be due to: the differences in size and shape of tomatoes and of the internal structure, thickness of exocarp/pericarp that can change the reflectance signals; number/position of measurements around the equatorial region, not representative of the whole; the differences between cv's in the skin/flesh proportion of lycopene.

Some more information to understand the results are needed.

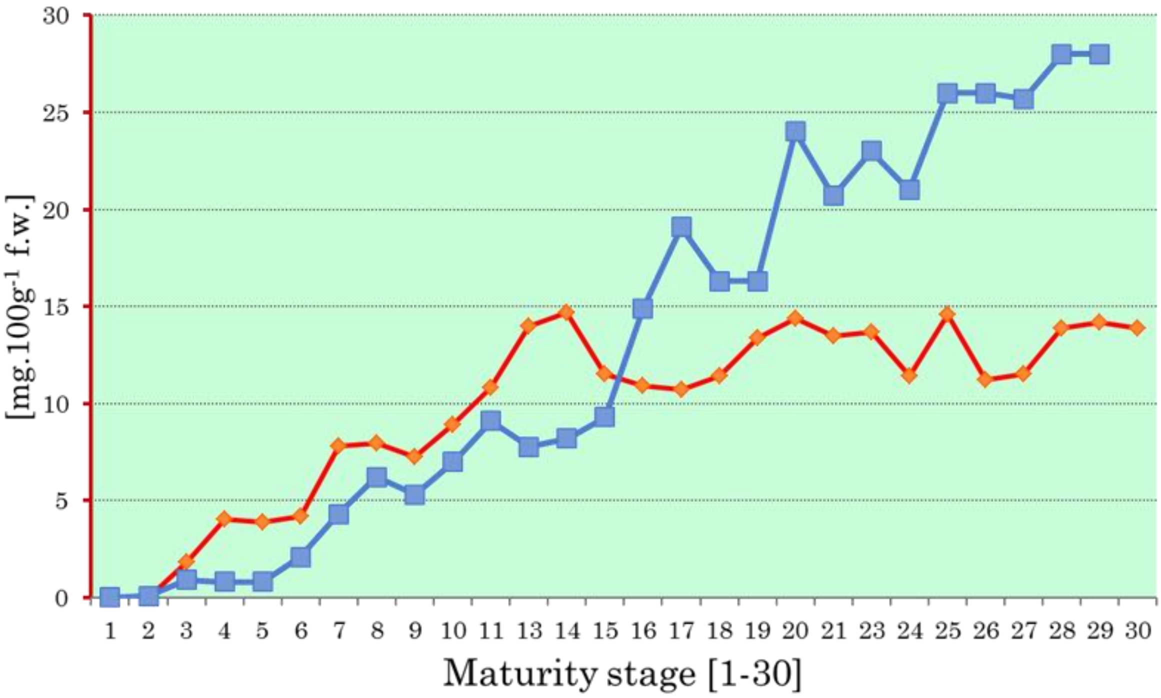


Figure 2 Influence of ripening stage on lycopene content in tomato fruits cv Volna (diamonds) and Calista (squares)

Cabbage

Results from the sensor calibration activities for cabbage:

- Fluorescence sensors non-destructive indices on cabbage leaves responded to N treatments as expected; the flavonols index decreasing with increasing N rates, and the chlorophyll index increasing with increasing N rates.
- Fluorescence sensors showed the presence of a significant gradient from the apical to the basal portion of the cabbage leaves in both flavonols and chlorophyll.
- The Dualex sensor indices measured on the leaves closest to the cabbage heads were able to discriminate the different N treatments, as showed by mapping the indices values.
- Fluorescence sensors were calibrated against destructive chemical analysis of leaf chlorophyll content. Calibration against flavonols content needs results from destructive HPLC analysis of samples, which are not avaliable yet.

From the work with varying N levels and identification of the initial properties of the cabbage raw material, an important note is that the waste fraction of cabbage contains much higher flavonol values than the edible parts which are normally consumed (Fig. 3). Similar observations were made also for ascorbic acid. This supports the great potential in utilizing cabbage waste biomass as a source for HBPC.

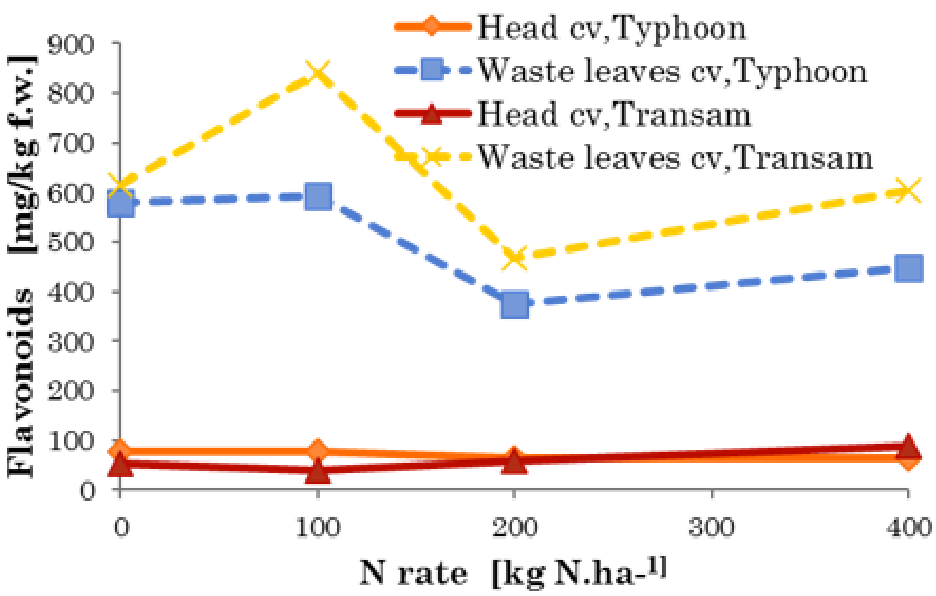


Figure 3 Amount of flavonoids in heads and waste fraction of two cabbage cultivars at different levels of nitrogen supply, at InHort, Poland 2014

2.2 WP2 – Rational design of tomato and/or Brassica vegetables containing foods according to food synergy concept

2.2.1 Active partners WP2

GUT (leader Agnieszka Bartoszek), InHort, ILVO, Nofima, Enbio, Nowak, Fjordland, Fjordkjøkken, Noliko

2.2.2 Aims WP2

1. To select and characterize raw materials for further use in the work package
2. To design food items and prepare laboratory prototypes based on different raw materials derived from tomatoes and/or brassica vegetables
3. To design prefabrication products and prepare laboratory prototypes that can be conveniently incorporated into meat, fish or ready dishes without altering current production lines
4. To prepare the most promising food items at a larger scale in cooperation with industrial partners
5. To verify the health-quality of laboratory prototypes and prepared in cooperation with industrial partners food items with the set of chemical and biological markers

2.2.3 Activities WP2

Raw material assessment for two varieties of white cabbage (cv's Transam and Typhoon) fertilized with different loads of nitrogen was carried out. In the case of edible parts of cabbage, the content of glucosinolates, indoles, total isothiocyanates, as well as antioxidant potential were determined (Fig. 4). Based on the analytical results, the conversion rate of glucosinolates to the beneficial derivatives (indoles and isothiocyanantes) was calculated.

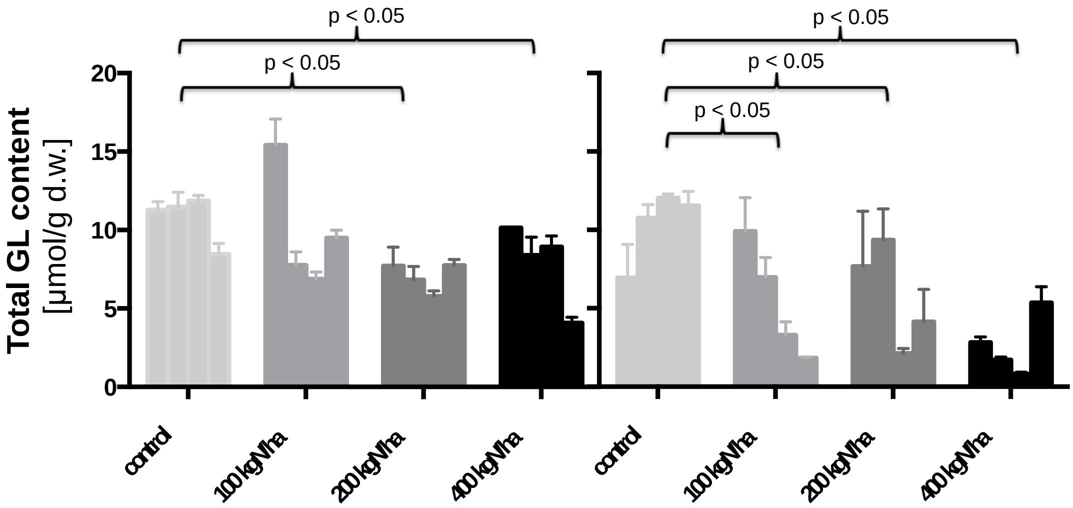


Figure 4 The content of glucosinolates in the individual heads (4 randomly chosen for each cultivar and nitrogen supply) of Transam (left panel) and Typhoon (right panel) cv's originated from InHort, Poland 2014

2.2.4 Highlighted results WP2

1. **N**itrogen fertilization seems to decrease GLs production by plants
2. Nitrogen fertilization increases production of I3ACN, which is an auxin and may be synthesized independently of GLs
3. ITC formation is very variable; it tends to decrease with the load of nitrogen
4. GLs conversion to ITC and indoles varies, but has not approached 100% in any case; thus the activity of other proteins than ESM in the cabbage varieties studied must be substantial
5. The nitrogen fertilization may decrease GL production at higher doses, it may also negatively affect their conversion to the most biologically active phytochemicals

2.3 WP3 – Modelling thermal effects on vegetable quality parameters

2.3.1 Active partners WP3

University of Ankara (leader Ferruh Erdogdu), Nofima, ALATA, MGEP, Fjordland, Fjordkjøkken, Noliko

2.3.2 Aims WP3

Preservation/breakdown mechanisms of PCs in tomato and *Brassica* based products are to be reviewed from literature and experiments of the other WP's. Changes in the quality factors will be modeled based on the time/temperature history during processing. Heat transfer modeling of tomato and *Brassica* products will be carried out to determine temperature distribution of the products during agitated retort processing to optimize the process. The results will be compared with the results of conventional processing techniques, e.g. still retorting

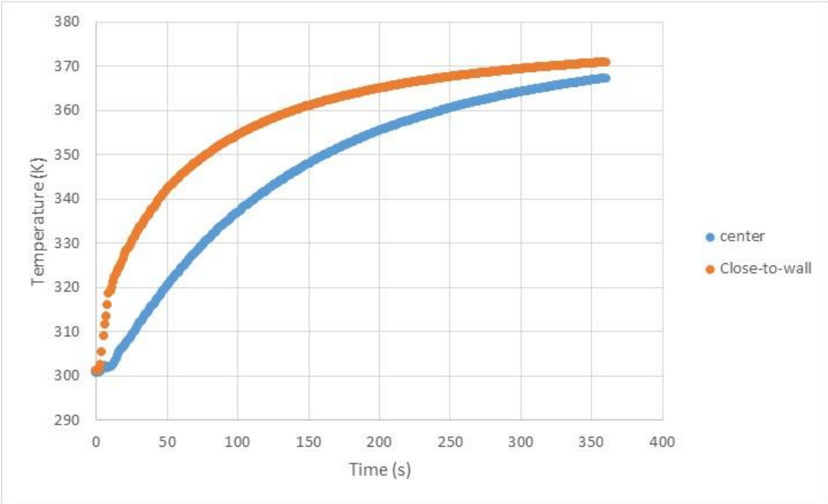
2.3.3 Activities WP3

In the first year of the project, the following tasks were carried out under WP3:

Experimental studies
Obtaining experimental data for a stationary retort and agitated retort process to further use in the numerical model validation:

In this part of the experiments, 98.2×115 mm (diameter × length) cans were filled with water with 2% headspace, and the experiments were carried out in boiling water under stationary case and under longitudinal agitation retort conditions at 140 strokes/min. The water to replace the food product was specifically chosen for the model validation studies since its thermal and physical properties were very well known. Based on the experience of the WP3 group in the modelling area, it was significant to apply the temperature effects on the thermal and physical properties (especially for the case of density and viscosity). There were two sets of experiments: boiling water under stationary case and under longitudinal agitation retort conditions at 140 strokes/min. Fig. 5 demonstrates the temperature changes at the given two locations for these three sets. These experimental data will be used in the validation of the numerical model.

a)



b)

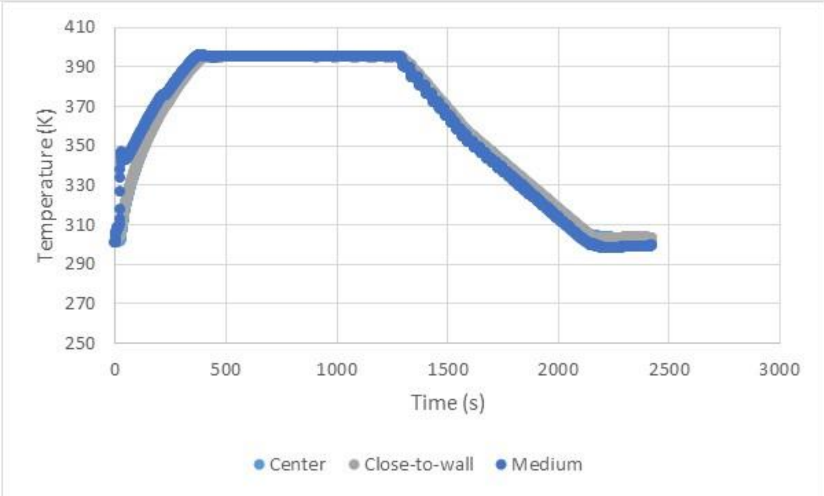


Figure 5 *Demonstration of time-temperature change of the centre and close-to-wall locations (a) under boiling water stationary case and (b) under longitudinal agitation conditions (140 strokes/min).*

Numerical Studies

Numerical studies were, first of all, composed of two parts. In the first section, a rectangular cross-section of the 3-dimensional can (Fig. 6) were used to decide upon a suitable mesh structure in the case of longitudinal agitation. In this section the mesh sizes of ≈10000, 15000, 25000, 38260 and 41520 were tried. Fig. 7 demonstrates the effect of mesh size in the temperature change of the two locations.

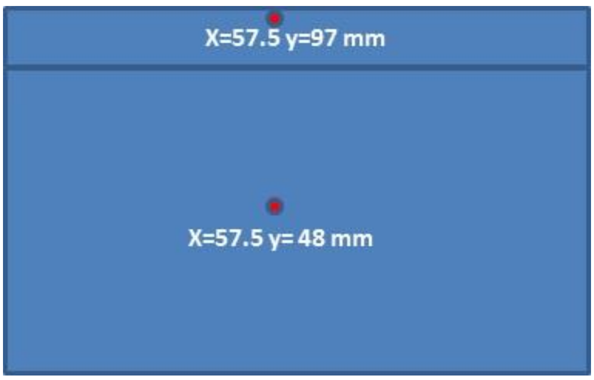


Figure 6 *A typical mesh structure of 2-dimensional rectangular computational geometry with the marked points where the time-temperature data were recorded.*

Due to the instabilities obtained with the mesh sizes of 38260 and 41520 at the point close to the wall (Fig. 7b), it seemed to be feasible to continue to the 3-dimensional simulations with a mesh structure of 24000 for the case of agitation conditions.

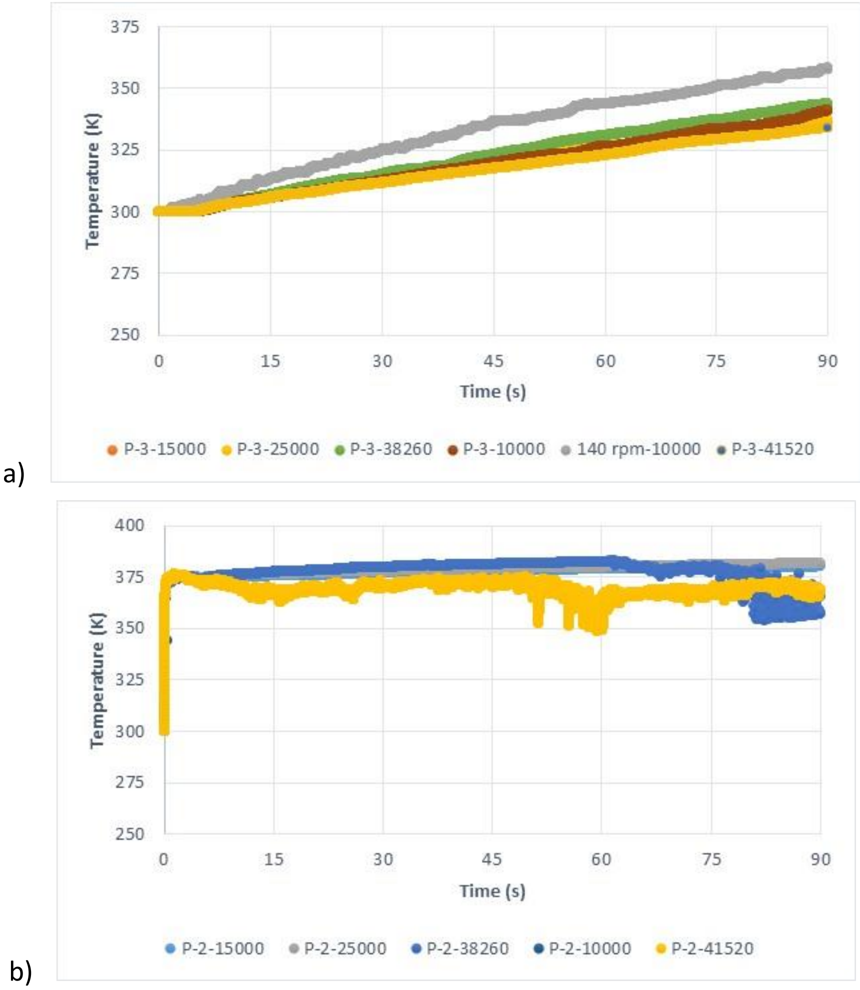


Figure 7 *Time-temperature change of the centre and close-to-wall points in the 2-dimensional rectangular geometry.*

Besides, a 2D numerical model for prediction of temperature history during agitated retort thermal processing and compared to static thermal processing. A 3D model for model validation and to demonstrate the effect of agitation is still under progress.

2.3.4 Highlighted results WP3

To demonstrate the effect of agitation, another set of 2-dimensional simulation was run for the case of agitation at 140 strokes/min. Figs. 8 and 9 shows the effect of agitation with respect to the stationary case for temperature and phase (air-headspace and water) distribution. In all these simulations, the wall temperature was constant at 121.1 °C with an infinitely high heat transfer coefficient and constant uniform initial temperature distribution.

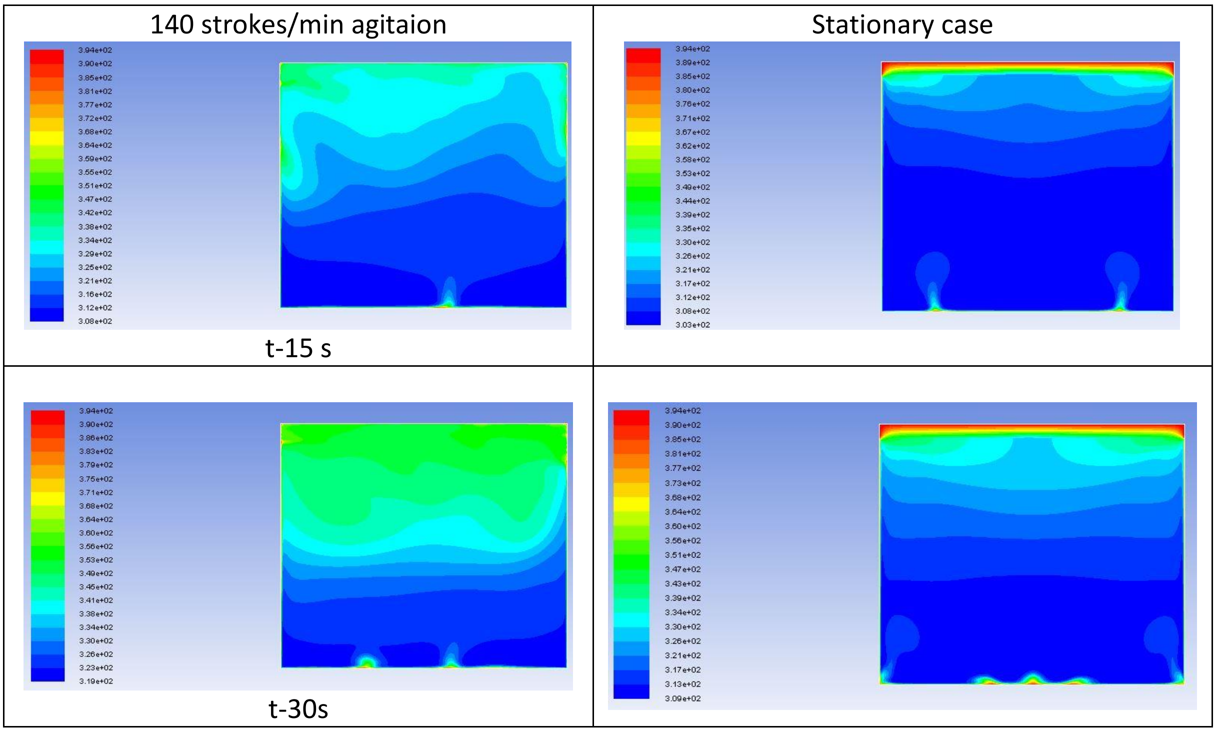


Figure 8 *The effect of agitation with respect to the stationary case for temperature distribution.*

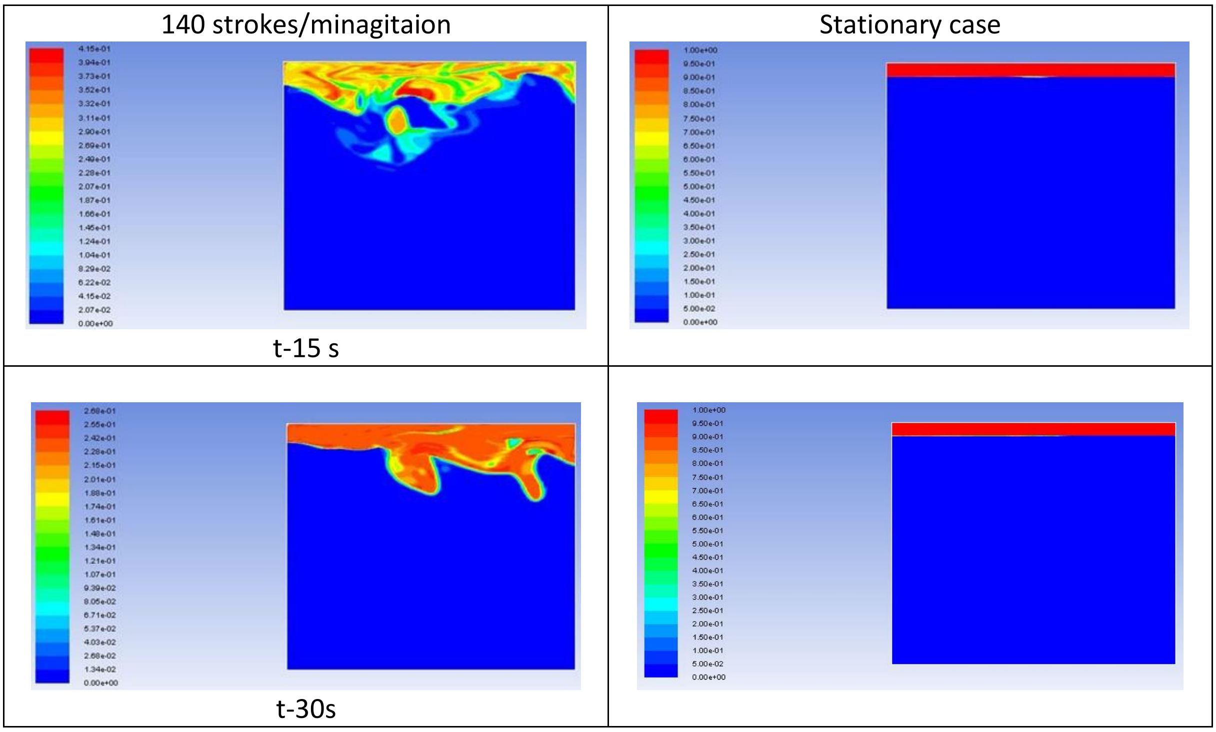


Figure 9 *The effect of agitation with respect to the stationary case for phase (air-headspace and water) distribution.*

2.4 WP4 Vegetable by-product processing for recycling into the food chain

2.4.1 Active partners WP4

ILVO (leader: Bart van Droogenbroeck), GUT, CNR-IFAC, INRA, InHort, Noliko

2.4.2 Aims WP4

The aim is to increase overall sustainability of the vegetable production by investigating the potential of underutilized vegetable biomass for recycling into the food chain as technical, nutritional, functional ingredients/additives.

The objectives are:

1. Estimate the potential of *Brassica*, tomato and other vegetable biomass for recycling into food chain based on: volumes; availability; important chemical-nutritional-phytochemical parameters
2. Evaluate the potential of innovative stabilization and processing techniques maximally preserving the quality of the raw material
3. Study the potential of most promising (stabilized) vegetable fractions as food ingredient/additive

2.4.3 Activities WP4

Information about the most relevant vegetable waste streams and by-products is collected among all partner countries. A biorefinery process scheme was developed for surplus product of tomato. In parallel the characterisation of the most important vegetable by-products available at Belgian partner NOLIKO was initiated. Pilot-scale test were carried out on black salsify by-product to evaluate the potential of alternative processing methods to recycle fractions/ingredients derived thereof into the food chain. Vegetable by-products available (apple press cake, salsify press cake, pea by-products) were air dried and provided to the partners in charge of WP5 for the analysis planned in this WP.

2.4.4 Highlighted results WP4

1. A questionnaire was put together and sent out to all the EU partners with the aim to collect relevant information (volume? periodical availability? origin? Etc) about the most relevant vegetable by-product and waste streams in their country. The collected data sheets will be used to map the most important underutilized vegetable biomass streams in the partner countries. This info can be relevant for companies with international activities searching for specific biomass fractions, such as DCM.
2. The work initiated at the beginning of the project on tomato was continued and resulted into a biorefinery scheme. Fig. 10 depicts a schematic representation of the process developed. Using the spiral-filter press, surplus tomatoes were converted into a liquid and a solid fraction. The process was optimized to obtain a press cake that only consisted of tomato skins and intact seeds. The liquid fraction, tomato juice, can be pasteurized and used as ingredient in food product development. The skins present in the press cake can be separated from the seeds via a sedimentation process. These tomato skins can be used to extract carotenoids or as natural colorants. The seeds can be pressed to be obtain tomato seed oil, and ingredient that can be used

in cooking oil and cosmetic products. More detailed characterization of all the fractions generated, with special interest of tomato HBPC, i.e. carotenoids, in collaboration with SUNNIVA partners, is ongoing. Estimation of the economic feasibility is also ongoing, as well as discussion with stakeholders interested in the implementation of some of the results.

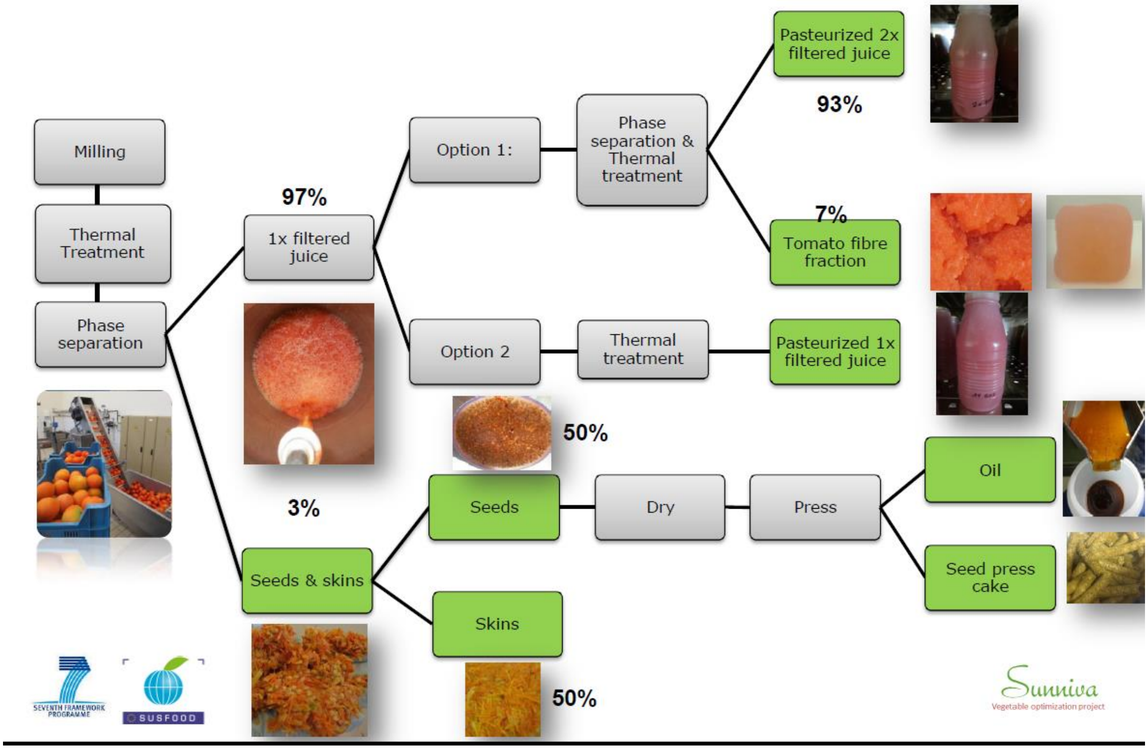


Figure 10 Schematic representation of the biorefinery process developed with the aim to valorize surplus tomatoes

3. Pilot scale experiments were carried out using the black salsify by-product as a feedstock with the aim to evaluate the potential of alternative/innovative processing technologies to recycle fractions/ingredients derived thereof in the food chain. Both processing technology available at NOLIKO and at ILVO (oxygen-free pressing using the spiral filter press) was used to transform the salsify by-products into a puree or juice (cfr. Fig. 11). From the initial tests it could be concluded that multiple technologies are suitable to process the different salsify by-products into a salsify puree with good physicochemical stability. No technical bottlenecks were discovered.

Figure 11 Photo of the press cake obtained using the same technology, but different parameters, to process black salsify by-product into puree

2.5 WP5 Side flow valorization of vegetable by-products through incorporation into organic fertilizer and soil amendments

2.5.1 Active partners WP5

KU Leuven/DCM (leaders: Christine Vos/Inge Hanssen), INRA, CNR-IFAC, Bioforsk, InHort, ILVO

2.5.2 Aims WP5

1. Study the potential of vegetable waste or side-flows as raw materials for organic fertilizer or soil amendment. Relevant parameters are plant nutritional value, organic material, bioactive components, and substrates for microorganisms.
2. Processing (drying and stabilizing), such waste/side flows to improve their valorization potential as raw material for organic fertilizer or soil amendment according to the criteria listed in (1).
3. Study the suitability of the processed raw materials as carriers for beneficial microorganisms (BM) and study the tomato response (growth and disease resistance) to the processed raw materials and BM, for design of a true test product.
4. Study the plant response to the test product in greenhouse and/or field tests with tomato and Brassica to assess biomass production, plant disease resistance as well as plant secondary metabolites and HBPC content in response to the test product.

2.5.3 Activities WP5

The waste or side-flows of the Belgian partners within the consortium have been identified, as well as their seasonal availability. The plant nutritional value of the flows is being assessed. Lab-scale plant tests for growth and disease resistance are being optimized. The HBPC content of the press cakes is being investigated.

2.5.4 Highlighted results WP5

1. The available waste or side-flows include: press cakes from tomato, grape seed, apple peel, black salsify, carrot peel, peas and beans
2. Press cakes have to be dried to a maximum water content of 10%, which can be achieved by air drying in an oven. This is feasible in an experimental setup but needs to be optimized or upscaled for industrial use.
3. The tomato and grape seed press cake have an interesting plant nutritional (NPK) profile, which makes them suitable candidates as raw materials in soil amendments.
4. The NPK profile of the already analysed press cakes is similar to that of cacao shells (which are already used as raw material), hence the cacao shells are included as control treatment for the plant tests
5. The analysis by UPLC-MS of the methanol extracts of the available waste and side flows revealed the presence of different families of HBPC, namely hydroxycinnamic esters (black salsify), proanthocyanidin derivatives (grape seed), alkaloids (cacao shell) and flavonoids (apple peel).
6. In order to analyze the different lycopene isomers present in the tomato press cakes, an extraction and an analytical method were developed and adapted from the existing literature. These methods are now used by for the lycopene analyses done in the WP5 and in the other WP of the project.

3 Dissemination and Communication

Web site: http://sunnivaproject.eu/

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