Final report

for the CORE Organic Plus funded project

"Innovative and eco-sustainable processing and packaging for safe and high quality organic berry products with enhanced nutritional value"
"EcoBerries"

Period covered: *2015-02-15—2018-03-15*

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1. Consortium

Project acronym:	EcoBerries	**Project ID:**	222
Project title:	Innovative and eco-sustainable processing and packaging for safe and high quality organic berry products with enhanced nutritional value		
Project website:	http://projects.au.dk/coreorganicplus/research-projects/ecoberries/		
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Start of project:	2015-02-15	End date of project:	2018-01-15
Duration in months:	**38**	New end date in case of a project extension:	2018-03-15

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1) University, Public research centre, Private research centre, Company, Other

2) PC = Project coordinator, WPL = Work package leader, WPCL = Work package co-leader, P = Participant

2. Summary

2.1 Post-term project summary suitable for web publication

The main goal of the project has been to develop innovative sustainable processing and packaging technologies to meet the growing consumer demand and boost the manufacturing of safe organic berry products with high nutritional quality and low environmental impact. The aim has been to evaluate technologies to naturally extend the shelf-life of fresh organic berries and to process berries into a wide variety of value added products.
Several solutions and technologies for extending shelf life and the overall quality of fresh and processed berry and fruit products have been identified and developed during the three years of the project. The major results and achievements are described below.

- A virtual Modified Atmosphere Packaging software system (MAP), has been upgraded and optimised to identify optimal O_2 and CO_2 concentrations in headspace and spoilage as a function of time. This has enabled measurements of respiration characteristics of any kind of fresh berries and determination of the shelf-life in given conditions, which will be a real added value for the stakeholders
- Pulsed electric field (PEF) and ultrasound (US) coupled with osmotic dehydration (OD) has been applied to improve functionality of semi-dried products. The mild technologies enabled preservation of the microstructures and the fresh-like characteristics of berries and fruits.
- The use of edible coatings in improving the shelf-life of blueberries was investigated and found to improve firmness, colour and reduce the growth kinetics of yeast and mesophilic aerobic bacteria.
- Microwave assisted extraction (MAE) of phenolic compounds in berries was optimised using response surface methodology. The results showed that 86% of the phenolics of blueberry and 88.7% of phenolics of strawberries could be extracted in short time.
- Drying and fractionation techniques were found to be useful for production of bilberry powders with preserved qualities and potential application as functional ingredients in e.g. dairy products
- The microbiological safety (especially mycotoxins) of pre-treated and processed berry and fruit products was evaluated and found to be good for all products
- Within the project, innovative berry ingredients and products have been produced, such as functional powders, healthy extruded snacks and 3D printed confectionaries.
- High-pressure homogenisation (HPH) was applied to organic juices of blueberries and kiwi fruit and demonstrated to increase shelf-life considerably (for blueberry juice 2 months at both cold and ambient storage and for kiwi fruit juice > 40 days at cold storage).
- A literature study has been made to identify important quality parameters limiting shelf life during storage of berries and a report on technical specifications has been delivered.
- Storage tests of fresh berries have been performed to analyse quality parameters at different temperature and humidity conditions and for validation of the mathematical model implemented in WP2. The recommendation is to store berries cold and in closed packages.
- Consumer behaviour studies have been made to identify factors that influence berry consumption in cross-national surveys. Consumers show high interest in products that are free from additives, with high nutritional content and organic. Consumer acceptance and con-joint studies have been conducted for dried organic strawberries. The conjoint studies were useful to obtain information of important aspects of design of new food products and packaging.

2.2 Short process update of the whole project

The characterization and comparison of organic and conventional berries was delayed until 2016 due to poor weather conditions during the summer 2015 but all parts with the chemical and microbiological characterization, evaluation of antimicrobial activity, antioxidative capacity and bioaccessibility have been performed during the project. (WP1)

The work within WP2 has enabled measurements of respiration characteristics of any kind of fresh berries using a consolidate protocol which will allow determination of the shelf-life in given conditions and assessment of the benefits of using MAP for the fresh berries food chain, which is a real added value for all stakeholders. Due to that no organic packaging were commercially available for MAP implementation in the condition of pack geometry defined in the simulation experiments performed to identify optimal CO_2/O_2 permeabilities, MAP experiments were carried out using conventional plastic films with adapted geometry and /or micro-perforations (WP2).

Semidried fruit and berry products have been obtained by application of mild technologies (PEF, US, OD) maintaining good quality parameters of treated fruits. The efficacy of a new type of edible coatings to maintain the overall quality of fresh blueberries during storage has been demonstrated.

Processing conditions for hot air drying, microwave assisted hot air drying and milling during processing of berries into powders have been studied and evaluated, as well as how the choice of processing conditions affect the resulting powder characteristics. (WP3)

Both established and emerging technologies have been used within the project to produce berry-based products such as functional powders and healthy extruded snacks with preserved content of bioactive compounds and increased shelf-life. HPH, drying, extrusion and 3D printing are technologies which can be considered to give low environmental impact in the sense that the entire harvest can be used and side streams such as press cake. (WP4)

The shelf life of berries (strawberries, bilberries, raspberries, blackcurrants) at different storage conditions have been assessed based on quality indicators. Consumer attitudes and preferences have been evaluated in different countries using quantitative analysis and conjoint studies have been made. An industry survey has been conducted to identify the main challenges in the berry value chain in different countries. Environmental assessments have been made to evaluate the impact of selected processing technologies (drying, milling, extrusion). (WP5)

Dissemination activities have been made through the website, a leaflet, a video, and a report in SciTech Europe and by participation in workshops, conferences and at seminars. 18 papers have been published or accepted to international pre-reviewed journals and 3 are submitted, 7 manuscripts are in progress for submission. (WP6)

General project meetings (in total 6) have been organized every sixth month, alternating between the facilities of the different partners. A final meeting was organized as a co-event to the TP Organic Research seminar at the Biofach congress in Nuremeberg. A mid-term report and final report has been prepared according to the time plan. (WP7)

3. Main results, discussion, conclusions and fulfilment of objectives

3.1 WP1

WP1	**Characterization of organic cultivated berries and products**
WP leader: VTT Responsible partners: Nofima, Chalmers	
Overall summary of main results, discussion and conclusions of WP1 *Chemical analyses* No significant differences were found in the concentration of phenolic compounds and ascorbic acid in organically and conventionally grown berries from Finland, Norway or Sweden. The impact of genotype and environment is likely more important than the cultivation system on the content of phenolic	

compounds and ascorbic acid. The same trend was observed in the compositional analyses covering anthocyanins, fatty acids, tocopherols and sterols. Minor differences were found e.g. in the fat content and fatty acid composition of strawberries, but primarily between berries cultivated in Finland or in Sweden and secondary between the cultivation systems.

Microbiological analyses

Culture based microbiological analysis revealed only small differences between organic and conventional berries and the conclusion was that organic and conventional berries investigated in the current study were equally microbiologically safe.

The DNA based analysis was compromised by the large amount of non-target DNA, and consequently many samples had to be removed from the analyses due to few sequences. This taken into account, the results did not indicate that either the fungal or bacterial microbiota differed based on cultivation method (organic versus conventional). There were some trends in higher or lower relative values for some taxa, but the overall composition did not seem to be different. This is in accordance with the plate counts reported earlier. We cannot exclude the possibility of a different result if there had been more samples and a more optimal DNA extraction (without the non-target DNA bias).

It should be noted that the berries included in the studies were only from Finland, Norway and Sweden and that the results may not apply to berries cultivated in other geographical areas.

Evaluation of selected berry products (details of the processing are described in WP3)

The application of different processing technologies and techniques to extend the shelf life of berries and fruits may cause alterations in the physical, chemical and biological properties of the products. To evaluate the effects of some of the mild processing technologies applied in WP3 on quality characteristics, studies were performed to assess the: (i) antimicrobial activity; (ii) antioxidant activity; (iii) bioaccessibility of anthocyanins. Strawberries and kiwifruit were treated with pulsed electric field (PEF), and/or osmotic dehydration (OD), and edible coating was applied blueberries with the aim to improve product properties and sustainability.

Antimicrobial activity of processed berries

The growth of *Escherichia coli* strain was found to be markedly inhibited at pH 4.7, and even stronger by the antibiotic chloramphenicol. The berry samples had only limited growth retarding effects on the *E. coli* strain, the strongest effect was obtained from strawberry samples with the lowest pH values (4.7 and 4.9). The growth of yeast was only limited affected by the berry samples.

Strawberry and kiwi samples (pH range 4.7-5.2) showed antibacterial effects against *B. subtilis*. Not all berry samples with low pH had similar effects so there might be other factors than pH and organic acids. e.g. phenolic compounds, contributing to the antibacterial effects. Processing (PEF), (OD), or edible coating) as such did not have a consistent effect of the antimicrobial activity.

Antioxidative capacity

The results indicate that the combination of PEF and OD treatments lead to some losses of antioxidant compounds in strawberry and kiwi fruit while the individual treatments did not seem to affect the antioxidant activity. The antioxidant activity of kiwi fruit was markedly lower than for strawberries and blueberries. For coated blueberries, storage for 2 weeks at 4°C enhanced antioxidant activity and the anthocyanin content.

Bioaccessibility of anthocyanins

Anthocyanins represent an important group of polyphenols and the consumption of foods rich in anthocyanins is related to decreased risks of developing e.g. cardiovascular diseases and cancer. To better understand the mechanisms of action and the impact of processing on anthocyanins it is important to study their biological activity but to estimate the amount that is available for absorption after digestion the bioaccessibility of these compounds s also need to be considered. LC MS-MS analyses of anthocyanin content in processed strawberry samples showed that the major anthocyanin recovered was Cyanidin 3-0 glucoside (kuromanin) but also other anthocyanins were identified (petonidin 3-O glucoside, peonidin 3-O

glucoside and cyanidin 3-O arabinose). In coated blueberry samples, oenin was the predominant anthocyanin, followed by delphinidin 3-O galactoside, petunidin 3-O glucoside, kuromanin, peonidin 3-O glucoside and cyanidin 3-O arabinos. After in vitro digestion, only a few anthocyanins were recovered. Kuromanin was recovered in digesta of strawberry samples and malvidin 3-O glucoside in digested blueberry samples. The other anthocyanins detected in processed samples were all below detection limits after the simulated digestion, which agrees with previous studies suggesting that anthocyanins are likely to be degraded during gastrointestinal digestion, either spontaneously or enzymatically into phenolic degradation products which then can be further metabolized and exert biological activities.

The seasonal availability of berries may limit their consumption and therefore the application of mild processing technologies is promising in terms of product properties and sustainability. Dietary intakes of anthocyanin-containing foods have been reported to have beneficial health effects and it is therefore important to evaluate how different processing techniques may affect the anthocyanin content and potential biological activities. The aim of this task was to assess the effects of PEF, OD and edible coating on the antimicrobial activity, antioxidant capacity and the content and bioaccessibility of anthocyanins after processing of fresh organic berries. The stability of anthocyanins during the treatments, to improve the quality and shelf-life of semi-dried products, suggest that the studied technologies can be effective processing strategies to obtain anthocyanin-containing foods. It can be concluded that the obtained results will be useful for defining directions for further development of berry and fruit processing and for the application of pre-processing technologies to improve functionality of berry and fruit products.

A Results obtained:

Task 1.1: *Chemical characterization of berries and products*.

The levels (range) of total phenolic content (TPC) and ascorbic acid (AA) in berries (Table 1) and anthocyanins, fatty acids (FA), tocopherols and sterols (Table 2) were compared in organic and conventionally cultivated berries from Finland, Norway and Sweden. Although there were some trends, the data did not allow to make conclude that there was a difference in the levels of the studied chemical compounds due to cultivation (organic/conventional).

Table 1. Total Phenolic Compounds (TPC) and ascorbic acid (AA) in organic and conventional berries.

Type/Number of samples	Country	Variety	TPC mg/g DW* range	AA mg/g DW range
Strawberry				
organic/4	Sweden	Malwina	13.8-19.0	3.5-4.4
conventional/4	Sweden	Malwina	13.9-14.9	3.2-4.2
organic/4	Finland	Rumba/Polka	7.1-12.4	2.9-3.4
conventional/4	Finland	Polka	6.0-7.4	2.1-2.4
Black currant				
organic/4	Sweden	Ben Tron	23-26	4.4-5.6
conventional/4	Sweden	Ben Tron	22-27	5.5-6.7
organic/2	Finland	Öjebyn	8.6, 9.8	3.8,-4.3
conventional/2	Finland	Öjebyn	12.1, 12.5	5.1,-6.1
organic/4	Norway	Ben Tron	26.3-30.5	9.1-9.5
conventional/4	Norway	Ben Tron	24.5-30.8	8.1-9.2
Raspberries				
organic/4	Norway	Glen Ample	6.8-7.0	1.5-1.7
conventional/4	Norway	Glen Ample	8.6-9.5	1.5-1.6

**Total phenolics are expressed as mg/gallic acid equivalent per g of dry weight (mg GAE/g DW)*

Table 2. Anthocyanins, fatty acids (FA), tocopherols and sterols in berries.

Type	Country	Variety	Anthocyanin mg / 100 g	FA g / 100 g	Tocopherol mg / 100 g	Sterols mg / 100 g
Strawberry						
organic	Sweden	Malwina	295 - 360	0.75 - 1.35	5.2 - 8.9	64.4 - 91.4
conv.	Sweden	Malwina	243 - 554	0.73 - 1.44	5.3 - 8.5	65.1 - 88.6
organic	Finland	Rumba/Polka	289 - 366	1.35 - 1.99	4.7 - 6.7	85.2 - 107.1
conv.	Finland	Polka	273 - 487	2.17 - 2.61	5.6 - 8.3	96.0 - 138.3
Black currant						
organic	Sweden	Ben Tron	1302 - 2374	0.89 - 2.51	34.0 - 38.5	104.5 - 160.6
conv.	Sweden	Ben Tron	1887 - 2084	2.11 - 4.72	34.4 - 41.6	151.8 - 182.9
organic	Finland	Öjebyn	1620 - 1880	0.39 - 1.27	39.5 - 42.5	114.2 - 120.5
conv.	Finland	Öjebyn	1369 - 2118	1.65 - 1.82	44.3 - 48.2	127.1 - 135.3

Task 1.2: *Microbiological safety*.

No differences in the microbiota berries could be detected based on the way of cultivation by culture-based techniques (Table 3). Based on the 16 s rRNA gene sequences the bacterial composition clustered according to berry type, and there was no clear difference between conventional and organic berries. Both organic and conventional berries are microbiologically safe.

Table 3. Culturable levels of enterobacteria (VRBGA agar), heterotrophic bacteria (PCA agar), moulds and yeast (DRBCA agar) in organic and conventional berries.

Type/ Number of samples	Country	Variety	CFU/ml			
			Entero-bacteria	Heterotrophic bacteria	Moulds*	Yeasts*
Strawberry						
organic/4	Sweden	Malwina	< 10	1.4-2.8 x 10^5	7.7 x 10^4- 2.2 x 10^5	3.0 x 10^3- 2.0 x 10^4
conventional/4	Sweden	Malwina	<10 - 60	1.9-2.7 x 10^5	6.3 x 10^4- 1.0 x 10^5	3.0 x 10^3- 2.0 x 10^4
organic/4	Finland	Rumba/ Polka	<10 - 1000	4.1-7.2 x 10^4	640 - 1.7 x 10^3	7.3 x 10^3- 4.6 x 10^4
conventional/4	Finland	Polka	<10	1.0-4.0 x 10^4	90 - 1.5 x 10^3	3.7 x 10^3- 1.2 x 10^4
Black currant						
organic/4	Sweden	Ben Tron	1.1 x 10^4 - 1.0 x 10^5	5.5 x 10^5 -2.6 x 10^6	<10 - 90	<10
conventional/4	Sweden	Ben Tron	1.0-2.7 x 10^3	1.1-1.4 x 10^6	10 - 200	<10 - 30
organic/2	Finland	Öjebyn	<10, 185	1.4 x 10^6, 1.8 x 10^6	1.3 x 10^5, 1.4 x 10^5	7.3 x 10^4, 8.7 x 10^4
conventional/2	Finland	Öjebyn	<10, 160	3.0 x 10^6, 3.2 x 10^6	1.1 x 10^5, 1.3 x 10^5	2.1 x 10^4, 4.6 x 10^4
organic/4	Norway	Ben Tron	<10	3.6 x 10^5 - 1.9 x 10^6	1.2 x 10^5 - 1.6 x 10^6	8.0 x 10^4 -3.7 x 10^5
conventional/3	Norway	Ben Tron	<10	1.7-4.1 x 10^6	2.6-8.3 x 10^4	3.0 x 10^3 - 1.1 x 10^5
Raspberries						
organic/4	Norway	Glen Ample	<10	150 - 1.1 x 10^4	3.4 x 10^3 - 7.4 x 10^4	>100 - 5.6 x 10^3
conventional/4	Norway	Glen Ample	<10	1.0-1.5 x 10^4	1.4-1.9 x 10^4	1.2-3.5 x 10^3

* *Presumptive identification based on colony morphology.*

Task 1.3: *Evaluation of antimicrobial and activity antioxidative capacity of selected products* (*from WP3)*.

Antimicrobial activity towards bacteria *(Escherichia coli* and *Bacillus subtilis)* was mainly driven by the pH of the berry preparations (strawberry, kiwi, blueberry) - the lower the pH the stronger antibacterial effect. Yeast (*Saccharomyces cerevisiae*) was not affected by the low pH of the berries. Processing did not seem to affect the antimicrobial activity of the berries.

The antioxidant capacity was measured using DPPH radical scavenging activity and oxygen radical absorbance capacity (ORAC). The antioxidant capacity was similar in pulsed electric field (PEF) treated strawberries compared with the fresh ones but a slight tendency of decrease was observed in samples after combined treatment with PEF and osmodehydration (OD, with sucrose and trehalose). For coated blueberries, the antioxidant activity, and the anthocyanin conten increased during storage for 2 weeks at 4°C. The antioxidant capacity/activity of kiwi fruit was markedly lower than for strawberries and blueberries.

Task 1.4: *Evaluation of effects of processing on the stability and bioaccessibility of phytochemicals in selected products*

The preservation of anthocyanins in the berries after processing and after in vitro digestion of selected products from WP3 was assessed using a LC MS-MS method and for estimation of bioaccessibility of anthocyanins a 3-step in vitro model was used. The four main anthocyanins quantified in PEF and/or OD treated strawberry samples were cyanidin 3-O glucoside (Kuromanin), petunidin 3-O glucoside, peonidin 3-O glucoside and cyanidin 3-O arabinoside. Kuromanin represented the highest proportion (~60-100 µg/g DW), followed by petunidin, peonidin and cyanidin, at markedly lower concentrations (~0.02-0.6 µg/g DW). The major anthocyanin in coated blueberries was oenin (~2.8-3.6 mg/g DW), followed by delphinidin 3-0 galactoside and petunidin 3-0 glucoside (~1.5-2.1 mg/g DW) and kuromanin, peonidin 3-O glucoside and cyanidin 3-O arabinose (~0.14-0.33 mg/g DW).

After in vitro digestion of processed berry samples only a few anthocyanins were recovered. Kuromanin was recovered in digesta of strawberry samples and malvidin 3-O glucoside in digested blueberry samples. The in vitro bioaccessibility of kuromanin in strawberry samples ranged between 2.1-6.8% and for blueberry samples the bioaccessibility of malvidin 3-O glucoside ranged between 0.02-0.14% (Figure 1). The other anthocyanins detected in processed samples were all below detection limits after the in vitro digestion. The results agree with previous studies reporting that the bioavailability of anthocyanins at the

intestinal level is low (<1%). The mechanisms of anthocyanin bioactivity are mostly unknown. Since the digestion process involves a wide range of pH variations, leading to transformations of anthocyanins into metabolites that can contribute to the beneficial effect of anthocyanin intake, further studies are needed to study the impact of the digestion on the bioactivity of anthocyanins.

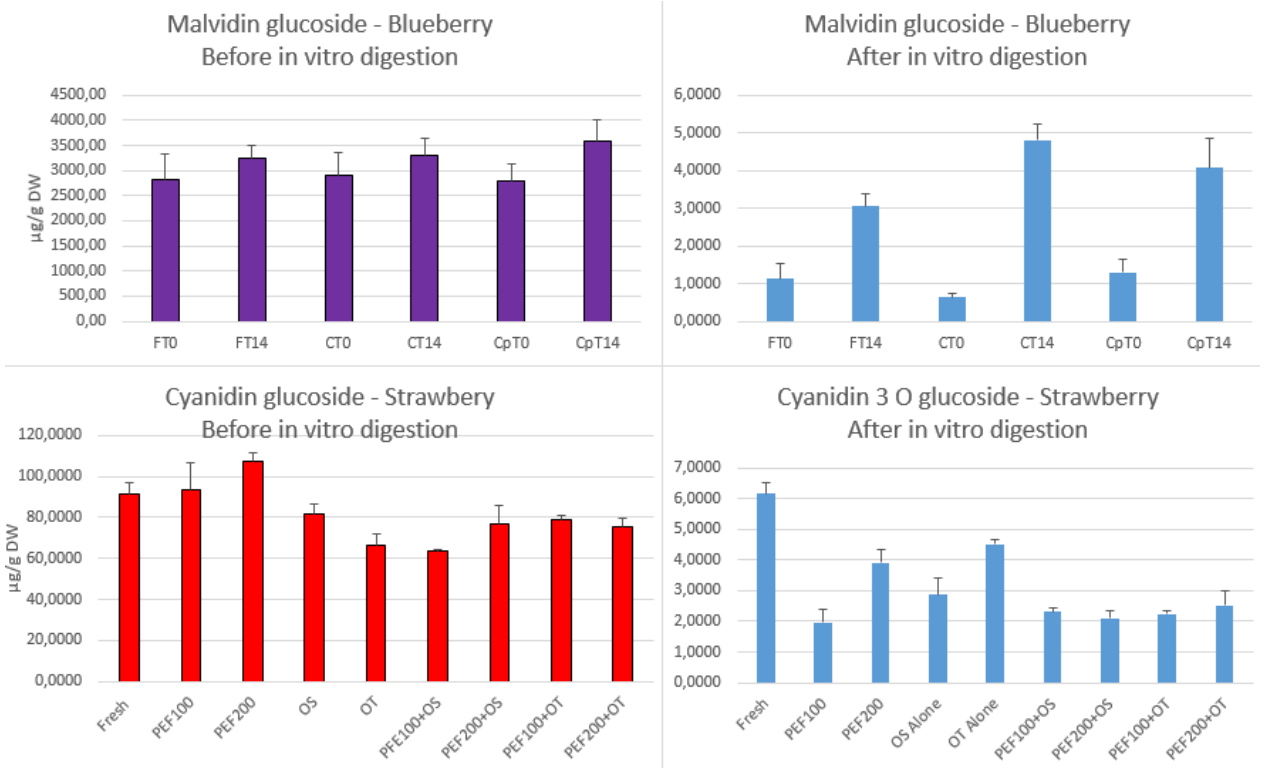

Figure 1. Recovery of malvidin glucoside and cyanidin glucoside in berry samples before and after in vitro digestion.

B - comments on deviations from the original plan:

Due to the poor weather in the summer 2015 organic vs. conventional berry comparisons were postponed and performed in 2016. Also during this summer, the weather conditions were not optimal especially for strawberries but the study was conducted anyway. Only in three countries (Norway, Sweden and Finland) comparable berry samples from organic and conventional were available from berry growers. Tasks 1.3 and task 1.4 were delayed due to that the preparation and delivery of samples between partners were delayed. To achieve comparable results, a decision was taken to wait with the analytical work and in vitro experiments until all samples could be analysed simultaneously.

C - fulfilment of objectives:

- Task 1.1 achieved 100%
- Task 1.2 achieved 100%
- Task 1.3 achieved 100%
- Task 1.4 achieved 100%

WP2	Title of WP2: Extend the shelf-life of organic fresh berries and products

WP leader: UMR IATE

Responsible partners: USAMVB, NOFIMA

Overall summary of main results, discussion and conclusions of WP1

(max 2 pages per WP, font size 11)

The objective of WP2 is to extend the organoleptic and nutritional qualities of fresh berries by using Modified Atmosphere Packaging (MAP) technology and minimize wastes by increasing shelf-life. In order to optimize the design of the MAP system (passive MAP or equilibrium MAP) and identify in advance the most suitable packaging material for a given application, IATE partner is using dedicated virtual MAP software (Tailorpack). This software computes the mass balance between the respiration characteristics of the

product and the permeation rate of O2 and CO2 through the packaging film and permits to identify the optimal O2/CO2 permeabilities of the packaging. From these targeted specifications, the nature of the packaging film could be chosen by querying dedicated databases. Once optimal O2/CO2 permeabilities are identified, we can select the packaging material for MAP implementation in the condition of pack geometry defined in the simulation. In the framework of Ecoberries project, no organic packaging were commercially available for the foreseen application. Therefore, MAP experiments were further carried out using conventional plastic films with adapted geometry (IATE) and/or micro-perforations (NOFIMA).

To apply the aforementioned approach, a good knowledge of respiration characteristics (modelled using Mickaëlis-Menten equation) is necessary. Data for strawberry were collected in the literature and also experimentally assessed in the framework of EcoBerries. A close collaboration between IATE, USAMVB and NOFIMA was performed with an exchange of protocols for assessing respiration characteristics of strawberries, especially cultivars from Norway ('Zephyr' and 'Sonata') and France ('Charlotte', 'Gariguette' and 'Mara des bois'). In Norway respiration rate was additionally measured for raspberries cv. 'Glen Ample'. A comparison of cultivar respiration characteristics across different European areas (north and south Europe) was done. In Nofima, the following variety were characterized:

- Zephyr (2015) – conventional
- Sonata (2016) – conventional – two maturities
- Sonata (2017) – conv. and organic
- Glen Ample (2016) – organic

No significant differences between organic and conventional fruits of the same cultivar on the respiration characteristics were noted. However, in 2017, Nofima observed slightly higher respiration rate for organic Sonata compared to conventional. The differences in the curves are at the same level as differences found for the two maturities in 2016.
Once parameters of Mickaëlis Menten equation for strawberries are known, the O2/CO2 permabilities of the packaging material suitable for achieving the optimal O2 and CO2 concentration at a given temperature and for a given pack geometry are identified using the Tailorpack software. In the framework of Ecoberries the mathematical models of Tailorpack have been upgraded considering temperature change (Arrhenius Law) during storage. Therefore, temperature cycle could be modelled using IATE virtual MAP tool.

Currently virtual MAP software did not estimate food shelf life gain by using MAP. One of the objective of IATE's work was also to propose an innovative approach to predict shelf life of food product packed in MAP and to link it to a reduction of food losses and wastes. In this purpose, the virtual MAP software (Tailorpack) was upgraded by coupling a new predictive deterioration model (based on visual surface prediction of deterioration encompassing colour, texture and spoilage development) with models of the literature for respiration and permeation. This mathematical model was concomitantly validated at IATE and NOFIMA on conventional and organic berries.
Because of the large availability across Europe of strawberry, this fruit was selected as model berry for validating the approach, carrying out shelf life tests in MAP and estimate the gain of shelf life achieved using optimised combination of packaging and cold chain for fresh berries.
Conventional strawberries of the variety *Charlotte* were selected in France (IATE) and *Sonata* and *Zephyr* varieties (organic and conventional ones) were selected in Norway (NOFIMA). MAP trials were conducted in both institutes. Work on conventional *Charlotte* strawberries permit to finely tune and validate the modelling approach. Work on *Sonata* (conv. and organic) strawberries permit to compare conventional/organic berries. The type of culture route (conventional versus organic for a same variety) influence the initial contamination. Therefore, the degradation curve is higher for organic than conventional strawberries.
No other significant differences in quality evolution with time between organic and conventional strawberries were noted during MAP experiments. The mathematical model succeeded in predicting the gas exchange and fruits' deterioration in different realistic storage conditions (MAP and temperature).

This WP is strongly linked to WP5 (Shelf-life assessment, environmental assessment and consumer studies). The D5.1. is a compilation of literature studies conducted in both WP2 (task 2.1.) and WP5.

Report on the results obtained (A), and fulfilment of objectives (B)
(max 2 pages per WP, font size 11, graphs and tables allowed)

A- results obtained:
Task 2.1: A literature survey was conducted to identify technologies to handle the berries before packaging, to identify critical factors limiting shelf life and to collect and capitalize data as regard respiration characteristics (input parameters in the Mickaëlis Menten equation). This task was conducted concomitantly with WP5.1 and data collected in the present task were presented in D5.1. Respiration characteristics of strawberries, different cultivars, were collected in this task and capitalized in dedicated databases. Experiments with the strawberry cultivars 'Zephyr' and 'Sonata' (Norway), 'Charlotte' and 'Gariguette' (France), and the raspberry cultivar 'Glen Ample' (Norway) were carried out to confirm these data.' The biological variability is indeed very impacting on these data and experimental validation at each harvesting period is thus necessary. Results on respiration were completed. Only slight differences between organic and conventional fruits of the same cultivar on the respiration characteristics were noted.

Task 2.2: Based on data collected or measured in WP2.1, and by using a virtual MAP model, the packaging specifications in terms of barrier properties i.e. O2 and CO2 were determined using Tailorpack software. The Tailorpack virtual MAP model was upgraded in order to consider temperature variations (achieved), to predict spoilage (achieved) and food shelf life (achieved). The current version of the software permits to identify the O2 and CO2 permeability. It could also predict, once O2 and CO2 permeabilites are known, the evolution of O2 and CO2 concentrations in headspace and spoilage percentage as a function of time (Fig. 1).

Task 2.3: Using the packaging specifications in terms of barrier properties identified by the software in the previous task, optimal biodegradable/biosourced packaging solution(s) was (were) identified. According to preliminary results, commercial biodegradable and/or biosourced packaging solutions suitable for passive MAP of strawberries are not yet available. Biopolymers currently available on the market (PLA, starch based blends, etc.) are not easily adapted to the packaging machinery available in the research lab facilities. Microperforated polyamide based film (Stepac provider) was not available either. Therefore, it was decided to validate the model by using oil-based film such as LDPE to pack strawberries in flowpack (France) and sealed HDPE trays with perforations made with acupuncture needles for the experiments performed with strawberries at Nofima (Norway).
At IATE, strawberries of the variety Charlotte were selected as the model food for its high perishability allowing it to be representative of challenging post-harvest storage. The 'MAP modeling tool' was validated in isothermal conditions (5, 10 and 20°C) and in dynamic temperature conditions mimicking strawberries' post-harvest storage. For the investigated temperature profile, a shelf life gain of 0.33 days was obtained in MAP compared to conventional storage. Shelf life gain of more than 1 day could be obtained for optimized post-harvest conditions as numerically investigated. Such shelf life gain permitted to anticipate a significant reduction of food losses at the consumer steps.

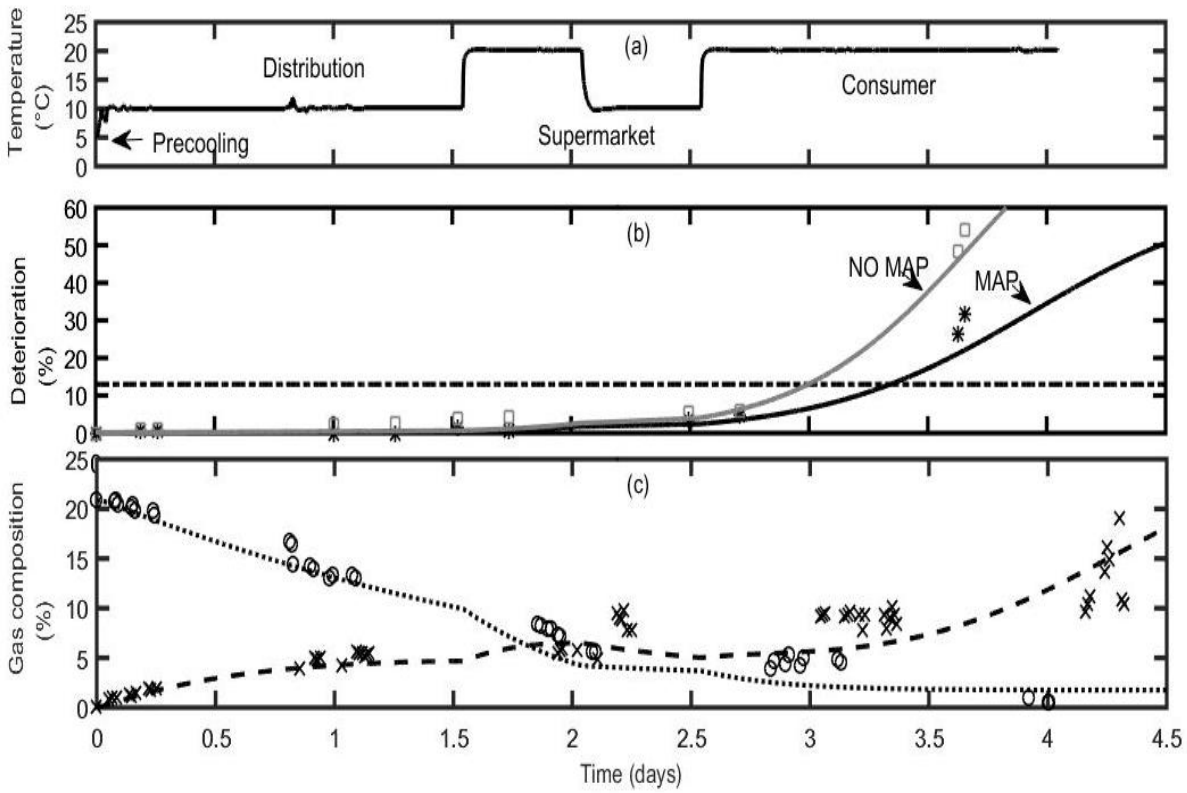

Figure 1: Example of MAP experiments carried out on Charlotte variety : (a) evolution of post-harvest temperature profile as a function of time during which (b) experimental deterioration in MAP (*) and NO MAP (□) is compared to the predicted one in MAP (—) and NO MAP (—) conditions. A deterioration value of 13% was considered as a limit of acceptability on figure (b) to set up product's shelf life (from Matar et al. 2018. Postharvest biology and technology.

Then, upgraded IATE mathematical model was tested on Nofima's data obtained on organic and conventional berries packed in MAP conditions. The model was able to predict the deterioration of strawberries provided that the initial deterioration state (higher for organic than conventional strawberries) is adjusted.

B- fulfilment of objectives:
Task 2.1.: achieved.
Task 2.2.: achieved.
Task 2.3.: achieved 100%. Validation of the film selection done (link with WP5 activities)

Following Ecoberries work, we are able to (1) measure respiration characteristics of any kind of fresh berries using a consolidate protocol (tested concomitantly by IATE and NOFIMA), (2) to identify O2 and CO2 optimal permeabilities for a given berry, in a given pack geometry and given storage conditions (temperature) and (3) to predict evolution with time of berries' deterioration and O2 and CO2 concentration in headspace in passive MAP system. Berries' deterioration permits to determine the product shelf-life in given conditions and to concretely assess the benefit of using MAP for the fresh berries food chain, which is a real added value for all stakeholders.

WP3	Title of WP3 **Mild drying technologies for organic berries**

WP leader: Univ. Bologna

Responsible partners: RISE (former SIK and SP), USAMVB, Gaziantep University (GU), GDAR / CRIFFC

Overall summary of main results, discussion and conclusions WP3

The effect of pulsed electric filed (PEF) and ultrasound (US) coupled with osmotic dehydration (OD) were investigated in order to obtain different semidried organic fruit products. Both pre-treatments were able to increase the mass transfer during OD process. Moreover, the application of PEF as a pre-treatment of OD reduced the final sugar concentration in kiwifruit compared with not pre-treated samples. An electric field strength of 100 V/cm was identified as optimal to compromise between efficacy for mass transfers during OD and the need to preserve the fruit micro-structure and their fresh-like characteristics.

During storage, US pre-treatment led to lower weight reduction in cranberry samples treated with any type of the solution in comparison to those without US pre-treatment. Moreover, during storage, the US pre-treatment promoted changes in the qualitative characteristics, in particular of colour leading to a higher lightness (L*) in comparison to the untreated fruit. The sample that preserved the best chemico-physical and microbiological characteristics during storage was the one treated with 61.5% sucrose solution, due to the lowest water activity.

The effect of differently formulated edible coatings on blueberry samples were studied. All applied coatings showed a positive effect mainly on maintaining the firmness and decreasing the microbial growth of treated blueberries samples. Results from this study demonstrated the efficacy of new type of coating ingredients (chitosan and natural procyanidins) to maintain the overall quality and high antioxidant activity of fresh blueberries during storage.

The effect of pre-processing methods (mixing into a puree; juice pressing resulting in a press cake), drying techniques and powder fractionation on functionality of bilberry powders was studied. The choice of pre-processing method clearly influenced the drying time required to reach the desired water activity (whole berries>puree>press cake). Powders from press cake boosted the total phenolic content (TPC) and improved the powder flowability while powder from whole berries and purée was beneficial for an improved dispersibility. TPC could further be enhanced by fractionation of press cake powder into small size particles. The nutritional value of berry powders produced using different drying techniques (hot air drying - HAD and microwave assisted hot air drying - MWD) for use in extruded snacks was evaluated. The drying time to achieve the aimed 18 % of moisture content differed between the two drying techniques (360 min for HAD and 215 min for MWD). TPC was reduced markedly by drying, but no difference in TPC was found between HAD and MWD.

The effect of different pre-treatments before drying of whole blueberries was evaluated by either dipping whole berries in olive oil or by combining immersion of berries in apple juice concentrate with Ultrasound treatment. Osmotic pretreatment together with ultrasound application contributed the good quality of final dried berries although they did not reduce significantly the time of drying at any microwave level. However, the application of ultrasound assisted osmotic pretreatment with high levels of microwave power produced high quality (better color, higher phenolics) berries in a shortened drying time. The most effective change in time of drying was observed when microwave power was increased to 210W together with osmotic pretreatment.

Finally, the microbiological safety (especially mycotoxins) of differently pretreated and processed semi-moist and dried berries as a function of water activity, temperature and packaging was assessed. The patulin was not detected in any of dried cranberries and bilberries samples, and it was not detected in the analyzed fresh blueberries and strawberries. Concerning the organic bilberry press cake, the results showed that the samples were in limits, according to the Romanian legislation: max. 5 CFU/g Enterobacteriaceae and max. 500 CFU/g for yeast and molds.

Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:

3.1. Organic technologies for pretreatments to replace sulfites with natural compounds and to improve functionality of final semidried products

Study 1: PEF assisted osmotic dehydration (OD) of organic kiwifruits and strawberries.

The aim of this study was to analyse the effect of PEF application on mass transfer phenomena, quality parameters and metabolic response of osmodehydrated kiwifruit *(Actinidia deliciosa cv Hayward)* and strawberries *(Fragaria+ananassa* var. *Alba).* Three different electric field strengths were applied (100, 250 and 400 V/cm) with a train of 60 pulses. Immediately after the PEF treatment the samples were OD treated by immersing the samples in hypertonic sucrose and/or trehalose solution at 25°C for up to 120 min. The obtained results showed that although similar effects on the investigated parameters were observed by using sucrose or trehalose solutions, the combination of PEF with trehalose allowed to obtain a high dewatering effect without increasing solute uptake or even reducing it. Concerning the PEF strength, the lowest one (100 V/cm) was able to positively affect the mass transfer, maintaining at the same time the fresh-like characteristics, in terms of colour and texture, of investigated fruits.

Study 2: Ultrasound assisted osmotic dehydration of organic cranberries.

The aim of this work was to analyse the effect of ultrasound assisted osmotic dehydration on mass transfer parameters and on quality characteristics during storage of cranberries. Ultrasound treatment was performed at the frequency of 21 kHz for 30 min in three osmotic solutions - 61.5% sucrose, 30% sucrose with an addition of 0.1% of steviol glycosides and 40 % trehalose on cut in half cranberries. Afterwards, the cranberry samples were subjected to osmotic dehydration process at 40°C for 72 h and then stored at 10°C in climatic chamber in microperforated plastic bags (PLA) for 8 weeks. The obtained results indicated that ultrasound application significantly affected the mass transfer parameters during osmotic treatment, as well as it did the type of osmotic solution used. Thermal analysis showed the variations in sugar melting temperature and enthalpy as a result of osmotic treatment and storage. The sample that preserved the best chemico-physical and microbiological characteristics during storage was the one treated with 61.5% sucrose solution, due to its lowest water activity.

Study 3: Edible film application on blueberries

The aim of this study was to investigate the effectiveness of differently formulated edible coatings in improving the shelf-life of blueberry fruits. In the first study case different types of coatings were used: sodium alginate, pectin and sodium alginate + pectin, while in the second one chitosan from mushroom and chitosan enriched with procyanidins from grape seeds were used as a film. Uncoated and coated blueberries were investigated for some quality parameters, cell vitality, antioxidant activity and microbial growth during 14 days of storage at 4°C. Obtained results showed that the application of coatings improved the firmness of blueberries and reduced the growth kinetics of yeasts and mesophilic aerobic bacteria. Moreover, the innovative coatings, in particular the one with chitosan and procyanidins showed a positive effect on increasing the antioxidant activity of blueberry samples.

Task 3.2. Selection of organic technologies like mild concentration and drying technologies/direct formulation to enhance nutritional value of extracts and powders

Study 1: Functionality of bilberry powders as affected by preprocessing methods

The aim was to investigate how the functionality of bilberry powders can be tailored by applying preprocessing techniques (mixing into a puree; juice pressing resulting in a press cake), drying technique (HAD vs MWD) and particle size fractionation (< 500, 500 – 710, > 710 µm) Results: The choice of preprocessing technique clearly influenced the drying time required to reach the desired water activity: 27 h for whole berries, 15 h for puree and 7.5 h for press cake. Bilberries have a waxy skin, and the reduction in drying time for preprocessed bilberries was explained by destruction of the skin. In case of press cake, drying time was also reduced by the lower initial moisture content. The whole berry and purée powders were very cohesive while the press cake powder was cohesive on the cross-section to easy flowing. Puree and whole berry powder showed a similar degree of dispersibility while powder from press cake had markedly lower dispersibility. For all type of bilberry powders, the dispersibility was higher in cream than in water. For all type of bilberry powders, the dispersibility was higher in cream than in water. Press cake powder showed a higher TPC than purée and whole berry powder, and the TPC could be enhanced further

by fractionation of the press cake powder into small size particles (< 500 µm). The choice of drying technique (HAD or MWD) showed no large difference in powder functionality in this study.

Study 2: Drying study on bilberry presscake for extruded snack

Aim: Evaluation, in terms of nutritional value, of berry powders produced using different drying techniques (HAD and MWD) to be used in extruded snacks. Results: The drying time to achieve the aimed 18 % of moisture content differed between the two drying methods (360 min for HAD and 215 min for MWD). The water activity of the dried and milled materials was 0.76 for both HAD and MWD. The particle size distribution of the dried and milled materials after HAD and MWD was similar for the two drying methods, although there was a tendency of a little more finely milled particles using MWD than HAD. The total content of phenolic compounds was reduced markedly by drying, but was not different when the two drying methods were compared.

3.3. Organic technologies for dried berries. Validation of mild microwave/infrared technology according organic production requirements.

In this task, blueberries have been dried by microwave following the ultrasound assisted osmotic pretreatment. First, whole berries were dipped into 5% K2CO3 and 1% organic olive oil for 2 min in order to increase skin permeability. Berries were immersed into organic apple juice concentrate (70 °Brix) and placed into ultrasonic bath. Here, 30 and 40% Ultrasound (US) power levels (corresp. 192 and 256W) were applied for 20, 40, and 60 min. Pretreated berries were dried in fan assisted microwave (MW) oven (150, 180, 210W; 60°C air flow).

The results showed that ultrasound application in water rather extended the drying times. It was clear indication of the necessity of osmotic solution together with the ultrasound application. Although apple juice concentrate did not favor drying times, it provided a much better look to the end product, which was polished (better color values (L, a, b) with shining appearance) and better shaped. Increasing ultrasound time at constant ultrasound level of 40% decreased the total drying time at microwave level of 150W. When the ultrasound power level was increased drying time was shorter. The most effective change in time of drying was observed when microwave power was increased to 210W together with osmotic pretreatment.

So, it can be concluded that, osmotic pretreatment together with ultrasound application contributed the quality of final dried berries even if they did not reduce significantly the time of drying at any microwave level. However, the application of ultrasound assisted osmotic pretreatment with high levels of microwave power produced high quality (better color, higher phenolics) berries in a shortened drying time.

3.4. Determination of mycotoxins in dried or semi-dry organic berry products, compared with conventional products. Assessment of the microbiological safety

The aim of this task was to assess the microbiological safety (especially mycotoxins) of organically pretreated and processed semi-moist and dried berries as a function of water activity, temperature and packaging.

In this study patulin was determined for 31 samples of dried organic cranberries, 2 samples of organic bilberry press cake and 2 fresh samples (blueberry and strawberry). Samples taken in the study for patulin determination were from Italy (31 samples), Sweden (2 samples) and Turkey (2 fresh samples).

Following HPLC-DAD analysis of the purified and concentrated extracts of the studied samples, patulin was not detected in any of dried cranberries and bilberries samples, and it was not detected in the analyzed fresh blueberries and strawberries.

The microbial contamination was determined for organic bilberry press cake. The results obtained showed that the samples were within limits, according to the Romanian legislation: max. 5 CFU/g Enterobacteriaceae and max. 500 CFU/g for yeast and molds.

B- fulfilment of objectives:

The objectives of the WP3 were completely (100%) fulfilled.

The fulfilment of the WP 3 objectives was achieved by the developing a semidried or coated organic fruit products obtained from by application mild technologies maintaining a good quality parameter of treated fruits. Processing conditions for hot air drying, microwave assisted hot air drying and milling during processing of berries into powders have been studied and evaluated, as well as how the choice of processing conditions affect the resulting powder characteristics. Optimal processing conditions depend

on the desired characteristics of the berry powder.

WP4	Added value organic berry products

WP leader: RISE

Responsible partners: UNIBO, GU, GDAR/CRIFF, VTT

Overall summary of main results, discussion and conclusions WP4

The objective of WP4 was to explore both established and emerging technologies for production of berry-based products with preserved content of bioactive compounds while assuring safety, high bioaccessibility and low environmental impact. The technologies in focus of WP4 was High Pressure Homogenization (HPH), Extrusion and 3D printing.

High pressure homogenization (HPH), having great potential as alternative to thermal treatment, and extrusion, established technology in the food industry, have been used within the project to evaluate safety, potential to increase shelf life and quality parameters of perishable berry-based products such as juice (HPH), and for the development of novel, added-value snack products (extruded) out of side streams from juice manufacturing. Using HPH treatment proved to be successful for the reduction of both pathogen and spoilage microorganisms in blueberry and Chinese gooseberry juices, without any negative effects on juice quality. Thus, long shelf life of juices could be achieved using HPH (cold storage >40 days and ambient storage 2 months for blueberry juice and 10 days for Chinese gooseberry juice). Long shelf life of otherwise perishable berries and berry-based products facilitates waste reduction as well as provision of convenient products for the consumer. Moreover, the application of HPH on Chinese gooseberry juice induced a significant increase in total polyphenols and with a less extensive degradation of bioactive compounds during storage

Addition of bilberry press cake powders (10 and 25%) to wholegrain rye flour was made to produce extruded snacks high in dietary fibre and bioactive compounds. Sensory evaluation of the extruded snacks showed that 10% addition of bilberry press cake powder resulted in snacks that were slightly better liked than snacks with 25% of bilberry press cake. Using berry powder in a cereal-based extrusion formulation is a novel way to utilize berry side streams for production of healthy snacks. Prior to extrusion, berry press cake was dried and milled into a fine powder. Production of stable powders from berries assures a whole-year-round availability of berry material, which contributes to waste reduction. Also, utilizing berry sides streams is a promising approach to recycle valuable components such as polyphenols vitamins and fibres as well as flavour and colour compounds in the food chain.

3D printing is an emerging technology which offers new possibilities to shape products, as well as efficient production of small production volumes. During the early 2000s 3D printing has been introduced in the food sector with rapid development during the past years. 3D printing offers new possibilities to produce food with innovative geometries and structures. The technology is suitable for on-demand production and for customized products. It is also possible to make new products with specific textures through management of porosity and/or co-printing of several ingredients in different patterns. Both in the food research sector and the business sector development of 3D printers for food and suitable food ingredients is intense.

Berry based purées have potential to be suitable raw materials for extrusion 3D printing. As berries are rich in micronutrients, confectionaries based on berry purée without sugar addition can serve as healthy snacks. Strawberries were chosen as raw material as they are popular in confectionaries and desserts, and they are also produced in large quantities in Europe. The case study on 3D printing of berry-based confectionaries was carried out through screening of a range of texturizing agents commonly used in berry-based foods and with rheological properties that were expected to be suitable for 3D printing. The texturizing agents were added to strawberry purée and texture and printability was evaluated. Four of the texturizing agents (Agar, kappa-Carrageenan, Low acyl gellan gum, High acyl gellan gum:

with/without Xanthan addition) successfully produced strawberry samples that were possible to print in a paste extrusion 3D printer. When using hydrocolloids for 3D printing, it is important to master both the rheological properties and the gel forming properties to be able to print the material into shape stable food items. In order to print more complex shapes, addition levels of the texturizing agents needs to be fine-tuned, as well as dissolution protocols and co-addition of other hydrocolloids. Also, shape stability over time, microbiological shelf-life and sensory properties needs to be evaluated.

Within the project, innovative berry ingredients and products have been produced, such as functional powders, healthy extruded snacks and 3D printed confectionaries. High Pressure Homogenization, Extrusion (of dried berry powders) and 3D printing are technologies where the whole berry harvest can be used (regardless of visual flaws), and possibly also side streams such as press cake, which can contribute to waste reduction. These technologies are commonly used without any harmful chemicals in the production or cleaning process. High pressure homogenization is a useful technique for reduction of preservatives in food products. Also, the use of energy and water resources are fairly low and therefore these technologies can be considered to have low environmental impact. An environmental assessment of the extrusion process used in the project was further evaluated in Task 5.4 using LCA.

Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:

Task 4.1 High pressure homogenization

High Pressure Homogenization (HPH) is used as a continuous process allowing more efficient reduction in particle size than classical homogenization for fluid products (juices and pulps), with a concomitant reduction of microbial cell loads. Juices (blueberry and Chinese gooseberry*)* have been processed with different HPH treatments to define the processing conditions to obtain an increased shelf-life. HPH treatment was used both in combination with a heat exchanger (to avoid the effect of heat during pressure treatment) and without. Challenge tests were carried out to understand the inactivation dynamics by HPH and the potential microbial re-growth in juices during storage at various storage conditions.

Both pathogenic (*L. monocytogenes, E.coli*) and spoilage (*S. cerevisiae Z. bailii,* and *Lb. plantarum*) microorganisms were studied in blueberry and Chinese gooseberry juice. In blueberry juice, all pathogenic species were inactivated immediately after HPH treatment due to the combination of HPH and low pH. Spoilage microorganisms were reduced enough by HPH to achieve a shelf-life of two months, in both cold and ambient storage, depending on processing conditions (cold storage: 100 MPa for 6 passes and thermal exchanger, ambient storage: 100 MPa for 4 passes without heat exchanger).

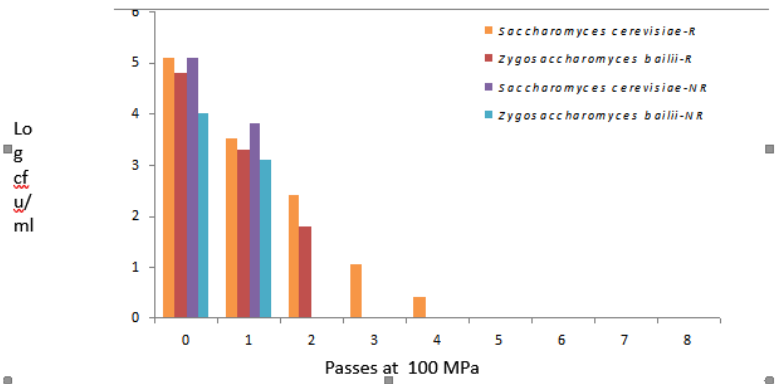

Figure 2. Inactivation of *S. cerevisiae* and *Z. bailii* in berry juice in relation to the passes at 100 MPa and the presence of thermal exchanger (R - with; NR - without).

For Chinese gooseberry juice, HPH treatment increased the death kinetics of the pathogenic *L. monocytogenes*, which has no re-growth potential in the pH-range found in the juice. Spoilage microorganisms were reduced enough by HPH treatment to achieve a shelf-life of >40 days at cold

storage (200 MPa for 3 passes) or 10 days at ambient temperature (200 MPa for 3 passes). HPH treated gooseberry juice maintained its green colour and no decrease in total phenolic content was detected. The HPH treated juice resulted in higher viscosity than control juice.

Task 4.2 Novel extrusion processing

Extrusion processing has been applied to produce berry-based snacks. Berry press cake was chosen as raw material to up-grade side streams from fruit-juice manufacturing. Bilberry press cake was dried to 18 % moisture content using two drying techniques; hot air drying (HAD) and microwave assisted hot air drying (MWD) and milled into powders (reported in WP3). In order to avoid over processing and large energy consumption, drying was conducted to a satisfactory moisture level for milling and extrusion of the material. The drying techniques were evaluated in terms of moisture content, water activity, total phenolic content and particle size distribution of the berry powders. The use of MWD reduced the drying time (215 min) compared with HAD (360 min). The resulting powders were similar in powder characteristics with the main differences that MWD powder had a slightly larger fraction of small particles. The berry powders were mixed with whole grain rye flour and puffed extrudates were made using a twin-screw extruder. Two levels of berry powder addition 10 and 25 % (w/w) were made. The extrusion settings were adjusted to achieve a puffed extruded snack product with appropriated textural characteristics. The snacks were evaluated regarding texture, degree of expansion, sensory properties and total content of phenolic compounds. The sensory evaluation was carried out using a convenience consumer panel with the aim to perform a feasibility study, answering the needs of early stages in a product development process.

The extruded , bilberry press cake supplemented snacks were appreciated by the consumers in the sensory evaluation. Increased berry content resulted in a lower degree of expansion and higher crispness index (extracted from the uniaxial force-deformation curves). Higher crispiness index means that the structure is easier to fracture whereas lower crispiness index refers to crunchy and rather hard, more compact structure. The crispiness index was similar for both wholegrain rye flour snacks and snacks with 25 % MW dried bilberry addition. As expected, increased berry content implied higher content of phenolics, and the microwave dried samples had a slightly higher content than the air-dried samples. Air dried samples, however, were a little bit more appreciated by the sensory panel. The results of this study were presented as a poster session and in a peer reviewed publication. Drying (using HAD and MWD) and the extrusion process was studied further in the environmental assessment carried out in Task 5.4.

Task 4.3 3D printing

Trials have been carried out to find suitable formulations and processing conditions for 3D printing of strawberry based confectionaries. When printing food purées it is necessary to add a texturizing agent to the food formulation to be able to print a shape stable product. Both the choice of texturizing agent and then pre-processing steps prior to printing, as well as printer settings for temperature, speed and nozzle size affect the resulting product. The case study on 3D printing of berry-based confectionaries was carried out through screening of a range of texturizing agents commonly used in berry-based foods and with rheological properties that were expected to be suitable for 3D printing. Only non-animal originating additives possible to use in organic products were considered. The texturizing agents were added to strawberry purée. Based on the texture and colour of each texture agent infused strawberry puree, the most promising ones were selected for 3D printing trials, and processing protocols for mixing and temperature control was defined. Various formulations were printed using a Focus printer from ByFlow. Four of the texturizing agents (Agar, kappa-Carrageenan, Low acyl gellan gum, high acyl gellan gum: with/without Xanthan addition) successfully produced strawberry samples that were possible to print in a paste extrusion 3D printer.

B - comments on deviations from the original plan:
The milestone M4.1 on processing conditions for HPH was delayed from month 3 to month 6 in order to complete the studies on blueberry juice. The deliverable D4.1 on HPH was delayed from month 12 to month 18 in order to include all results from the trials on both blueberry and Chinese gooseberries.

C- fulfilment of objectives:
Both established and emerging technologies have been used within the project to produce berry-based products with preserved content of bioactive compounds and increased shelf-life. HPH, drying, extrusion and 3D printing are technologies which can be considered to give low environmental impact in the sense that the entire harvest can be used (regardless of visual flaws), and possibly also side streams such as press cake, which reduces waste. Within the project, innovative berry products have been achieved, such as functional juices and powders, healthy extruded snacks and 3D printed confectionaries.

WP5	Title of WP5 **Shelf-life assessment, environment assessment and consumer studies**

WP leader: USAMVB
Responsible partners: UMR-IATE, Nofima, RISE

Overall summary of main results, discussion and conclusions of WP5
The objective of WP5 is to identify the most promising berry/packaging solutions by measuring different quality aspects, such as microbial spoilage, changes in color, texture and nutritional content during storage experiments. Environmental assessment studies will be made on selected products. Evaluation of consumer attitudes and preferences will be made to identify consumers' price sensitivity for berry products, together with the importance of organic and health claims associated with such products, and consumer segments on the organic berries market.

To find most promising solution for storage and packaging of berry fruits first were identified relevant quality parameters necessary for shelf life assessment by USAMVB through a literature review. Regarding the storage experiments, USAMVB, Nofima and UMR-IATE performed for both WP2 and WP5 various storage experiments, at different temperature conditions, in CA (controlled atmosphere), MAP and with fruits packed in PP pouches containing biodegradable tray inside. The experiments were conducted mainly with strawberries organic and conventional, but USAMV also worked with blackcurrant, bilberry and raspberry.

All analyzed berries samples show variations in the ascorbic acid content, the intensity of antioxidant activity and the total polyphenols content.

All organic strawberry samples stored in controlled atmosphere presented significant decay reduction and shelf-life was considerably extended as compared to the control.

A 15% CO_2 concentration has role in reducing the intensity of respiration process during storage period better than other two concentrations tested, but when all conditions return to normal (air conditions and ambiant temperature) this cause the highest respiration and transpiration rate.

The MAP packages had no weight loss, whereas the open trays had up to 8% weight loss after 7 days of storage. MAP had minor influence on microbiota, color and chemical quality parameters (soluble solids, titratable acidity and pH). It is recommended to store berries cold and in closed packages.

Based on discussions with the project group from WP3/WP4, a cross-national consumer study was conducted with focus on mild-processed organic dried berries. It was investigated consumers' stated preferences for organic dried strawberries varying in their origin (national or European), price levels, technology (air drying or microwave drying) and nutrient contents in Norway, Romania and Turkey. Also, in Romania, Turkey and France a quantitative study was performed and only for Romania in parallel a conjoint study was done. Almost all consumers participating in the survey consider that taste and naturalness of the product are the most important aspects when buying products based on berries. Most of the respondents consider important issues as pack, price and certification of the products origin and not least the availability and store promotions. Less than half of French and Turkish respondents are not impressed by advertisements, health benefits and extended shelf-life and more, they do not consider recommendations of other consumers while Romanian respondents consider the recommendations of

other consumers and the novelty of the products.
Occasional fresh fruits buyers group shop once a week or less but are still receptive and know the benefits of eating products based on berries but sometimes are influenced by price, revenue, convenience and accessibility. The respondents who does not buy fresh berries products think that these products are perishable and that there are quite heavy and are considered luxury and for them produce essentially the same benefits.
The purpose of the environmental assessment was to evaluate the sustainability of processing solutions used within the project. The activities from WP3 and WP4 of processing bilberries into powders and extrusion of snacks were selected for assessment. Different pre-processing methods and drying processes of bilberries was included, as well as the product supply chain from farm to industrial gate. Also, the impact of using a renewable energy source and the impact of including bilberry pickers' travels was included. The method used was Life Cycle Assessment. The processing technologies evaluated were; hot air-drying (HAD) and microwave assisted hot air drying (MW-HAD). The HAD was performed in a convection oven with three types of raw-materials, whole berries (from frozen), berry puree and press cake to determine the optimal raw material to be used. Hot air drying was performed in a combined microwave convection oven, where the MW+HAD was also performed with press cake as the raw material to determine the most efficient processing technology.

Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:

Task 5.1 Identification of relevant quality parameters

Based on the literature review regarding the relevant quality parameters of berries, it was concluded that the most determined ones were: pH, total titratable acidity, soluble solids (physical-chemical parameters); the content of ascorbic acid (vitamin C) (titrimetric method, HPLC), total phenolic content, total anthocyanin content, antioxidant capacity (DPPH, FRAP, HOSC, ORAC, ABTS, NO) (nutritional parameters); yeasts and moulds, mesophilic aerobic total germ (microbiological parameters); aflatoxins (AF), toxins produced by *Alternaria* sp., ochratoxin A (OTA), patulin (PAT) (chemical contaminants); sensory attributes (panel - taste, aroma, texture, colour, appearance), colour – colorimetric, texture – texturometer (sensorial analysis).

Task 5.2 Storage experiments

Based on the results from a preliminary storage experiment with conventionally grown strawberries (in 2016), the main experiment was performed in August 2017. Organically and conventionally grown strawberries (cv. Sonata) were delivered from the same grower. Unfortunately, the organic berries had inferior quality compared with the conventional berries. The strawberries were stored in high or low CO_2 MAP or in open trays at 5 °C (cold storage) or at 5 °C followed by 1 day at 20 °C (realistic storage). After 7 days at cold storage, the CO_2-concentration in the low and high CO_2 packages were about 7 and 17%, respectively, while stored at the realistic conditions the CO_2-concentrations reached 20 and 32%, respectively. The MAP packages had no weight loss, whereas the open trays had up to 8% weight loss after 7 days of storage. MAP had minor influence on microbiota, colour and chemical quality parameters (soluble solids, titratable acidity and pH). There was limited effect of elevated CO_2 at cold storage. After one day storage at abused temperature, on the other hand, there were significant positive effects of high CO_2 on decay and spots, but the berries had developed chemical odour and flavour.
Few experiments for chilling and CA storage were performed for strawberries, blackcurrants, bilberries and raspberries. When they are stored at 3°C in air, the respiration and transpiration intensities are slowing down, and the quality parameters are well preserved compared to those stored at 5°C. In CA (controlled atmosphere) was established that the best storage conditions of the tested organic strawberries Regina were 5% O_2, 15% CO_2 and 80% N_2 with 75% relative humidity at 3°C.

Task 5.3 Consumer acceptance/conjoint studies of berry products developed in WP3/WP4

We investigated consumers' stated preferences for organic dried strawberries varying in their origin (national or European), price levels, technology (air drying or microwave drying) and nutrient contents in Norway, Romania and Turkey. Data from a total of 614 consumers were collected through an online conjoint choice experiment. We analyzed the data with Mixed Logit modelling, Principal Component Analysis and Partial Least Squares Regression to (i) identify the key drivers of organic dried strawberry

choices in each country, (ii) investigate individual technology preferences and characterize consumer segments in terms of attitudes, habits and socio-demographics at cross-national and national levels. Results show that consumers' preferences are driven by price, conventional drying technology and national production. Drying technology was the main driver of individual choice differences in Romania and Turkey, but not in Norway. Consumer characterization revealed that younger consumers (18-19 years old), consumers with positive attitudes to new food technologies, consumers careful of price, and Norwegian consumers are more inclined to adopt microwave-dried organic strawberries. These consumers also tend to reject higher prices. On the contrary, older consumers (54-65 years old), consumers with positive health, naturalness and organic attitudes, consumers with high food technology neophobia, consumers careful to product information regarding GMOs, additives and shelf life, and Turkish consumers are more inclined to reject microwave-dried organic strawberries for the benefit of air-dried alternatives. These consumers are also more acceptant of higher prices.

Choice-based conjoint analysis of responses only in Romania reveals that specific attributes affect consumer purchase decisions of organic dried berries mix. We found that consumers' willingness to pay for microwave-dried berries is low, independent from values associated with price, origin and nutritional claim. A utility is a measure of relative desirability or worth. The higher the utility, the more desirable the attribute level. Levels that have high utilities have a large positive impact on influencing respondents to choose products. In this case, consumers prefer air-dried organic berries that come from Romania, at lower price, and with higher nutritional content. In terms of consumers' attitudes, the study reveals that the "healthy eating" trend is also present in Romania. Consumers show higher interest in nutritional content, additive-free and organic claims. Conjoint studies technique proved a useful instrument in designing new food products and the food packaging claims. The findings pose an opportunity for the food industry. Production processes, ingredients, packaging, and marketing need to be combined in a way that consumers perceive the products as natural foods that have similarities with traditional ones. Companies working on innovative food technologies should design these in a way that consumers perceive the new food products as natural. Summarizing also the results and conclusions of the consumer quantitative research conducted in order to establish the determinants of Romanian, French and Turkish consumer behavior to buy products based on berries, it can be said that market dynamics based products berries in Romania compared with one in France is still moderate and restrained by economic factors (income per Romanian person consumer is significantly lower compared to average for French consumer income per person in the EU). As with French responders, most Romanian and Turkish participants in the survey consider the taste and naturalness of the product the most important aspects when buying products based on berries. But also, Romanian and Turkish responders consider that the price, packaging, certification of origin and the store availability and promotions are also important.

Task 5.4 Environmental assessment

Conclusions that can be drawn from the LCA is that regarding raw material, the most sustainable option is to use press cake, as this material enters the production system with no previous environmental burden, as it is considered as a waste in the systems it comes from. The other pre-processed materials (puree) also had a better environmental profile than whole berries, as the energy demand is lower when dehydrating this type of material as berry skin and cell walls have been ruptured and water is more readily released during the drying process. The results indicate that the MW+HA drying technology is the more sustainable technique as the MW+HA drying technology had lower environmental footprint compared to HA drying for all environmental impact categories. The sensitivity analysis showed that the bilberry product production system would become even more sustainable if the energy source was hydropower rather than average Swedish electricity (which is dominated by nuclear power, 63%). Also, the inclusion of the bilberry pickers' travels, especially pickers that travel to Scandinavia from Asian countries, would greatly increase the environmental footprint of the bilberry products if they are included.

B- fulfilment of objectives:

Task 5.1 Identification of relevant quality parameters

- Identification of the most relevant quality parameters of berries (physical-chemical, nutritional and microbiological parameters, chemical contaminants and sensorial analysis) – achieved.

Task 5.2 Storage experiments

Identification of the most promising berry/packaging solutions by measuring different quality aspects,

during storage experiments – achieved. Ecoberries work permits to determine the product shelf-life in given conditions and to concretely assess the benefit of chilling, MAP and CA for fresh berries food chain for various berries such as strawberries, blackcurrant, bilberry and raspberry.

Task 5.3 Consumer acceptance/conjoint studies of berry products developed in WP3/WP4 achieved the following objectives**:**

- Conduct a conjoint study in Norway, Romania and Turkey, with a representative sample of at least 150 persons/country (effective: >200 respondents per country),
- Measure consumer attitudes to organic and health attributes in three European cultures. In addition, natural interest and food technology neophobia were investigated,
- Investigate consumer stated acceptance of mild-processed berry products from technologies investigated in WP3/WP4,
- Investigate consumers' price sensitivity for mild-processed organic berry products,
- Characterize consumer segments of similar attitudes and preferences towards mild-processing technologies within and across nations.

Task 5.4 Environmental assessment achieved the following objectives:

- Evaluation of the environmental impact of the studied food processing technologies (different drying techniques, milling, extrusion) to identify the most optimal system on an environmental basis.
- Evaluation of the most optimal raw material to process (whole berries or mechanically pre-treated berries in form of puree or press cake).
- Assessment of the impact of using a renewable energy source and the impact of including bilberry pickers' travels in the LCA.

WP6	Dissemination and Technology transfer

WP leader: Chalmers
Responsible partners: All

Overall summary of main results, discussion and conclusions WP6

The objective with the work package is to disseminate information about the project across research centres, universities, companies and stakeholders during conferences, seminars and workshops. During the whole project information has been disseminated through participation in workshops, conferences, research seminars and meetings, with both oral presentations and posters, and through newsletters, a leaflet, a video and the website. Manuscripts have been submitted and published in international peer reviewed journals and in popular magazines. Contacts have been established with farmers and stakeholders.

Report on the results obtained (A):

Task 6.1 Provide stakeholders with project information through website and leaflets. A project web-site and a leaflet were created during spring 2015.

Task 6.2 Organize workshops in collaboration with European Food federations. A Workshop was performed on "Strategies to improve quality of organic products: an European perspective" at the University of Teramo, Teramo, 3 March 2016. A Workshop was organized as a side-event to the The 2nd Euro-Mediterranean Symposium on Fruit and Vegetable Processing Fruit and vegetable in Avignon, France (4-6 April 2016) for the participants of the symposium.

Task 6.3 Participate in international conferences and publish scientific papers.
We have participated in several international and national conferences, in total more than 20.
Some examples follow below:

- 7th Shelf life International Meeting (SLIM), Milano, Italy (22-23 Oct, 2015)
- The 2nd Euro-Mediterranean Symposium on Fruit and Vegetable Processing Fruit and vegetable in Avignon, France (4-6 April 2016)
- Diaspora and its friends Conference, 25-28 April 2016, Timisoara, Romania.
- The 9th International Conference on Water in Food – Leuven, May 22-24, 2016
- 6th International Conference BIOATLAS on Food and Tourism, 27-28 May 2016, Brasov, Romania.
- The International Conference Agriculture for Life, Life for Agriculture, 9-11 June 2016, Bucharest, Romania
- 4th International ISEKI Food Conference, 6-8 July, 2016, Vienna, Austria
- EFFoST International Conferences, 30th 28-30 November 2016 in Vienna Austria and 31st 13-16 November 2017, Sitges, Spain
- 18 papers have been published or accepted and 3 have been submitted to international per-reviewed journals, 7 manuscripts are in progress.

Task 6.4 Extension activities to reach farmers

- Newsletter of CIAB internal committee of INRA on organic agriculture (www.inra.fr/ciab), Innovative and eco-sustainable processing and packaging for safe, high quality and healthy organic berry products
- We have established contacts with farmers in Norway, Finland and Sweden
- Participation in workshops: Fruit and Veg processing in Avignon, April 2016; Food Innova, Cesena, Italy, January 2017; SUSORGANIC "Innovative strategies to improve quality and safety of organic products" workshop in Teramo, Italy November 2017
- Oral presentations at Swedish Berry network meeting, Göteborg, Sweden October 2016 and October 2017

B - comments on deviations from the original plan: Deliverable 6.2 Midterm leaflet - after discussion with the CO it was decided in November that a mid-term leaflet was not needed, as an alternative the website was used to provide stakeholders with information about the project.

C- fulfilment of objectives:
Task 6.1 100% achieved
Task 6.2 100% achieved
Task 6.3 100% achieved
Task 6.4 100%achieved
We have: (1) established a website and a leaflet (2) organized and participated in workshops (3) participated in international conferences and papers published and submitted to international pre-reviewed journals (4) established contacts with farmers and stakeholders and organisations

WP7	Management

WP leader: Chalmers
Responsible partners: All

Overall summary of main results, discussion and conclusions WP6

The objective of the work package is coordination of scientific and administrative work and contacts between the Call Secretariat, national funding agencies and the partners. It also includes organization of the project and project meetings and delivery of reports and scientific deliverables on time. A consortium agreement was established at the initiation of the project and was signed by all partners. General project meetings have been organized every sixth month, alternating between the facilities of the different partners. A mid-term report and a final report have been prepared.

Report on the results obtained (A)

A consortium agreement has been established and signed by all partners. The organization and the contacts between the partners are working efficient. A number of separate WP-meetings (Skype/telephone) have been held during the project and the following General project meetings with all

partners have been organized:

- Kick-off meeting, hosted by Chalmers University of Technology in Gothenburg, Sweden, 18-19th February, 2015
- Project meeting, hosted by UNIBO in Bertinoro, Italy, 14-16th October 2015
- Project meeting hosted by UMR IATE in Avignon, France, April 7th, 2016
- Project meeting hosted by USAMBV in Bucharest, Romania, 19-20 October 2016
- Project meeting hosted by Nofima, in Ås, Norway, 3-4 May, 2017
- Project meeting hosted by UMR IATE in Montpelier, 11-12 October, 2017
- Final project meeting organised by Chalmers in Munich, Germany, 15 February 2018
- TP Biofach Resarch seminar in Nuremberg, Germany, 16 February 2018

The mid-term and final reports have been prepared.

C- fulfilment of objectives:
Consortium agreement – achieved
Coordination of scientific and administrative work- achieved and ongoing
Organization of project meetings- achieved and ongoing
Mid-term report – finished
Final report – draft submitted

4. Milestones and deliverables status

Deliverable No.	Deliverable name	Link to the document	Planned delivery month[1)]	Actual delivery month[1)]	Reasons for changes/delay and explanation of consequences
D1.1.	Data on chemical composition and microbiological safety of berries		9 (11/2015) (starting date 26.2.2015)	18 for culture-based analysis of microbiota	Due to the poor weather in the summer 2015 organic vs. conventional berry comparisons were postponed and performed in 2016. Culture-based microbiological analysis has been done, but DNA based as well chemical analysis will be done in the autumn-winter 2016.
D1.2.	Data from studies on antioxidant capacity and antimicrobial activity		12	36	The delivery of processed products was delayed. These activities were measured only after all samples were available for a simultaneous analysis.
D 1.3.	Report on retention/degradation and bioaccessibility of nutrients and		32	38	The delivery of processed products was delayed. The studies were made when all samples were available for a simultaneous analysis.

	phytochemicals in berry products, interaction with WP3 and WP4				
D2.1.	Packaging specifications on mass transfer properties (O_2, CO_2, and water vapour) to dimension passive modified atmosphere packaging, Month 24		24	D2.1.	Packaging specifications on mass transfer properties (O_2, CO_2, and water vapour) to dimension passive modified atmosphere packaging, Month 24
D.2.2	Ranking of optimal packaging solutions proposed by the DSS		36	D.2.2	Ranking of optimal packaging solutions proposed by the DSS
D3.1.	Report on organic pre-treatment technologies to avoid sulphites and improve functionality of semi-dried products according to organic requirements		20	28	The report was delayed due to the limitation of availability of organic berries
D3.2.	Report on technologies to produce dried berries and berry powders according to organic requirements		30	30	Report on technologies to produce dried berries and berry powders according to organic requirements
D3.3.	Report on safety assessment on possible mycotoxin (and microbial) contamination of organically pre-treated and processed berries		36	36	Report on safety assessment on possible mycotoxin (and microbial) contamination of organically pre-treated and processed berries
D4.1.	Report on High Pressure Homogenization treatment on berry juices and pulp with rheological and sensorial evaluations		18	18	The deliverable D4.1 on HPH was delayed from month 12 to month 18 to include all results from the trials on both blueberry and Chinese gooseberries. The delay to month 6 did not imply any consequences for the

					project, as the deliverable D 4.1 was completed in the first half of the project time.
D4.2.	Report on berry snack formulations using extrusion-based technologies		24	24	
D4.3.	Case study to demonstrate the suitability of 3D printing for organic products		30	30	
D5.1	Report on technical specifications		3	12	USAMVB signed the contract with 9-month delay (Nov.2015)
D5.2	Report on the validation of packaging solution(s), proposed by the decision support system, on a selected berry product		30	36	
D5.3	Report on conjoint studies		34	36	
D5.4	Report on environmental assessment studies		34	36	
D6.1	Project web-site established and first leaflet produced		6	6	D6.1
D6.2	Midterm leaflet produced		18		Decision to not produce a mid-term leaflet after discussion with the CO, updates were published on the web-page instead
D6.3	Participate in international conferences		14	14	D6.3
D6.4	Industrial workshop and SME activities		14	14	D6.4
D6.5	Conference presentations		14	14	D6.5
D6.6	Final leaflet	http://projects.au.dk/coreorganicplus/currently/nyhed/artikel/vid	36	36	A video was produced instead and uploaded on the CO plus web page

		eo-mild-technologies-to-improve-shelf-life-and-quality-of-organic-berries/			
D6.7	Publications and reviews submitted			36	D6.7
D7.1	Consortium agreement		0	0	D7.1
D7.2	Mid-term report		18	18	D7.2
D7.3	Final report		36	41	A non-cost extension of the was approved by CO plus

Milestone No.	Milestone name	Planned delivery month[1)]	Actual delivery month[1)]	Reasons for changes/delay and explanation of consequences
M1.1.	Phytochemicals and nutrients in selected berries determined and data on microbiological safety available	12	18 for culture-based analysis of microbiota	Due to the poor weather in the summer 2015 organic vs. conventional berry comparisons were postponed and performed in 2016. Culture-based microbiological analysis has been done, but DNA based as well chemical analysis will be done in the autumn-winter 2016.
M1.2.	Antioxidant capacity and antimicrobial activity determined	12	34	These activities were measured only after all samples were available for a simultaneous analysis.
M2.1.	Availability of data on targeted berries requirements (safety and quality)	18	18	M2.1.
M2.2.	Implementation of survey on constraints/ needs of the berries supply chain	30	30	M2.2
M1.3.	Relationships process-phytochemical profile/bioaccessibility on products	34	36	Due to delayed due delivery of processed samples the bioaccessibility studies were finished in the end of the project
M3.1.	Identification of pre-treatments and mild processing technologies	20	24	The milestone was delayed due to the limitation of availability of

				organic berries
M3.2	Technological parameters and optimal processing conditions of selected technologies to obtain organic dried berries, powders and extracts	26	30	M3.2
M3.3	Compositional analysis and safety assessment by microbial and mycotoxins contamination of organic berries compared with conventional products	36	36	M3.3
M4.1.	Processing conditions on High Pressure Homogenization to obtain berry juices and pulps with improved shelf-life and sensorial quality	3	6	3 months was too little to complete the studies on HPH. The delay to month 6 did not imply any consequences for the project, as the deliverable D 4.1 was completed in the first half of the project time.
M4.2.	Recipe and processing parameters identified for organic berry based healthy added-value extruded snacks	14	10	M4.2
M4.3.	3D printing technology tested and process conditions identified	14	14	M4.3
M5.1.	Relevant quality parameters identified	3	12	M5.1
M5.2	Storage/packaging studies completed	30	36	M5.2
M5.3	Conjoint analysis completed	36	36	M5.3
M5.4	Environmental assessment studies completed	36	36	M5.4
M6.2	Industrial workshops and seminars implemented	36	36	M6.2
M6.3	Project results disseminated to main stakeholders, conferences, publications	36	36	M6.3

[1)] Measured in months from the project start date (month 1)

Additional comments on deviations from the original project implementation plan in case there is an impact on fulfilment of the overall project objectives.

5. Publications and dissemination activities

5.1 List extracted from Organic Eprints

(Publications affiliated to European Union > CORE Organic II > "project acronym", grouped by Eprint type, with date of extraction)

{Project} EcoBerries: ***Innovative and eco-sustainable processing and packaging for safe, high quality and healthy organic berry products.*** Runs 2015 - 2018. Project Leader(s): Alminger, Prof. Marie; Dalla Rossa, Prof. Marco; Popa, Prof. Mona Elena; Saarela, Assc. Prof Maria; Ahrné, Prof. Lilia; Gontard, Prof. Nathalie and Gogus, Prof. Fahrettin, Chalmers University of Technology .

Höglund, Evelina; Eliasson, Lovisa; Oliviera, Gabriel; Almli Lengaard, Valerie; Sozer, Nesli and Alminger, Marie (2018) **Effect of drying and extrusion processing on physical and nutritional characteristics of bilberry press cake extrudates.** *LWT- Food science and Technology*, 92, pp. 422-428.

Mannozzi, Cinzia; Cecchini, Juan Pablo; Tylewicz, Urszula; Siroli, Lorenzo; Patrignani, Francesca; Lanciotti, Rosalba; Rocculi, Pietro; Dalla Rosa, Marco and Romani, Santina (2017) **Study on the efficacy of edible coatings on quality of blueberry fruits during shelf-life.** *LWT - Food Science and Technology*, 82 (Part B), pp. 440-444.

Mannozzi, Cinzia; Tylewicz, Urszula; Chinnici, Fabio; Siroli, Lorenzo; Rocculi, Pietro; Dalla Rosa, Marco and Romani, Santina (2018) **Effects of chitosan based coatings enriched with procyanidin by-product on quality of fresh blueberries during storage.** *Food Chemistry*, 251, pp. 18-24.

Nowacka, Malgorzata; Tylewicz, Urszula; Romani, Santina; Dalla Rosa, Marco and Witrowa-Rajchert, Dorota (2016) **Selected chemical and physico-chemical properties of ultrasound-assisted osmodehydrated kiwifruit.** In: Pittia, Paola; Schleining, Gherard; Silva, Cristina L.M; Neri, Lilia and Habershuber, Anita (Eds.) *Book of Abstracts*, p. 344.

Nowacka, Malgorzata; Tylewicz, Urszula; Tappi, Silvia; Siroli, Lorenzo; Lanciotti, Rosalba; Romani, Santina and Witrowa-Rajchert, Dorota (2018) **Ultrasound assisted osmotic dehydration of organic cranberries (Vaccinium oxycoccus): Study on quality parameters evolution during storage.** *Food Control*, 93, pp. 40-47.

Popa, Mona Elena; Geicu-Cristea, Mihaela; Popa, Alexandra; Drãghici, Mihaela; Tãnase, Elisabeta Elena; Mitelut, Amalia Carmen; Iorga, Corneliu Sorin; Guillaume, Carole; Gontard, Nathalie; Guillard, Valérie; Gogu, Fahrettin and Yanik, Derya Kocak (2017) **Consumption and attitudes regarding berries-based products - comparative analysis of Romania, France and Turkey.** *Romainian Biotechnological Letters*, 22 (3), pp. 12568-12576.

Tãnase, Elisabeta Elena; Popa, Vlad Ioan; Popa, Mona Elena; Geicu-Cristea, Mihaela; Popescu, Paul; Drãghici, Mihaela and Mitelut, Amalia Carmen (2016) **Identification of the Most Relevant Quality Parameters for Berries – A review.** *Scientific Bulletin. Series F. Biotechnologies*, XX, pp. 222-233.

Traffano-Schiffo, Maria Victoria; Laghi, Luca; Castro-Giraldez, Marta; Tylewicz, Urszula; Rocculi, Pietro; Ragni, Luigi; Dalla Rosa, Marco and Fito, Pedro J. (2017) **Osmotic dehydration of organic kiwifruit pre-treated by pulsed electric fields and monitored by NMR.** *Food Chemistry*, 236, pp. 87-93.

Traffano-Schiffo, Maria Victoria; Tylewicz, Urszula; Castro-Giraldez, Marta; Fito, Pedro J.; Ragni, Luigi and Dalla Rosa, Marco (2016) **Effect of pulsed electric fields pre-treatment on mass transport during the osmotic dehydration of organic kiwifruit.** *Innovative Food Science and Emerging Technologies*, 38 (Part A), pp. 243-251.

Traffano-Schiffo, Maria Victoria; Tylewicz, Urszula; Laghi, Luca; Castro-Giraldez, Marta; Romani, Santina; Rocculi, Pietro; Ragni, Luigi; Dalla Rosa, Marco and Fito, Pedro J. (2017) **Effect of pulsed electric field pre-treatment on microstructure and internal transport throughout osmotic treatment of organic kiwifruit.** In: Mahnic-Kalamiza, Samo and Heller, Richard (Eds.) *Book of Abstract of the 2nd World Congress*

on Electroporation and Pulsed Electric Fields in Biology, Medicine, and Food & Environmental Technologies, Norfolk, VA, USA.

Tylewicz, Urszula; Mannozzi, Cinzia; Romani, Santina; Dellarosa, Nicolò; Laghi, Luca; Ragni, Luigi; Tappi, Silvia; Rocculi, Pietro and Dalla Rosa, Marco (2016) **Effect of PEF pre-treatment coupled with osmotic dehydration on physico-chemical characteristics of organic strawberries.** In: Pittia, Paola; Schleining, Gherard; Silva, Cristina L.M.; Neri, Lilia and Habershuber, Anita (Eds.) *book of abstract*, p. 81.

Tylewicz, Urszula; Tappi, Silvia; Mannozzi, Cinzia; Romani, Santina; Dellarosa, Nicolò; Laghi, Luca; Ragni, Luigi; Rocculi, Pietro and Dalla Rosa, Marco (2017) **Effect of pulsed electric field (PEF) pre-treatment coupled with osmotic dehydration on physico-chemical characteristics of organic strawberries.** *Journal of Food Engineering*, 213, pp. 2-9.

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Other publications

Matar, C., Gaucel, S., Gontard, N., Guilbert, S., Guillard, V., Predicting shelf life gain of fresh strawberries 'Charlotte cv' in modified atmosphere packaging. Postharvest Biology and Technology (2018), https://doi.org/10.1016/j.postharvbio.2018.03.002

AYSEL ELIK, DERYA KOÇAK YANIK, FAHRETTIN GÖGÜS - Optimization of microwave-assisted extraction of phenolics from blueberry, Romanian Biotechnological Letters, accepted for publication (DOI: 10.26327/RBL2017.134).

BDI+SCOPUS Articles

Adina Alexandra Baicu, Mona Elena Popa, Trends in prolonging the post-harvest life of strawberries – a review, articol acceptat spre publicare la The Annals of the University Dunarea de Jos of Galati, Fascicle VI Food Technology (http://www.ann.ugal.ro/tpa/ft_2018_no_1.htm).

ISI Articles

Mona Elena Popa, Amalia Carmen Mitelut, Elisabeta Elena Popa, Andreea Stan, Vlad Ioan Popa, Organic foods contribution to nutritional quality and value, Trends in Food Science & Technology Available online 31 January 2018 (https://www.sciencedirect.com/science/article/pii/S0924224417303679)

Alminger, M. The Ecoberries project. SciTech Europe Quaterly, 27, June 2018

Submitted papers:

Mona E. Popa, Luminita Catana, Elisabeta E. Popa, Amalia C. Mitelut, Urszula Tylewicz, Marco Dalla Rosa, Patuline analysis of some organic dried fruits samples by HPLC-DAD, articol trimis spre publicare la Romanian Biotechnological Letters (under review)

Tailoring bilberry powder functionality by processing – Effects of preprocessing
Lovisa Eliasson, Gabriel Oliveira, Maria Ehrnell, Evelina Höglund, Marie Alminger

Tailoring bilberry powder functionality by processing: Effect of drying and fractionation on total phenolic content of press cake with focus on anthocyanins. Gabriel Oliveira, Lovisa Eliasson, Maria Ehrnell, Evelina Höglund, Thomas Andlid, Marie Alminger

Popular science publications

Quality of strawberries (cv. Sonata) stored in modified atmosphere. Popular Science paper for a Norwegian journal. Larsen H., Aaby, K.

Manuscripts for peer-reviewed scientific publications
Chemical composition of organic and conventionally produced nordic berries.
Seppänen-Laakso T, Oliveira G, Alminger M, Saarela M.

Microbiological safety of organic and conventionally produced nordic berries.
Moen B, Saarela M, Salo S, Oliveira G, Alminger M.

Antioxidant evaluation and anthocyanin composition of processed berries
Oliveira G, Tylewicz U, Dalla Rosa M, Andlid T, Alminger M.

Validation of a fast and sensitivy LC MS/MS method to quantify anthocyanins after in vitro digestion.
Oliveira G, Ross A, Savolaine O, Landberg R, Andlid T, Alminger M.

Effetcs of anthocyanins after in vitro digestion on yeast metabolome: A cell model to evaluate health benefits. Oliviera G, Andlid T, Alminger M.

Quality of organic and conventionally grown strawberries (*Fragaria X ananassa*) stored in different atmospheres at two temperature regimes. Larsen H., Aaby, K.

Effect of high pressure homogenization on the shelf-life and functionality of organic kiwifruit juice. Food Research International, submitted.

5.2 Additional dissemination activities

National and International Conferences
Oral presentations
Mona Popa, Mihaela Geicu-Cristea, Alexandra Popa, Mihaela Drăghici, Elena Tănase, Amalia Miteluţ, Carole Guillaume, Nathalie Gontard, Valérie Guillard, Consumption and attitudes regarding berries-based products – comparative analysis of Romania and France, oral presentation at 2nd Euro-Mediterranean Symposium on Fruit and Vegetable Processing, 4-6 April 2016, Avignon, France

MONA POPA, Shelf-life extension of berries: Most relevant quality parameters and new techniques used for berries processing, oral presentation at 6th International Conference BIOATLAS on Food and Tourism, 27-28 May 2016

Elisabeta Elena Tanase, Vlad Ioan Popa, Mona Elena Popa, Mihaela Geicu-Cristea, Paul Popescu, Mihaela Draghici, Amalia Carmen Mitelut, Identification of the most relevant quality parameters for berries - a review, oral presentation at International Conference "Agriculture for Life, Life for Agriculture", 9-11 June, 2016

Mona Popa, EcoBerries „Innovative and eco-sustainable processing and packaging for safe and high quality organic berry products with enhanced nutritional value", oral presentation at Diaspora in Scientific Research and High Education in Romania.

Mihaela Cristina Drăghici, Paul Alexandru Popescu, Adina Baicu, Mona Elena Popa, Market research regarding the demands of the business operators on the supply chain logistics, oral presentation at International Conference „Agriculture for Life, Life for Agriculture", 8-10 June 2017, Bucharest, Romania.

Mona Elena Popa, Mihaela Draghici, Alexandra Jurcoane, Elena Popa, Amalia Mitelut, Sorin Iorga, Consumer acceptance regarding organic berries-based products processing techniques, oral presentation at 4th North and East European Congress on Food, 11-13 September, Kaunas, Lithuania.

Adina Alexandra Baicu, Mona Elena Popa, Trends in prolonging the post-harvest life of strawberries – a review, oral presentation at The 8th international symposium EuroAliment, *Mutatis mutandis* in food, 7-8 September 2017, Galati, Romania.

Mona Elena Popa, Tendinte in procesarea fructelor de padure si comportamentul consumatorului (Trends in berries processing and consumer behavior), oral presentation at Ziua Mondiala a Alimentatiei – Perspective ale alimentatiei secolului XXI (World Alimentation Day – Alimentation Perspectives for XXI century), 30 October 2017.

Mona Elena Popa, Organic and wild berries value chain in Romania, oral presentation at Organic Agriculture in Romania Workshop, 16 November 2017.

Guillard, V., Buche, P., Gontard, N. & Guillaume, C. Food safety and shelf life modelling for a better dimensioning of the food / packaging system. 7th Shelf life International Meeting (SLIM), Milano, Italy (22-23 Oct, 2015)

C. Matar, S. Gaucel, V. Guillard, C. Guillaume, S. Costa, S. Guilbert, N. Gontard. Predicting food waste and losses for fresh produce in modified atmosphere packaging. 30th EFFoST International Conference, 28-30 November 2016 | Vienna, Austria, selected for oral presentation

Tylewicz Urszula - Oral presentation of ECOBERRIES Project "Innovative and eco-sustainable processing and packaging for safe and high quality organic berry products with enhanced nutritional value" at WORKSHOP on „Strategies to improve quality of organic products: an European perspective“. University of Teramo, Teramo, 3 March 2016

Marco Dalla Rosa – Oral presentation on “Overview on mild technologies applied to organic berries to increase stability and functionality“ at the Ecoberries workshop during the 2nd Euro-Mediterranean Symposium on Fruit and Vegetable Processing, Avignon, 4-6 April 2016

Tylewicz U., Mannozzi C., Romani S. , Dellarosa N., Laghi L., Ragni L., Tappi S., Rocculi P., Dalla Rosa M. - Oral presentation on “Effect of PEF pre-treatment coupled with osmotic dehydration on physico-chemical characteristics of organic strawberries”. At 4th International ISEKI_Food Conference, 6-8 July, 2016, Vienna, Austria, p.81. Book of Abstract ISBN 978-3-900932-34-3

Tylewicz Urszula - Oral presentation on “Mild drying technologies for organic berries“ at Workshop “Strategies to improve quality of organic products in an European perspective” within the ongoing EcoBerries project, as a side event of FoodInnova 2017 Conference, 31 January 2017, Cesena, Italy

Traffano-Schiffo M. V., Tylewicz U., Laghi L., Castro-Giraldez M., Romani S., Rocculi P., Ragni L., Dalla Rosa M., Fito Pedro J. Orat presentation on “Effect of pulsed electric field pre-treatment on microstructure and internal transport throughout osmotic treatment of organic kiwifruit” at 2nd World Congress on Electroporation, Norfolk 24-28 September, 2017.

Tylewicz Urszula – Oral presentation on «New technologies for transformation and conservation of berries-Ecoberries project» at Workshop on Innovative Strategies to improve quality and safety of organic products. Teramo (Italy), 10th November 2017.

Oral presentation of the EcoBerries project at a combined meeting of the Swedish Berry Network and a Swedish Health Network the 12th of October 2016, Sweden. Maria Ehrnell, RISE Agrifood and Bioscience

Oral presentation at the Swedish Berry Network, October 2017, Sweden. “3D printing of berry based products” Evelina Höglund, RISE Agrifood and Bioscience.

Oral presentation at the EcoBerries workshop at the Fruit & Veg processing Symposium, Avignon 4-6th April 2016. “Functional powders - processing for added value products” Evelina Höglund, RISE Agrifood and Bioscience.

Oral presentation at FoodInnova 2017 ”Effect of (ultra)-high pressure homogenization and natural antimicrobial based nanoemulsions on kiwi juice safety and shelf-life” Francesca Patrignani, Researcher, University of Bologna

Poster presentations

Elena Tănase, Paul-Alexandru Popescu, Vlad Ioan Popa, Mona Elena Popa, New techniques used to improve berries shelf life, poster presented at 2nd Euro-Mediterranean Symposium on Fruit and Vegetable Processing, 4-6 April 2016, Avignon, France

Mona Elena Popa, Elena Tănase, Vlad Ioan Popa, Quality indicators and postharvest shelf life assessment of fresh berry fruit, poster presented at 2nd Euro-Mediterranean Symposium on Fruit and Vegetable Processing, 4-6 April 2016, Avignon, France

M.E. Popa, E.E. Tanase, A. Stan, V.I. Popa, L. Badulescu, A.C. Mitelut, M. Draghici, Effect of chilling temperatures on quality and nutritional indicators of fresh organic strawberries, poster presented at International Conference EFFoST, 28-30 November 2016, Vienna, Austria.

Mona Popa, Andreea Stan, Vlad Popa, Elisabeta Elena Popa, Liliana Badulescu, Amalia Mitelut, Effect of chilling temperature storage on some berries postharvest period, poster presented at International Conference on Food Innovation (FOODINNOVA), Cesena, Italy, 31 January – 04 February 2017.

Mona Popa, Andreea Stan, Vlad Popa, Elisabeta Elena Popa, Liliana Badulescu, Amalia Mitelut, Organic strawberries shelf life improving using controlled atmosphere, poster presented at International Conference on Food Innovation (FOODINNOVA), Cesena, Italy, 31 January – 04 February 2017.

Mona Elena Popa, Alexandra Jurcoane, Elena Tanase, Amalia Mitelut, Paul Popescu, Vlad Ioan Popa, Mihaela Draghici, Influence of different product attributes on romanian consumer purchase decisions for organic dried berries, poster presented at International Conference Food Quality & Safety, Health & Nutrition (NUTRICON), 5-7 October 2017, Skopje, Macedonia.

Elisabeta Elena Tănase, Adina Alexandra Baicu, Vlad Ioan Popa, Amalia Carmen Miteluț, Mihaela Draghici, Andreea Stan, Paul Alexandru Popescu, Mona Elena Popa, Sustainable packaging solutions for organic fresh berries, poster presented at „The 7th International Conference Biotechnologies, Present and Perspectives”, 24-25 November 2017, Suceava, Romania.

Asioli D., Rocha C., Wongprawmas R., Popa M., Gogus F., Almli V. L., European consumers' preferences for organic processing technologies: case study on dried berries in Norway, Romania and Turkey, poster presented at 12th Pangborn Sensory Science Symposium, 20-24 August 2017, Providence, Rhode Island, USA.

Larsen, H. Temperatur og lysforhold har mye å si for matens holdbarhet (Temperature and lighting conditions has high impact on food shelf life): oral presentation at REforReM Seminar, Oslo, 28. September, 2017.

Oliveira G, Tylewicz U, Dalla Rosa M, Andlid T, Alminger M. “Antioxidant evaluation and anthocyanin composition of processed berries”. Science and Technology day, Chalmers. 19th April 2018.

Alakomi, Salo, Barbosa, Alminger, Moen, Saarela. ” Microbiological safety of organic and conventionally grown berries”. Poster presentation in 3rd International workshop. Interactions between crop plant and human pathogens. 12.-.13.3.2018, HU Berlin, Dahlem, Germany

Barbosa G., Höglund E., Eliasson L., Almli V., Sozer N., Alminger M. “Extruded snacks produced from bilberry press cake” FoodInnova, Cesena, Italy, Jan 2017.

Guillard, V., Matar C., Gaucel, S., Gontard, N. & Guilbert, S. Decision Support Tool to predict food shelf life and optimize Modified Atmosphere Packaging of fresh fruits and vegetables, 2nd Euro-Mediterranean Symposium on Fruit and Vegetable Processing, 4-6 Avril 2016, Avignon (France)

Dalla Rossa et al. Effect of high pressure homogenization on the quality of organic kiwi fruit juices” Fruit & Veg processing, Avignon 4-6th April, 2016.

Effect of high pressure homogenization on the quality of organic kiwi fruit juices. Fruit & Veg processing, Avignon 4-6th April, 2016-08-10. Francesca Patrignani, PhD in Food Biotechnology, Researcher-University of Bologna-DISTALItaly

Mannozzi C., Cecchini J.P., Tylewicz U., Romani S., Rocculi P., Dalla Rosa M. – Poster Presentation PI-35 on *„Study on the efficacy of edible coatings on quality of blueberry fruits during shelf-life“* at 2nd Euro-Mediterranean Symposium on Fruit and Vegetable Processing, Avignon, 4-6 April 2016, p 88.

Traffano-Schiffo, M.V., Laghi L., Tylewicz U., Castro-Giraldez M., Fito P.J., Ragni L., Dalla Rosa M. - Poster presentation –P2 on *"Study of the water distribution during osmotic dehydration of kiwifruit and the effect of pulsed electric fields as pre-treatment“* at 9th International Conference on Water in Food – Leuven, May 22-24, 2016

Nowacka M., Tylewicz U, Romani S, Dalla Rosa M., Witrowa-Rajchert D. – Poster presentation on “Selected chemical and physico-chemical properties of ultrasound-assisted osmodehydrated kiwifruit” at 4th International ISEKI_Food Conference, 6-8 July, 2016, Vienna, Austria, p.344. Book of Abstract ISBN 978-3-900932-34-3

Tylewicz U., Mannozzi C., Tappi S. , Dellarosa N., Rocculi P., Dalla Rosa M., Romani S. – „Effect of different freezing methods on the physico-chemical characteristics of organic strawberries” –poster presented at 30th EFFoST International Conference Targeted Technologies for Sustainable Food Systems on 28-30 November 2016 in Vienna, Austria.

M. Nowacka, U. Tylewicz, S. Tappi, N. Dellarosa, L.Laghi, L.Siroli, R. Lanciotti, M. Dalla Rosa[2,3], D. Witrowa-Rajchert. – «Ultrasound assisted osmotic dehydration of organic cranberries (Vaccinium oxycoccus). Study on osmotic dehydration kinetics and quality parameters during storage”-poster presented at 31st EFFoST International Conference , 13-16 November 2017, Sitges, Spain.

Dissertation and Bachelor thesis

Oancea Bogdan, Conservarea prin frig a unor fructe de pădure (Cold preserving of berry fruits), Coordonator științific: Popa Mona Elena

Albu Cristina - Analize post recoltă a unor fructe de pădure (Post-harvest analysis of some berry fruits), Coordonator stiintific: Prof. univ. dr. Mona Popa

MSc thesis
Kübra Atacan, Effect of spray drying parameters on blueberry and strawberry juice concentrates, Gaziantep University MSc Thesis (2017)

Aysel Elik, Optimization of microwave-assisted extraction of phenolics from organic berries, Gaziantep University MSc Thesis (2016)

Can S., Spray Drying of Strawberry and Blueberry Extracts.
Gaziantep University MSc Thesis (2017)

Master Thesis in Formulazione ed Innovazione di Prodotto (Qualità e Formulazione degli Ingredient c.i.).Title: **Disidratazione osmotica assistita con ultrasuoni di cranberries (Oxycoccus macrocarpon).** Cinetiche di disidratazione e studio delle proprietà chimico-fisiche e microbiologiche in conservazione. Presented by Enrico Casadei. Tutor: prof. Marco Dalla Rosa, Co-tutor. Dr. Urszula Tylewicz. AA 2015-2016.

Master Thesis in: "Analisi fisiche e reologiche degli alimenti" (Qualità e formulazione degli alimenti c.i.). Title: Modulazione delle caratteristiche chimico-fisiche e della mobilita dell'acqua di fragole sottoposte a differenti processi di trasformazione. Presented by Alessio Lops. Tutor: prof. Pietro Rocculi, Co-tutor. Dr. Urszula Tylewicz, Cinzia Mannozzi, AA 2015-2016.

Master Thesis in: "Analisi fisiche e reologiche degli alimenti" (Qualità e formulazione degli alimenti c.i.). Title: Combinazione di osmosi e PEF per l'ottenimento di prodotti processati al minimo a base di kiwifruit e fragole biologiche. Presented by Alessio Lops. Tutor: prof. Pietro Rocculi, Co-tutor. Dr. Urszula Tylewicz, Silvia Tappi, AA 2016-2017.

5.3 Further possible actions for dissemination

- Articles published in National Journals

- ELİK AYSEL,KOÇAK YANIK DERYA,GÖĞÜŞ FAHRETTİN (2017). Optimization of Microwave-assisted Extraction of Phenolics from Organic Strawberry Using Response Surface Methodology. Harran Tarım ve Gıda Bilimleri Dergisi, 21(2), 143-154.

- Atacan Kübra,KOÇAK YANIK DERYA (2017). Yaban Mersini (Vaccinium corymbosum L.) Suyu Konsantresinin Püskürtmeli Kurutucuda Kurutulması:
- Tepki Yüzey YöntemiyleOptimizasyon. Akademik Gıda, 15(2), 139-148., Doi:
- 10.24323/akademik-gida.333667,

5.4 Specific questions regarding dissemination and publications

- Is the project website up-to-date? Yes,

Researchers, organisations, stakeholders, industry: through several oral and poster presentations at conferences and seminars and the project results will be further disseminated during coming conferences and through publications. A workshop in Avignon was organised as a side-event to the 2nd Euro-Mediterranean Symposium on Fruit and Vegetable processing. The organisation and partners of the symposium included the University of Avignon, INRA, EFFOST, OPTIFEL, Terralia, CTCPA and participants included researchers, stakeholders and industries and the symposium was therefore an excellent opportunity for dissemination activities to different categories. An industry survey questionnaire has been performed in Romania. The project partners participated during the TP Organic Biofach Science Day "Organics in future EU research & Innovation policy" in Nuremberg, Germany 16 February 2018. A video was recorded during the Biofach Science Day and has been uploaded on the Core Organic webpage. http://projects.au.dk/coreorganicplus/currently/nyhed/artikel/video-mild-technologies-to-improve-shelf-life-and-quality-of-organic-berries/

A report with a summary of the activities within the EcoBerries project has been published in June 2018 in the SciTech Europa Quartley 27, a website providing latest news and information from across the field of European Science and technology research, development and innovation www.scitecheuropa.eu/ecoberries-project/87121/.

- **Networks:** Dissemination of the project has also been made to different networks through newsletters and presentations during seminars.
- **Farmers:** Contacts have been established with organic and conventional farmers in Norway, Sweden and Finland
- **Consumers:** Through popular science presentations of the project. Consumer behaviour studies have been made in three countries
  - List the categories of end-users/main users of the research results and how they have been addressed/will be addressed by dissemination activities

6. Project impact

Our results on chemical and microbiological characteristics of organic and conventional berries confirmed the earlier findings that any differences in the berries are more likely to result on differences in varieties, soil and climate than on the actual way of culturing. Both ways of culturing proved to be equally microbiologically safe.

Innovative packaging solutions and processing solutions are crucial to help us prepare for the growing environmental and societal challenges, by new solutions for more efficient use of natural resources, to reduce waste, and to provide consumers with healthy foods by preventing the loss of valuable compounds.

MAP modelling tool: Food packaging makers, converters and users, food industries. Dissemination activities about these tools will continue in the framework of the just starting H2020 Glopack project (Granting society with LOw environmental impact innovative PACKaging, UM coordination, 2018-2021[1]) by IATE partner. A dedicated stakeholders' platform will be set up in the framework of that project where

[1] Call: SUSTAINABLE FOOD SECURITY – RESILIENT AND RESOURCE-EFFICIENT VALUE CHAINS
TOPIC: Innovative solutions for sustainable food packaging (SFS-35-2017)
Type of action: Innovation action

mathematical modelling tools and software developed at IATE will be demonstrated and tested. Ecoberries tools will be included in these demonstration activities.
IATE: significant breakthrough in the field of MAP modelling was achieved. In particular, we are able, for the first time, to predict the shelf life of a packed fresh product considering various storage conditions (including packaging and modified atmosphere conditions). It is especially relevant to assess the real usage benefit of innovative packaging solutions which is to increase food shelf life and then reduce food waste and losses. The mathematical tool developed within the framework of Ecoberries is a real added value for fresh food chain by allowing all stakeholders to choose the optimal packaging material in a fair and comprehensive manner.
Expected impacts are very important. Indeed, according to EU targets by 2050, a 50% decrease of food waste at the retail and consumer is expected/needed. By promoting market uptake of packaging innovations enabling extension and better management of food shelf-life. The results from Ecoberries will contribute to this demand for significant decrease of food waste, corresponding to a saving of about 100 million tons of food which correspond to an absolute decrease of 250 million tons of CO2-equivalents, about 18 km3 of water resources and 100 million hectares of land recovered at EU level.

Within the project, innovative products and ingredients have been produced. The obtained results will be useful for defining directions for further development of berry and fruit processing and for the application of pre-processing technologies to improve functionality of berry and fruit products. The technologies are used without any harmful chemicals in the production or cleaning process and will be useful for reduction of preservatives in food products. Evaluation effects of mild processing technologies as PEF, OD and edible coating on the content of anthocyanins after processing of fresh organic berries have shown that anthocyanins are preserved in the products, suggesting that the studied technologies can be effective processing strategies to obtain anthocyanin-containing foods. The obtained results will be useful for defining directions for further development of berry and fruit processing and for the application of pre-processing technologies to improve functionality of berry and fruit products. The results from consumer perception studies can be used to understand consumer purchasing decisions and improve communication between consumers, producers and scientists.

7. Added value of the transnational cooperation in relation to the subject

Cross-national collaboration between Norway, Sweden and Finland allowed having a more comprehensive picture on the effect of organic culturing on the chemical and microbiological quality of the berries in Nordic conditions.
IATE: Main advantage of the transnational cooperation is to identify key actors working in a close domain of our expertise or to reveal some synergies between European research centres that were not considered outside the framework of such project: for instance, very few people are working on MAP of fresh fruits and vegetables at our national level. But a lot of people are interested in at a European level as a potential application. They do not own tools to design their MAP and we can offer that using our mathematical models.

8. Suggestions for future research

Sustainable packaging solutions for berry products (recyclable plastic materials, biobased materials) adapted to different waste management systems in European countries.

Annex 1: Cost overview and deviations from budget

Partner no.	Total person months	Spent person months	Total budget	Spent budget
P1	30	30	2 391 000 SEK (~239.3 EUR)	2 391 000 SEK ~(239.3 EUR)
P2	11.5	14.8	2 671 000 NOK (~280 EUR)	2 671 000 NOK (~280 EUR)
P3	36	39	150.6 EUR	150.6 EUR
P4	36	34.94	738.000 RON (163.200 EUR)	738.000 RON (163.200 EUR)
P5	8.87	9.2	157.145 EUR	157 297 EUR
P6	16.4	16.4	2 099 000 SEK (~209.9 EUR)	2 099 000 SEK (~209.9 EUR)
P7		10	31.5 EUR	31.5 EUR
P8	30	30	110.000 EUR	110.000 EUR
P9	36	36	62.500 EUR	62.500 EUR
TOTAL	204.77	220.34	1404.145 EUR	1404.145 EUR

Reasons for deviations from the budget and explanation of consequences (in case there is an impact on fulfilment of the overall project objectives).

Partner 2 (Nofima) budgeted with 11.5 person month, but because other personnel, with lower personnel cost, than original planned were involved in the project, more person months (i.e. 14.8) were available from the budget.