Final report

for the CORE Organic Plus funded project

"Development of quality standards and optimised processing methods for organic produce-SusOrganic"

Period covered: 01.03.2015-28.02.2018

[Note to coordinators: this report covers the whole duration of the project. Once approved by the funding bodies, the final report without the annexes should be made publicly available in Organic Eprints.]

Index

1. Consortium

Project acronym:	SusOrganic	Project ID:	603
Project title:	Development of quality standards and optimised processing methods for organic produce		
Project website:			
Details of the coordinator			
Name:	Dr. Sturm	First name:	Barbara
Telephone:	+495542981603	E-mail address:	barbara.sturm@uni-kassel.de
Institution:	University of Kassel	Country	Germany
Start of project:	01.03.2015	End date of project:	28.02.2017
Duration in months:	36	New end date in case of a project extension:	28.02.2018

Partner no.:	Country:	Institution/ organisation name:	Type of institution/ organisation[1]:	Functions[2]:	Involved in WPs:	Contact person with e-mail address:
1	Germany	University of Kassel	University	PC, WPL (WP 4 + 9)	1, 2, 3, 4, 5, 6, 8, 9	Barbara Sturm barbara.sturm@uni-kassel.de
2	Norway	SINTEF Energy Research	Research Center	WPL (WP 3 + 6)	1, 2, 5, 6, 7. 8, 9	Michael Bantle michael.bantle@sintef.no
3	Germany	Meridian Fruchthandelsgesellschaft GmbH	Company	WPL (WP 1)	1, 2, 3, 4, 8, 9	Albert Esper info@meridian-frucht.de
4	Sweden	Swedisch University of Agricultural Science	University	WPL (WP 7)	1, 3, 4, 5, 7, 8, 9	Girma Gebresenbet Girma.Gebresenbet@slu.se
5	Romania	University of Agronomic Sciences and Veterinary Medicine of Bucharest	University	WPL (WP 5)	1, 4, 5, 8, 9	Liliana Badulescu lilib_20@yahoo.com
6	Italy	University of Teramo	University	WPL (WP 8)	1, 2, 5, 6, 8, 9	Paola Pittia ppittia@unite.it
7	Italy	University of Tuscia	University	WPL (WP 2)	1, 2, 3, 5, 8, 9	Riccardo Massantini massanti@unitus.it

[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 SusOrganic project aimed to develop improved drying and cooling/freezing processes for organic products in terms of sustainability and objective product quality criteria.

Initially, the consortium focused on a pre-defined set products to investigate (fish, meat, fruits and vegetables). Contacting participants in the fruit and vegetable sector showed that there is only little perceived need for making changes for the improvement of the processes. At the same time, it became clear that hops and herb producers (drying) face several challenges in terms of product quality and cost of drying processes. Therefore, the range of products was extended to these products.

The results of a consumer survey conducted as part the project showed clearly that consumers trust in the organic label, but also tend to mix up the term organic with regional or fair-trade. Further, the primary production on farm and not the processing is explicitly included in the consumers' evaluation of sustainability. Appearance of organic products was found to be one of the least important quality criteria or attributes regarding buying decisions. However, there are indications that an imperfect appearance could be a quality attribute for consumers, as the product then is perceived to be processed without artificial additives.

Regarding drying operations, small scale producers in the organic sector often work with old and/or modified techniques and technologies, which often leads to an inefficient drying processes due to high energy consumptions and decreased product quality. Inappropriate air volume flow and distribution often cause inefficient removal of the moisture from the product and heterogeneous drying throughout the bulk. Guidelines for improvement of the physical setup of existing driers as well as designs for new drying operations, including novel drying strategies were developed.

Besides chilling and freezing, the innovative idea of superchilling was included into the project. The super-chilled cold chain is only a few degrees colder than the refrigeration chain but has a significant impact on the preservation characteristic due to shock frosting of the outer layer of the product and the further distribution of very small ice crystals throughout the product during storage. Super-chilling of organically grown salmon eliminated the demand of ice for transport, resulting in both, a reduction of energy costs and a better value chain performance in terms of carbon foot printing. This is mainly due to the significantly reduced transport volume and weight without the presence of ice. The product quality is not different but the shelf life is extended compared to chilled fish. This means that the high quality of organic salmon can be maintained over a longer time period, which can be helpful, e.g. to reach far distant markets. The same trend was found for superchilled organic meat products such as pork and chicken.

The consortium also developed innovative non-invasive measurement and control systems and improved drying strategies and systems for fruits, vegetables, herbs, hops and meat. Those systems are based on changes occurring inside the product and therefore require observation strategies of the product during the drying process. Through auditing campaigns as well as pilot scale drying tests it has been possible to develop optimisation strategies for both herb and hops commodities, which can help reduce microbial spoilage and retain higher levels of volatile product components whilst reducing the energy demands. These results can be applied with modifications to the other commodities under investigation. The environmental and cost performance of superchilling of salmon and drying of meat, fruit and vegetables were also investigated and the findings indicated that both superchilling and drying could improve sustainability of organic food value chains especially in case of far distant markets.

An additional outcome of the project, beyond the original scope was the development of a non-invasive, visual sensor based detection system for authenticity checks of meat products in terms of fresh and pre-frozen meats.

2.2 Short process update of the whole project

SusOrganic aimed to reach three main objectives: **1. Establishing of Quality standards and improved product quality** for organic foodstuffs preserved by drying and cooling/freezing for selected types of products. Standards for product quality have been defined, depending on both processors and consumers perception. Product quality controlled drying has been implemented to preserve the quality of processed organic food. Further, the innovative method of superchilling has been determined for organic products to improve quality, energy efficiency and competitiveness of organic processors.

2. Processing guidelines, optimised processes (product quality, more energy efficient) **and equipment, as well as environmental impact (LCA) and economic (LCCA) analysis** have been defined: Based on the project output, the consortium developed the document "Processing and quality guidelines of organic food" was developed consisting of 13 chapters covering the topics of interest. Topics involved are the influence of raw material heterogeneity, and the influence of heat and duration during drying on product quality. Further, improved drying strategies and process control concepts were introduced. Insights of the innovative technology of superchilling of organic fish and pork were introduced and the influence of pre-treatments on frozen storage. Economic and environmental impacts of organic food processing as well as best practice regarding practical drying and logistics aspects and cooling/freezing are described.

3. Stakeholder engagement: The outputs of the project provide the processing sector of organic products, especially small holders, with in depth information on improved processing for better product quality. During the project, 12 workshops and seminars in the participating countries were successfully held. The partners contributed to 7 workshops at conferences and fairs. The coordinator was further holding one producer seminar each in Austria and France for organisations who had become aware of the project through other events. The project results give several approaches for improved processing regarding increasing product quality and decreasing environmental impact and, therefore, decreasing processing costs. Raw material losses can be decreased by giving an idea on how to use products rejected by the market. Further, the stakeholders were provided with options for new control systems to be included into their systems and future improvements for saving energy, e.g. heat pumps. Self-training and processing & quality guidelines are available for stakeholders. 12 production and energy audits were conducted and two dryers designed for participants in the hop and herb sector.

Moreover, the project enabled the contribution of 33 young researchers (Bachelor, Master and PhD students), and thus, their further education, in different fields of food processing. Besides the stakeholders' workshops and seminars, the project has been presented at 15 conferences and led to an output of 13 publications in international journals with 4 further ones being submitted and as well as one 1 book chapter. The consortium further held an innovation day in adjunction of the 2nd Nordic Baltic Drying conference.

An e-learning course was developed targeting interested university students and processors which is hosted by the ISEKI Food Association and a video for optimisation of hop and herb dryers was produced together with the FiBL team.

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

3.1 WP1

WP1	Technology, market and consumer behaviour analyses
WP leader: Dr. Albert Esper Responsible partners: Meridian	
Overall summary of main results, discussion and conclusions of WP1 In this WP, surveys regarding sustainability and product quality for producers, consumers and retailers were developed, translated to all participating partner languages and distributed through several channels (internet, telephone, direct contact) to the participants. The responses were very different between the countries, which also might depend on the distribution of organic produce within the countries. Regarding the surveys for producers, the responses were very few, resulting from the fact that many producers are not interested in sharing their processing activities. This might be related to a lack of trust towards academic institutions adhering to confidentiality. In general, problems appearing in drying activities are	

the use of old/outdated techniques with minimal or no process control, the drying process does not take product quality into consideration, but use fixed drying times to the best knowledge of the processor. Drying parameters do not meet the optimum requirements for maximum retention of quality. Another challenge, especially for herb producers, is the low (so called gentle) drying temperatures required from some organic associations. That often results in close to critical microbial counts, particularly in the later stages of the vegetation period. Safety problems persuade producers to ask for help more than energy saving potential or to improve the product quality. One exception is the hop sector where the particular demands on retention of aromas lead to a collaboration.

In addition, the retailer survey was challenging. Many grocery stores belong to a business chain and, thus, permission for a survey with the branch manager had to be received by the headquarters. Large discounter chains were the most reluctant or gave no answer. Regional stores or organic markets were more cooperative and showed that the consumption of organic products and the willingness to pay a higher prize depends on the trust in the eco label, but also regionality is an incentive to buy in smaller shops. In Italy 21 retailers were surveyed, in Germany 6, and in Sweden 5 and Norway 3. However, it is also interesting to mention that the structure of grocery stores differs al lot between the partner countries, e. g. it is hard to find a store where only organic products are sold in Norway. Regarding the consumer survey, an online survey managed by UNITUS for all countries additionally to the other distribution ways was conducted. The web platform was developed by using the LimeSurvey software, which was hosted by the Amazon EC2 service. Data were collected and analysed by using the R computing software.

The survey was most successful in Norway (598 full responses by telephone interview), Italy got the best results from the online survey (449 full responses); Germany gained 280 full responses (244 by direct interview, 36 online), Romania 166 full online responses and Sweden 96 online responses. Except for Norway, organic production was evaluated as the more sustainable production way and except for Norway, more than half of the “typical” organic consumers were female. Consumers of organic food sometimes mix organic with regional or fair-trade production and when describing the sustainability that is by both, organic and conventional consumers, high ranked, in most cases the production on the farm level is mentioned, while further processing steps are not. The appearance of a product to evaluate the quality is ranked lower by consumers who regularly buy organic products, whereas there is a big trust from this side in the organic label to evaluate the quality as well as for making a buying decision. For consumers who prefer conventional products, the nutritional value is the most important parameter is the nutritional value for both quality evaluation and buying decision. Both consumer groups ranked the sustainability as a main factor for the quality of a product.

Alongside the surveys a total of 12 production and energy audits for hop and herb processors were conducted. Two new driers were designed for herb farmers.

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

A- results obtained:

Objective of this WP was to establish currently used technologies and process settings applied in drying and cooling/freezing of selected food products in the organic market and to define the relevant quality parameters based on the consumer demands identified.

Task 1.1: Technology and market review: This task focussed on technology used in the sector of hop, herb and fruit/vegetable drying. Two types of drying devices are usually used in hops and herb drying, the kiln dryer and the belt dryer, both with several layers. A main difference in those two devices is the air flow that goes through the product in the kiln dryer, but over the product in the belt dryer. Both systems are used continuously. The big advantage is the mixing of the product when changing from one to another layer however the tip point or the belt speed, respectively, are the critical factors influencing the final product quality. Herb and hops producers are often found to use very old technique and technologies or self-made copies of professional drying units. Many of these copies show a lack of understanding of the technology and processes and thus, the self-build units perform badly in terms of energy demands and resulting product quality.

Insufficient air volume flows are a dominant challenge leading to unsatisfying product quality which leads to significant variations in energy consumption (7964 to 12655 kWh/t for herbs, 4300 to 7000 kWh/t for slow drying hops varieties and 3600 and 6100 kWh/t for faster drying varieties. Additionally, the relatively low drying temperature, so called gentle drying temperatures of between 30 and 40 °C, are a big challenge for herb producers in terms of microbial growth, particularly towards the later part of the harvesting season when the raw material enters the system with relatively high MO counts. Particularly in condensing dryers the air circulation leads to the circulation of spores. So while the system is more energy efficient, the MO count problem is increased. Fruits and vegetables are usually dried as single layers in tray dryers are very common in this sector. Tray drying is a batch process based on the overflow of heated air.

Task 1.2: Identification of the commonly used process and storage settings: A processors survey in all participating countries was conducted. Within this survey it became clear that the majority of processors are very reluctant to share their information with the project. Processors in the chosen commodities (fruits and vegetables) proofed to be reluctant to provide information (only 3 answers by email received in Germany, 10 incomplete from Italy) on their production due to fears of this information being forwarded to the competition. Further, as the products currently have a secure market, energy costs/usage are not a vital factor for the companies' livelihoods and the consumers accept the product quality they are provided with. Therefore most companies are satisfied with the status quo. For this reason, the hops and herb sector was included into the project, which led to 12 audits. Usually fossil fuels are used as energy source, in few cases wood as a renewable energy source is used. Fruits and vegetables are often dried in small scale tray dryers, while hops and herbs are dried in kiln dryers, in very few cases belt dryers are used. The bigger the yearly output, the more professional the producers are and for example include heat recovery. Energy audits for herbs and hops showed energy efficiencies that varied between <10% and ca. 60 %. Thus there is a big scope for improvement.

Task 1.3: Identification of consumer behaviour and expectations: For this task, a survey was developed and spread on different ways (direct contacts in supermarkets, online (created by UNITUs via LimeSurvey software) and by telephone) to the consumers of organic products. The survey ended up with overall 1593 completed answers (598 from Norway by telephone, 449 from Italy by the online survey, 244 from Germany by direct contact and additional 36 from online survey, 166 from Romania online and 100 from Sweden online). Some descriptive results are that, except for Norway, the typical consumer of organic products is female. The term "organic" is often mixed up with "regional" or "fair-trade". The main quality for consumers of organic products were found to be the nutritional value and the sustainability of a product and directly linked to the organic label in the consumers' minds and influence the perception for quality as well as the buying decision. Interestingly, the appearance is not a quality parameter for consumers of organic products and does not influence the buying decision.

Additional tasks which resulted from the above work: 12 production and energy audits were carried out in hop and herb processing companies. Consequently two new driers were designed (UniKassel and Meridian). Furthermore, one BA project was conducted on the drying behaviour of peppermint in one of the newly build dryers. However, throughout this project it became clear that the operator had ignored the majority of the design recommendations. This resulted in a dryer which showed the same challenges as the current standard ones. On top of that, the purchased heating unit was severely under dimensioned which led to a situation that the dryer would not be able to reach set temperature (35°C) for several hours on cool days.

B- fulfilment of objectives:

D1.1 done, report is written
D1.2 done, report is written
D1.3 done, report is written

M1.1 done, analyses of technologies and marked situation is finished
M1.2 done, analyses of common process settings is finished
M1.3 done, consumers expectations were analysed

Publications

Bosona, T., & Gebresenbet, G. (2018). Swedish Consumers' Perception of Food Quality and Sustainability in Relation to Organic Food Production. *Foods*, *7*(4), 54.

Meriluoto, L., von Gersorff, G., Hensel, O., Sturm, B. (2018). Food quality perception of organic consumers. (under preparation).
von Gersdorff, G., Bantle, M., Hensel, O., Sturm, B. (2017). Chapter 8: Improvement of Product Quality and System Performance in Processing of Organic Products, In Sustainable Food Systems from Agriculture to Industry: Improving Production and Processing, Springer, 245-273.
Stan A., Dobrin A., Zugravu M., Bezdadea-Catuneanu I., Iancu A., Lagunovschi-Luchian, V., Badulescu L. (2017) Perception and preference of the Romanian consumers regarding organic vs. conventional products quality – survey study. International Symposium Young People and Agriculture Research, Timisoara, Romania, 23th November 2017. Journal of Horticulture, Forestry and Biotechnology. 21 (3), 1-7

3.2 WP2

WP2	Drying tests

WP leader: Prof. Riccardo Massantini
Responsible partners: UNITUS

Overall summary of main results, discussion and conclusions of WP2

The WP2 investigated the feasibility of Vis/NIR hyperspectral and single point (NIR) spectroscopy as well as image/colour analysis as smart drying technologies for proactively and non-destructively detecting and monitoring quality changes in organic apple wedges (*Malus domestica* B. var. Gala) and carrot discs (*Daucus carota* L. var. Romance) during 8-h hot-air drying at 60°C and 40°C, respectively. Drying temperatures were chosen on the basis of screening results. Samples were subjected to Vis/NIR spectral data acquisition as well as determination of CIELab colour, moisture content, water activity, soluble solids content, titratable acidity, pH and total carotenoids content (carrot only). Finally, optimal drying temperatures for both apples and carrots were identified. Analysis on changes in total phenols content, antioxidant activity and chlorogenic acid content (apple only) during 8-h drying were performed. Anti-browning effects of blanching treatments (i.e. hot-water and microwaves) on wet material were also analysed, together with the evaluation of the impact of blanching pre-treatments and drying conditions on chemical and physicochemical characteristics of the dried product.

Vis/NIR spectroscopy was investigated as proved on-/in-line tool with high sensitivity to changes in moisture content, particle size and chemical state of food. Vis/NIR-based regression models were computed to predict sample analyte (e.g. moisture, water activity, etc.) during 8-h drying, while Vis/NIR-based classification models were developed to recognize the three phases of each drying process and thus to assign each sample to a specific dehydration phase on the basis of its spectral profile. Regression and classification models were computed using the partial least squares (PLS) regression and the partial least squares discriminant analysis (PLS-DA), respectively, through the SIMPLS algorithm. Specifically, classification models were developed using k-means and Partial Least Squares Discriminant Analysis (PLS-DA) algorithms in sequence. As initial step, k-means was employed to label each sample as belonging to a specific class (i.e. drying phase) on the basis of the observed changes in moisture content, water activity, CIELab colour, soluble solids content, titratable acidity, pH and total carotenoids (carrot only). As final step, the identified class membership was used as response variable (Y) for the development of PLS-DA models in which the predictor variables (X) were spectral profiles. Moreover, Interval PLS (iPLS) and Interval PLS-DA (iPLS-DA) algorithms were used to select subset of wavelengths, which could describe superior prediction compared to models based on all features dataset. Both iPLS and iPLS-DA algorithms were configured in stepwise forward mode for the selection of a maximum of 10 wavelengths. One main result to be named is that Vis/NIR-based regression models with excellent prediction performances were obtained for moisture, water activity, soluble solids, carotenoids (carrot only) and CIELab colour coordinates. Furthermore, the identification of the drying phase based on Vis/NIR classification models was successful. The feature selection procedure improved the performance of each prediction model.

In addition, the WP2 adapted microcomputer (i.e. Raspberry Pi), microcontroller (i.e. Arduino Uno) and micro sensing devices (i.e. temperature, relative humidity and load cell sensors as well as both high-end and low-cost cameras) to a classic hot-air drier. The modified drier was tested for the acquisition of data during 8-h drying for both apples and carrots.

Further related works were conducted on the investigation of meat, hops, potatoes, apples using Vis/NIR hyperspectral and colour imaging, see also WP4. Regarding potatoes, UNITUS strictly collaborated with UNI-KASSEL in developing of regression models based on spatial information paired with reflectance differences between all possible pairs of wavelengths in the 500-1010-nm spectral region to predict changes in moisture content, Hue Angle and White/Yellow ratio in tuber slices of 5-, 7- and 9-mm thickness. Further cooperation was established with SINTEF in the area of on-/inline colour analyses, product quality (Browning index) and drying conditions.

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

Objective of WP2 was to identify the impact of standard drying conditions on the quality of the resulting products (i.e. apple, carrot and potato) utilising the market research carried out in WP1.

Task 2.1: Adaption of the drying devices: in this context, the near-infrared (NIR) spectroscopy in the 1100-2300-nm spectral range was used to proactively and non-destructively detect and monitor changes in quality parameters of apples wedges (*Malus domestica* B. var. Gala) and carrot slices (*Daucus carota* L. var. Romance) during hot-air drying. For this purpose, regression and classification models were developed for both untreated and thermally pre-treated products. Optimal features were also selected for both regression (PLS) and discriminant (PLS-DA) analysis by using the interval PLS algorithm configured in stepwise forward mode.

Task 2.2: Conduction of base line and standard tests: the objective of the present task was to select (1) thermal pre-treatments to be used to prevent oxidation, during hot-air drying, and (2) optimal drying temperature of both organic apple wedge and carrot slice.

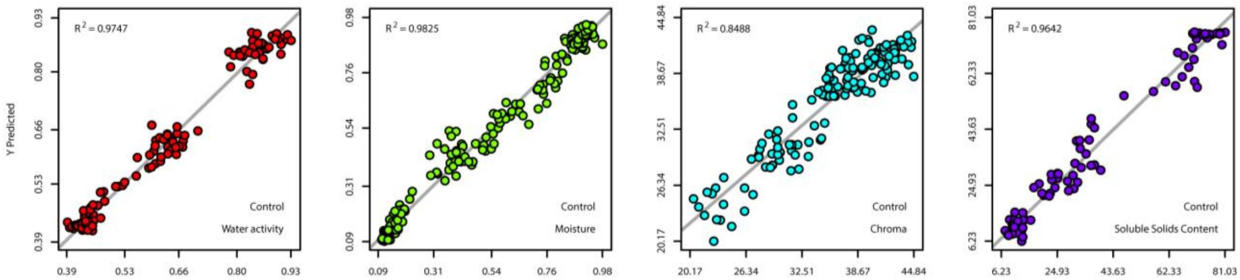
Regarding the apples, the effect of thermal treatments on apple wedges was evaluated for both hot-water blanching and microwave heating treatments at pre-established ranges of temperature and power, respectively. To monitor the thermal treatment, peroxidase was used as indicator enzyme due to its higher thermal stability and easiness in being assayed. In fact, the POD inactivation gives reasonable assumption that other quality-deteriorative enzymes (e.g. pectin methylesterase, polyphenol oxidase, etc.) are also inactivated. Inactivation kinetics were determined through semi-log plot of residual POD activity versus time. Results showed excellent linear fits (R^2 = 0.93-0.99) at all temperatures/powers studied, consistent with inactivation occurring by first-order kinetics. Although all treatments reached the inactivation threshold (decimal reduction, 90%), considerably faster reductions in POD activity were only achieved with microwave heating. In fact, hot-water blanching was less effective, showing slowest inactivation rate constants (k) (0.17, 0.46 and 0.79 min^{-1} at 80, 90 and 95°C, respectively) in comparison with microwave heating (1.08, 1.81 and 3.03 min^{-1} at 350, 650 and 850 W, respectively). Moreover, microwave treatment led to better colour retention in apple wedges than hot-water blanching (data not shown). Although the mechanism is still unclear, and several controversial opinions must be faced, similar results were reported in literature. It seems that microwave irradiation may be more effective and faster for facing enzyme inactivation when compared with conventional methods, because of concurrent thermal (i.e. heat denaturation of protein) and non-thermal (i.e. microwaves interaction with polar and/or charged moieties of protein) effects of microwaves. Eventually, the lowest decimal reduction time (D) among treatments was achieved by using microwave at 850 W for 0.77 min (~ 46.2 sec) of irradiation. Thus, considering that the evaluation of the effects of thermal treatment on nutritional value of product was not part of the present work package, microwave heating at 850 W for 45 sec was selected as the most adequate treatment to obtain colour-stable apple wedges to use further in the experimentation.

Regarding the carrots, the effect of thermal treatment on carrot slices was evaluated for hot-water blanching over the pre-established range of temperature.

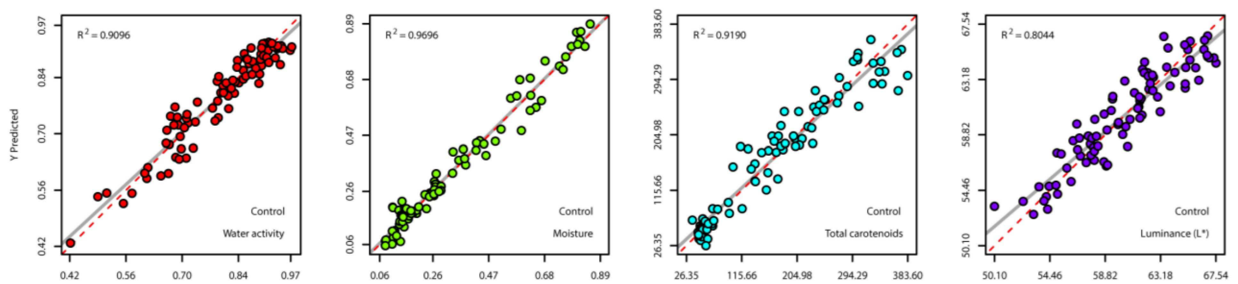
Inactivation kinetics was determined through semi-log plot of residual POD activity versus time. Results showed excellent linear fits (R^2 = -0.98÷-1.00) at all temperatures studied, consistent with inactivation occurring by first-order kinetics. Although all treatments reached the D-value, considerably faster reductions in POD activity were only achieved at 90 and 95°C. In fact, both hot-water blanching at 80 and 90°C were less effective, showing slowest inactivation rate constants (k) (0.20 and 0.57 min^{-1}, respectively) in comparison with 90 and 95°C (0.77 and 1.60 min^{-1}, respectively). Moreover, hot-water blanching at 90 and 95°C led to more vivid and pleasant colour (data not shown). Similar results were reported in literature; some authors observed greater hue angle and chroma, and thus better colour than those from unblanched carrots. The colour of carrots is deeply affected by the presence of α- and ß-carotenes, which are known to be relatively heat-stable at combination of temperature and time used in our experiments. In fact, carotenoids degradation and isomerization into cis-isomers are responsible for loss of vivid colour and a shift from orange to redder colour, which is not our case. Finally, the lowest decimal reduction time (D) among treatments was achieved by using hot-water blanching at 95°C for 1.44 min of dipping. Thus, considering that the evaluation of the effects of treatment on nutritional value of product was not part of the present WP, hot-water blanching at 95°C for approx. 1.45 min was selected as the most adequate treatment to obtain colour-stable carrot slices to use further in the experimentation.

Task 2.3: Analysis of the drying behaviour and impact of drying conditions on product quality: the objective of the present task was to demonstrate the use of visible/near-infrared (Vis/NIR) spectroscopy to non-destructively detect and monitor quality changes in organic apple wedges, and carrot and potato slices, pre-treated and not pre-treated to prevent oxidation, during hot-air drying. Experimental activities on potatoes were performed in collaboration with WP4 (UniKassel).

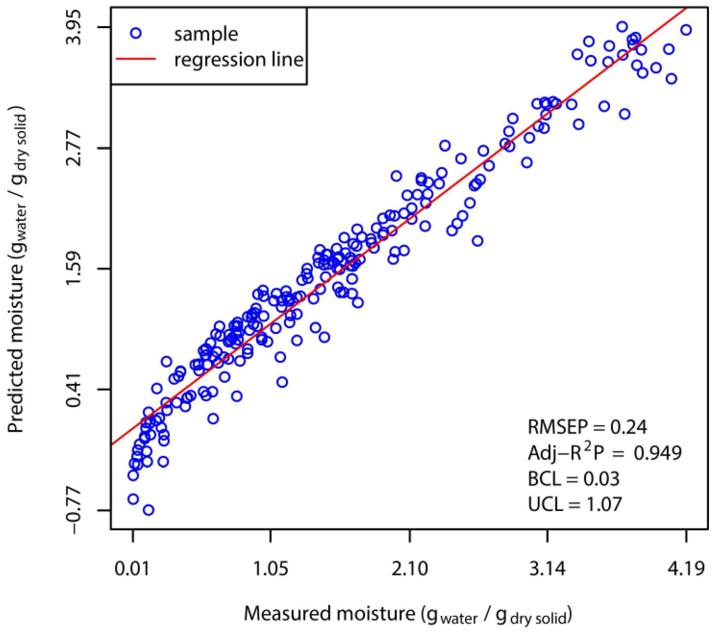
Regarding apples, regression models were characterized by very good or excellent performances for water activity (R^2 = 0.97÷0.98; RMSEP = 0.03÷0.04), moisture content (R^2 = 0.97÷0.98; RMSEP = 0.04÷0.05), SSC (R^2 = 0.96÷0.97; RMSEP = 4.54÷4.99) and chroma (R^2 = 0.77÷0.86; RMSEP = 2.31÷2.75). Regarding the discriminant analysis, PLS-DA algorithm obtained high accuracy rate in classifying the apple wedges into classes as drying phases based on the spectral profile. Specifically, NIR spectroscopy showed an excellent classification (accuracy rate > 0.95) for apple wedges belonging to 'Drying phase I' and 'Drying phase II'. Differently, misclassified apple wedges were primarily assigned to 'Drying phase II', which however showed a very-good accuracy rate higher than 0.90. It should be noted that the development of regression and classification models were affected by the microwave heating treatment in terms of number of features and selected wavelengths. More details are reported in publication #1.



Regarding carrots, both PLS and PLS-DA models obtained either very good or excellent results. Specifically, for regression analysis, models characterized by remarkable performances were obtained in collaboration with UASVM for water activity (R^2 = 0.91-0.96; RMSEP = 0.03-0.04), moisture content (R^2 = 0.97-0.98; RMSEP = 0.03-0.04), total carotenoids content (R^2 = 0.92-0.96; RMSEP = 22.62-29.51 μg g^{-1} fresh sample), lightness for unblanched carrots (R^2 = 0.80-0.83; RMSEP = 1.66-1.79) and hue angle for blanched samples (R^2 = 0.85-0.87; RMSEP = 1.34-1.46). In addition, while soluble solids content was poorly predicted for both treatments (RMSEP = 3.43-4.40), blanched carrots showed better coefficients of determination (i.e. R^2 > 0.85) than unblanched samples (i.e. R^2 < 0.70). Regarding the discriminant analysis, PLS-DA algorithms obtained high accuracy in classifying drying phases based on the spectral profile. However, better results were obtained for models computed using blanched carrots. Specifically, NIR spectroscopy showed an excellent classification accuracy (> 0.90) for carrot slices belonging to 'Drying phase I' and 'Drying phase III'. On the other hand, misclassified carrot slices were primarily assigned to 'Drying phase II', which however showed accuracy greater than 0.85. It should be noted that the development of regression and classification models were affected by the blanching treatment in terms of number of features, selected wavelengths and model performances. More details are reported in publication #2.



Regarding potato, the analysis of spectral features used in the best-performing models delivered valuable information for identifying the relevant parts of the spectra in monitoring the drying process of potato slices. Features for regression models comprising wavelengths that resulted in the best prediction results were generally in the ~510-, 760÷820-, 880÷920- and 970÷1000-nm spectral bands. Results suggest these are the predominant bands for detection of dry basis moisture content, which may be related to water and starch content, and colour changes due to non-enzymatic reactions (i.e. hue angle and L^*b^{*-1} ratio). Since the discolouration also exhibits features at 540÷660 nm, it is hypothesised that losses in total carotenoids content could be the underlying chemical basis for regression.
The best prediction results were obtained using the forward-selection iPLS algorithm. However, both datasets of raw reflectance differences and raw reflectance ratios showed potential for the development of models with low complexity and thus more easily transferable to a low-cost dryer. Finally, yet importantly, the combination of spectral data (i.e. R[511 nm]-R[994 nm]) with spatial data (i.e. relative area shrinkage of potato slice) has proven to be a viable and preferable alternative to both the best PLS and iPLS models in predicting the dry basis moisture content. More details are reported in publication #3.



B- fulfilment of objectives:

D2.1 activity completed, and report done
D2.2 activity completed, and report done
D2.3 activity completed, and report done

M2.1 Drying devices are adapted and fully functioning
M2.2 Drying tests are finalized
M2.3 Quality changes and interdependencies between the process settings are analysed and evaluated

Publications

Moscetti, R.; Raponi, F.; Ferri, S.; Colantoni, A.; Monarca, D. & Massantini, R. (2018) Real-time monitoring of organic apple (var. Gala) during hot-air drying using Near-Infrared spectroscopy. Journal of Food Engineering, 222, pp. 139-150.

Moscetti, R.; Haff, R.P.; Ferri, S.; Raponi, F.; Monarca, D.; Liang, P. & Massantini, R. (2017) Real-Time Monitoring of Organic Carrot (var. Romance) During Hot-Air Drying Using Near-Infrared Spectroscopy. Food and Bioprocess Technology, 10 (11), pp. 2046-2059.

Raponi, F.; Moscetti, R.; Monarca, D.; Calantoni, A. & Massantini, R. (2017) Monitoring and optimization of drying fruits and vegetables process using computer vision: a review. Sustainability, 9 (11), pp. 1-27.

Retz, S.K.; Porley, V.E.; von Gersdorff, G.J.E; Hensel, O.; Crichton, S.O.J. & Sturm, B. (2017) Effect of maturation and freezing on quality and drying kinetics of beef. Drying Technology, 35 (16), pp. 2002-2014.

3.3 WP3

WP3	Optimisation of drying conditions and energetic analysis
WP leader: Ingrid Camilla Claussen Responsible partners: SINTEF	

Overall summary of main results, discussion and conclusions of WP3

The main objective of this work package was the investigation of different drying methods for organic food with focus on food quality and energy efficient processing. In order to reach the objectives, the following 3 tasks were performed.

The atmospheric freeze-drying process (AFD) of organic apples was investigated with respect to their thermophysical properties. The experiments were conducted at -10.0, -5.0 and 3.0 (reference) °C drying temperatures. The dynamic mode of drying was also proposed based on the analysis of thermophysical properties with the aim to investigate its influence on quality of the dried apples. Inflection point of glass transition of blanched fresh apples was determined in the range between -55.0 and -53.0 °C. The onset of ice melting of blanched fresh apples was found at -44.2(1.2) °C, when unfreezable water content reached 3.7 (0.3) % w.b. The state diagram of organic apples was obtained using Clausius-Clapeyron and Gordon-Taylor equations. The study revised the amount of unfrozen water content with respect to drying temperatures and moisture content. Initial ice content, when drying at -10.0 and -5.0 °C, was measured at 75.7 and 70.7% respectively. At the same time significant amount of moisture were unfrozen at these temperatures. The water concentration in unfrozen solution reached 60.0 and 43.0 % w.b respectively. Thus the drying process was governed by diffusion process and ice melting phenomena, when the so-called ice front does not appear within the thickness of the product. Analysis of drying kinetics revealed that drying at -10.0 °C resulted in significantly longer process, when compared with other modes. At the same time sorption characteristics and lightness were much better for samples dried at -10.0 °C, when compared with other samples. The effective diffusivity values, which were obtained in this study were relatively low, varying from 1.3 to 1.8 *10-10 m2 s-1 for -5.0 and -10.0 °C respectively. Application of dynamic regime provided the effective diffusivity value at 1.7 *10-10 m2 s-1 and the quality, which was comparable with drying at -10.0 °C.

Drying is an energy intensive thermal process. A product specific, heat and mass transfer models were developed for drying of organic products (meat and apples). The model was programmed as dynamic object in the Modelica-language and included a process simulation library (in-house tool, supplementary to the TIL library, TLK-Thermo, Braunschweig, Germany). This enabled the simulation of a drying production process combining mass transfer (how does the product dry under different drying conditions) and heat transfer (how efficient is the process and what drying conditions can be reached by the energy supply system).

The Specific Energy Consumption in industrial systems is normally higher than 0.8 kWh/kg_{water} and the thermal energy demand in most drying systems is provided through burning of fossil fuels. The potential of using R744 (CO_2) as working media in a heat pump drier was investigated for a drying process at 45°C, 60°C and 70°C. These drying conditions were chosen in cooperation with UNITUS and Meridian. The trans-critical temperature glide of CO_2 reduces the large temperature differences during re-heating of the drying air. The obtained Coefficients of Performance were between 3.4 and 4.3 resulting in specific energy consumption in the range of 0.24 to 0.27 kWh/kg of evaporated water for the different drying processes. The simulations confirm that heat pump assisted drying has the potential to reduce the energy demand by around 70% in general and shows the feasibility of applying heat pump drying also at drying conditions up to 70°C

Modern sensors in combination with a smart control system allow dynamic drying processes, which can determine certain drying states and react on it by varying drying parameters to improve energy efficiency and/or product quality. Especially optical alternations of food like browning, shrinkage and deformation have influence on the product quality and the customers' acceptance to purchase it. Browning, shrinkage and deformation is often associated with a deterioration. Therefore, optimization of the drying processes by referring to these parameters can be very useful.

In this task an industrial convective drying chamber was modified with a camera system which took an

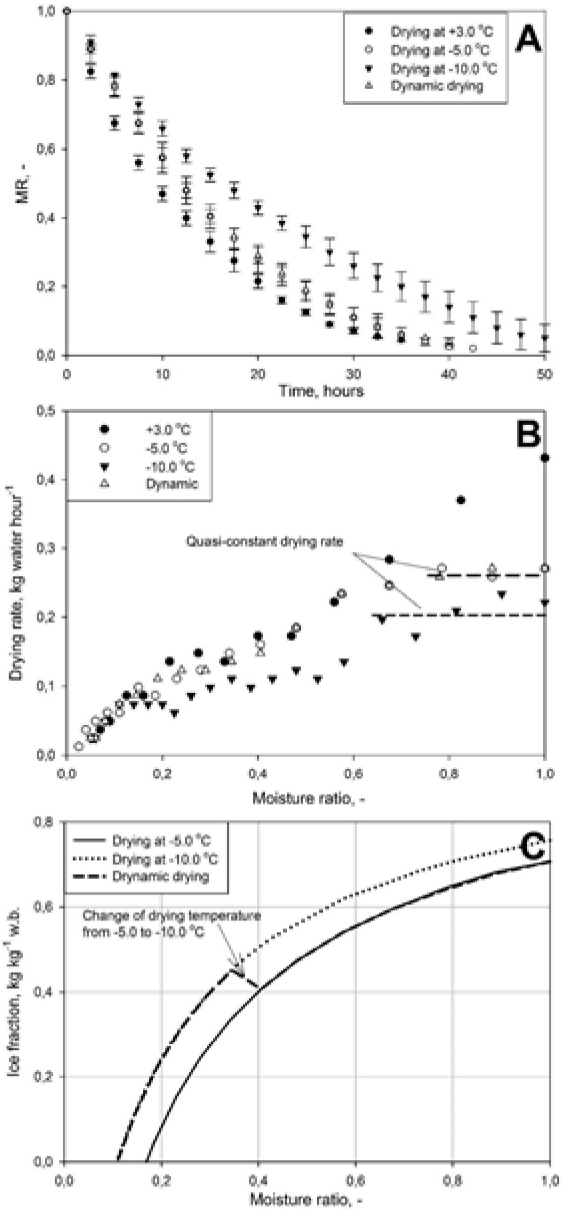
image of the drying product each 5 minute during the drying process. The activity was coordinated with Uni Kassel. The so obtained data were analyzed on color alternation (CIE-L*a*b* color space and Browning Index), shrinkage and deformation. To verify the measuring methods, apple slices were dried at different conditions and the results checked on plausibility and compared with other experiments. The camera system in combination with the analyzing software was able to generate very precise and continuous data. The dependence between browning index, color alternation and moisture content in the apple slices was determined at different temperatures and relative humidity. Shrinkage and deformation were measured with a shape recognition algorithm in the same continuous and precise quality. The sidelong deformation of the apple slices was measured as well. Both, shrinkage and deformation showed merely dependence on humidity but temperature. The experiments showed that optical parameters depend on the drying conditions. This might offer new "smart" drying programs with focus on improved energy effectivity and/or product quality. The system enabled the demonstration of an event-controlled or "smart" drying process in which the drying temperature was constantly controlled in a way that the product temperature was constant. Hence, the drying process was faster, since the drying temperature was higher than in conventional drying system where the drying temperature is held constant. At the same time the product quality was not different between the "smart" and the conventional drying process.

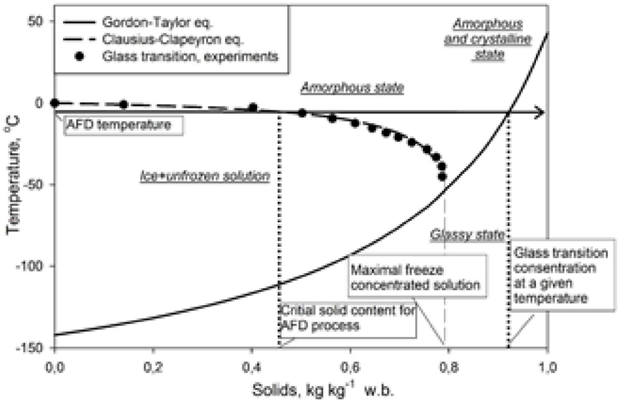
Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:

Task 3.1: Drying tests for selected products: The drying process for low temperature drying, drying rate and drying curves for organic apples at constant as well as changing conditions were determined (see Figure to the right). The initial expectation that organic apples could be dried in atmospheric freeze drying was not fulfilled. The decreasing water content during the process causes the frozen structure of the apple to melt due to the high sugar content.

In order to verify and explain this phenomena the state diagram for organic apples was determined, which shows the relation of solid content and temperature (see Figure below). In order to achieve superior product quality due to freeze drying the drying conditions should be adapted in way that the process is performed in the glassy state. This is however not possible at common conditions in atmospheric freeze drying. Hence the performed experiments classify as low temperature drying, but not freeze drying.

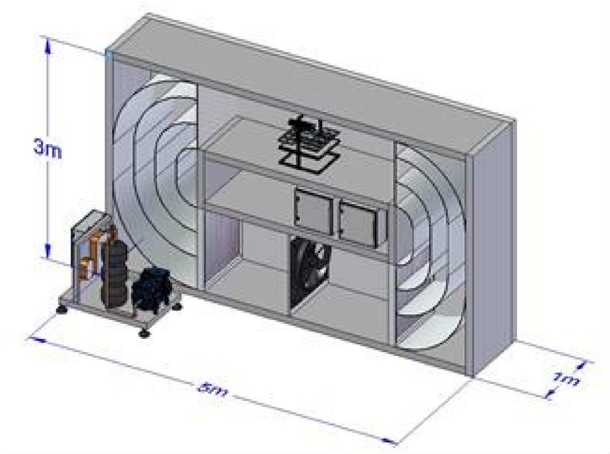


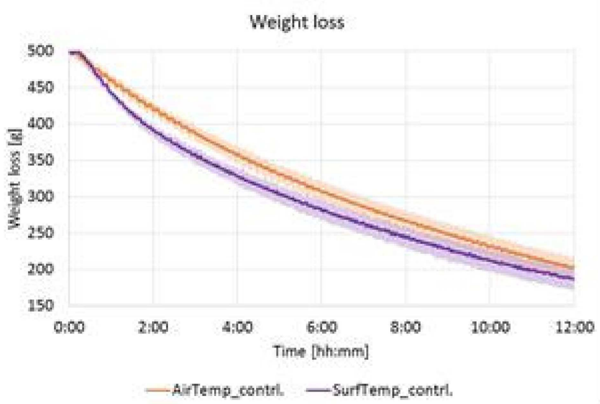


Task 3.2: Model development for dynamic object oriented simulation: The simulation and model work resulted in a detailed performance prediction for a heated ambient air and heat pump drying process. The energy saving potential is given in the following table:

Drying temperature:	45°C	60°C	70°C
Heat flow in evaporator	101 kW	109 kW	118 kW
Heat flow in gas cooler	100 kW	108 kW	116 kW
Compressor power	23 kW	28 kW	32 kW
COP for heating	**4.3**	**3.9**	**3.6**
COP for heating and cooling	8.8	7.8	7.2
SEC	968 kJ/kg	917 kJ/kg	865 kJ/kg
SEC	**0.269 kWh/kg**	**0.255 kWh/kg**	**0.240 kWh/kg**
High pressure	75 bar	100 bar	130 bar
Low pressure	37.9 bar	45 bar	57.3 bar
Mass flow of CO_2	0.56 kg/s	0.62 kg/s	0.72 kg/s
Moisture content air into drier	0.012 kg/kg	0.025 kg/kg	0.039 kg/kg
Moisture content air from drier	0.018 kg/kg	0.033 kg/kg	0.049 kg/kg
Air temperature after condensation	17.1 °C	30.5 °C	39.4 °C
Air temperature from drying	28.8 °C	39.2 °C	46.4 °C
Removed water	**0.024 kg/s**	**0.031 kg/s**	**0.037 kg/s**
Temperature after compressor	73 °C	87 °C	96 °C
Temperature before throttling	24.5 °C	27.0 °C	30.2 °C

Task 3.3: System solutions for energy efficient drying: An industrial sized dryer (Figure below, to the left) was equipped with an "smart" control system which can determined product quality and drying progress during the process and alter the drying conditions in order to increase drying rate and sustain product quality. The potential of this concept was demonstrated for a surface-temperature controlled process for apples (Figure below to the right).





B- fulfilment of objectives:

The objective of the WP3 was to investigate different drying methods for organic food and focus on food quality and energy efficient processing. The following main activities were performed and objectives achieved:

D3.1: Activities are finished, report is written
D3.2: Activities are finished, report is written
D3.3: Activities are finished, results have been presented at NBDC 2017
D3.4: Activities are finished, results have been presented at NBDC 2017
D3.5: Activities are finished, results have been presented at Gustav Lorentzen Natural Working Fluids Conference, 2016

M3.1: Determination of drying behaviour of organic fruit products performed
M3.2: Dynamic mass transfer model for drying developed and included into energy simulation
M3.3: Workshop ("Novelty Day") on Nordic Baltic Drying Conference 2017 was organized
M3.4: Heat pump drying system simulated and model and energy saving potential verified

Additional results beyond the original scope:

1. Calorimetric data for organic foods were analysed and related to drying kinetics for low

temperature drying. F

2. New sensor technology was included into drying chamber and possibilities for event controlled drying conditions were verified.
3. Drying experimemtns of brown seaweed (classified as organic products) towards the development of the novel maritime food products.

Publications

Bantle, Michael; Kvalsvik, Karoline Husevåg; Tolstorebrov, Ignat. Performance simulation on a heat pump drying system using R744 as refrigerant. I: 12th IIR Gustav Lorentzen Conference on Natural Refrigerants GL2016 : Proceedings. International Institute of Refrigeration 2016 ISBN 9782362150180

von Gersdorff, G.J.E.; Porley, V.E.; Retz, S.K.; Hensel, O.; Crichton, S.O.J. & Sturm, B. (2017) Drying behavior and quality parameters of dried beef (biltong) subjected to different pre-treatments and maturation stages. Drying Technology, 36 (1), pp. 21-32.

Tolstorebrov, I, Bantle, M., Eikevik, T.M. Sturm, B., Shokina, Y. (2018). Towards understanding the atmospheric freeze-drying process of organic apples by analysis of thermophysical properties and drying kinetics, Drying Technology (submitted manuscript)

Tolstorebrov, I, Eikevik, T.M., Bantle, M. (2017) Low Temperature Drying and Thermo-Physical Properties of Brown Seaweeds (Saccharina Latissima). 2nd Nordic Baltic Drying Conference 2017, 7.-9. June 2017, Hamburg

Christian Kopp, Technical modification of a drying chamber for scientific investigations of drying processes on the bases of apple slices, Technical Report SINTEF Energy Research 16.01.2018 (Master thesis)

Simon Danco, Mass transfer in a 3D food structure, Report SINTEF Energy Research 29.02.2015 (Internship)

Tolstorebrov, I., Bantle, M., Eikevik, T.M., K. Paykacheva, State diagrams in low temperature and atmospheric freeze drying of organic fruit products, 2nd Nordic Baltic Drying Conference 2017, 7.-9. June 2017, Hamburg

Workshop: "Novelty day on sustainable organic foods – drying and processing", 11 presentations from SusOrganic; 2nd Nordic Baltic Drying Conference 2017, 7.-9. June 2017, Hamburg

Bantle, M., Kopp, C., Claussen, I.C., Tolstorebrov, I., Influence of the low temperature drying process on optical alternations of organic apple slices, 21st International Drying Symposium, València, Spain, 11-14 September 2018 (submitted manuscript)

3.4 WP4

WP4	Development of measurement and control systems, and placement strategy for sensors and linkage of quality criteria
WP leader: Barbara Sturm Responsible partners: Uni Kassel	

Overall summary of main results, discussion and conclusions of WP4

The aim of this WP was to develop a non-invasive measurement and a control system for agricultural products. Experiments in drying of apples, hops, potatoes and beef were conducted and correlated to hyperspectral imaging. Prediction models were developed and minimum wavelength sets for each product were determined that allow the prediction for moisture content and chromaticity during the drying process. For drying of apples and potatoes, dried at 50, 60 and 70 °C air temperature, also different pre-treatments (blanching, ascorbic acid) were conducted, which did not affect the wavelength selection. Pre-treatments of salt or salt and vinegar, as well as freezing and aging for beef dried at 70 °C air temperature, resulted in different selected wavelength each. The developed models achieved coefficients of deviation <0.9 for moisture content, for chromaticity values < 0.7 are achievable. Investigations on enzyme activity and chlorogenic acid content in apples showed no possibility for hyperspectral analyses, but investigations, also for vitamin C content are still in progress and will be further investigated within the SusOrgPlus project. While the pre-treatments for apples and potatoes do not affect the drying time, pre-treatments do affect the drying kinetics for beef and results in faster drying for samples treated with salt and vinegar and slower drying for salted samples. Moisture content of all commodities investigated can be

predicted using a reduced sub-set of wave lengths.
Investigations of the products named above, lead to the successful implementation of a RGB camera in a hop dryer to observe the colour change during drying, further, a hyperspectral camera was implemented to get further information on the wavelengths which are necessary to measure moisture content and chemical compounds.
As a side effect of the conducted drying tests on beef of different statuses (fresh, fresh-frozen-thawed, mature, mature-frozen thawed), a preliminary classification model has been developed, which allows for the non-invasive detection of meat status, using information from within the visible and Vis/NIR region. This has great potential for both the organic and the conventional sector as all currently used methods are invasive, which leads to an economic loss for the pieces of meat that have to be investigated. At the same time only random samples can be checked, which gives limited information. Further, first promising results were gathered for the development of detection of potential DFD (Dry, firm, dark) meat.
Several control systems related to drying have been developed, which were product temperature controlled drying in conventional dryers and enthalpy controlled systems for heat pump dryers.
Drying devices aim to provide good drying conditions throughout the whole device, therefore CFD simulations were conducted in cabinet and belt dryers and verified.

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

A- results obtained:
Task 4.1: Development of hardware set ups:
4.1.1 Laboratory single layer dryer
The single layer laboratory dryer is a product temperature controlled drying unit, which controls the air temperature and humidity using sensors and optical devices that are integrated within the controller. The complete dryer system consists of extractor, humidifier, heater and the dryer as shown below.

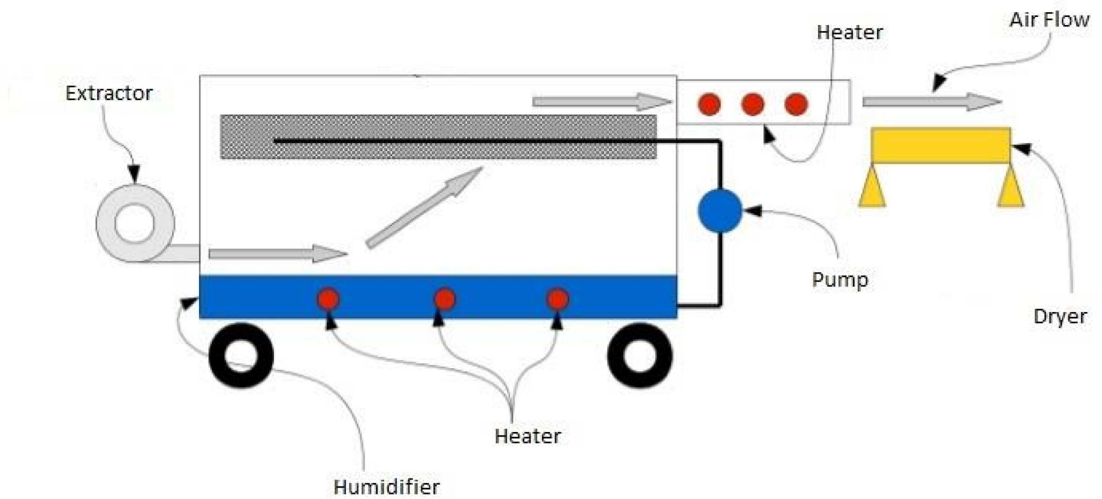


Figure 4.1: Set up for a Single Layer Dryer

The drying chamber itself was equipped with colour, hyperspectral and thermal cameras.

4.1.2 Pilot scale implementation hops
A hardware set up for measuring colour and requiring spectral information during the drying process for hop drying has been developed. A schematic demonstration is shown below:

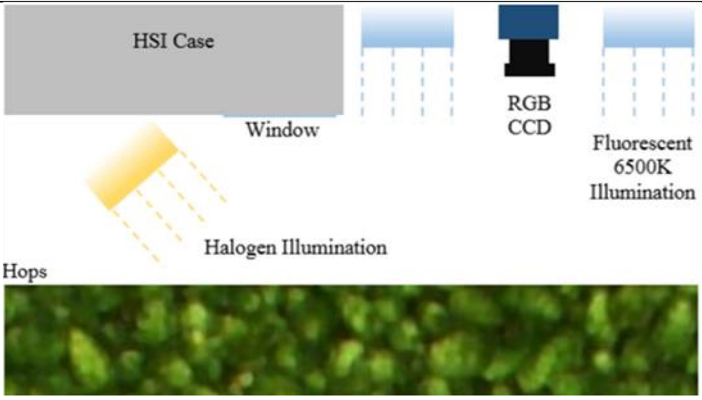


Figure 4.2: Set up for measurement device in a hop dryer

The dryer was equipped with an array of temperature, humidity and air flow sensors to assess the temporal and special conditions within the system. Combined temperature/humidity probes were installed and positioned at different filling heights within the bulks to measure the development of temperatures and air humidity throughout the bulks. Product temperature at the surface of the bulk was measured continuously. All values, except of the combined temperature/humidity probes, were transferred directly to a computer and stored. Chromatic measurements were carried out using a calibrated RGB camera within the dryer to monitor colour change, this was installed alongside the hyperspectral camera. This enabled hyperspectral measurements to be carried out at specific time points.
To achieve the best quality of data, the hyperspectral camera (Specim Spectral Imaging Ltd., Finland) was placed inside a protective casing within the dryer above the hop stack. The camera was used in combination with a mirror translation unit and a 35mm Schneider lens (Xenoplan 1.9/35, Schneider Optische Werke GmbH, Germany). Both, the RGB and the HIS system, were calibrated appropriate to the setting.

4.1.3 Prototype diagonal bucket batch dryer (Innotech)
The developed real-time image acquisition system consisted of a wooden imaging-box with cross sectional area equal to a food bucket's area (0.6m×0.4m), a USB CMOS MT9P031 sensor (Lens mount M12x0.5) Color Autofocus Camera (DFK 72AUC02-F, The Imaging Source, Germany) and a computer (Lenovo T500, 2.40 GHz, 3 GB RAM, 148 GB hard disk).

4.1.4 Small industrial scale implementation Innotech dryers
See Task 4.4

Task 4.2: Development of control systems:
(1) Inflexion point controlled drying: This strategy is based on the investigation that the drying process can be divided in three phases. In phase 1, the product temperature at the surface does not change until the free moisture is completely evaporated. This phase can be shortened by a higher drying air temperature and the product quality can be increased. In phase 2, which is conducted under a lower temperature to avoid quality losses. This phase lasts until only vapor is left inside the pores. In the final phase 3, Vapor diffusion occurs, which again can take place under a higher temperature than in phase 2. The different phases can be monitored by the surface temperature, or the development of this temperature, respectively.
(2) Product temperature controlled drying: The product temperature controlled drying is based on the fact that during drying at a constant temperature, the temperature of the drying air is higher than the product temperature due to the evaporation of moisture which cools the product during drying. For a control system, the surface of the product is monitored with pyrometric or infrared devices and the drying air temperature starts at a level, at which the product surface reaches the temperature defined before. During the drying process, the air temperature decreases, while the product temperature stays the same. This control system can lead to higher product quality, as the processing time is decreased and moreover decreases the energy consumption of the dryer.
A further control strategy is the enthalpy controlled drying. This strategy is valid for heat pump dryers, as

the drying gets inefficient in batch processes, when the sensible heat increases and the latent heat decreases due to less water evaporating during drying. An idea for a control strategy is the control of the air flow of the drying air. As far as the relative humidity inside the dryer falls below a certain value, the air flow decreases and would lead to constant high latent heat. However, this strategy needs further development.

Task 4.3: Identification of placement of the sensor: A model of a cabinet test dryer was overlaid with a CFD simulation. Results show a satisfying, almost uniform air velocity over all the tray, however, the velocity always shows slight higher values at the front of a tray which decreases over the length of it (Figure 4.3):

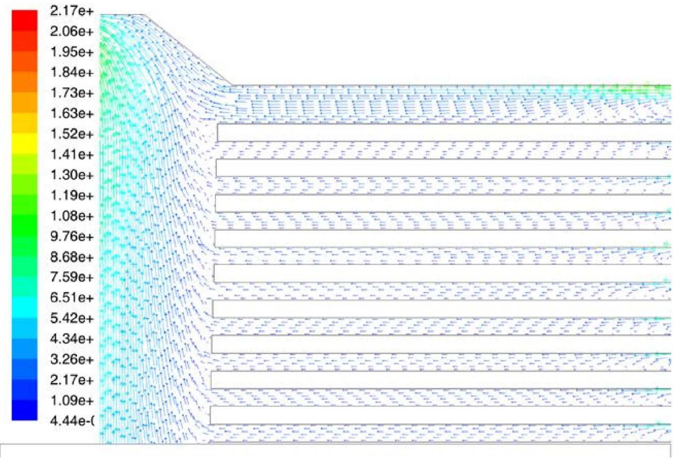


Figure 4.3: CFD simulation of a cabinet dryer (HTmini, Innotech Ingenieursgesellschaft mbH)

Based on the results of the CFD simulation, it was decided to install the sensor for monitoring the product temperature in the middle over the uppermost tray as this can be seen as representative for the rest of the dryer. Verification tests were conducted and a proof of concept could be delivered.

Task 4.4 Scale up tests in commercial cabinet dryers:

The development of the control system and the placement of the sensor were carried out in the smallest commercial dryer (HTmini) Innotech Ingenieursgesellschaft mbH is producing, and were successfully transferred to bigger cabinet dryers by Meridian.

Additional Task (beyond original scope): Meat status determination (fresh/frozen, age) and pH evaluation

Two approaches were developed to classify between, fresh and frozen thawed, and in a novel manner matured and matured frozen-thawed, as well as fresh and matured beef using the 500-1010 nm waveband, captured using hyperspectral imaging, and CIELAB measurements. The results show successful classification based upon CIELAB between 1) fresh and frozen-thawed (CCR = 0.93), and 2) fresh and matured (CCR = 0.92). With successful classification between matured and matured frozen-thawed beef using the entire spectral range (CCR = 1.00). The performance of reduced spectral models is also investigated. Overall it was found that CIELAB co-ordinates can be used for successful classification for all comparisons except between matured and matured frozen-thawed.

Threshold detection for pH level in beef with different freshness levels (fresh, fresh frozen-thawed, matured, and matured frozen-thawed) was conducted. Use of support vector machine (SVM) analysis allowed for the classification of beef samples with a pH above 5.9, and below 5.6, with an accuracy of 91% and 99% respectively. This methodology can help to generate a more complete meat status analysis as no sampling is necessary. With current standard methods random sampling is usually conducted as they are destructive, and thus, reduction of value of the investigated meat pieces results from this. On average only every 50th piece of meat is sampled.

B- fulfilment of objectives:

D4.1 Activities are finished

D4.2 Activities are finished, guidelines are written

D4.3 Activities are finished, protocol is written
D4.4 Verification was conducted, report is written

M4.1: Measurement hardware is working
M4.2: Guidelines for product temperature controller are written
M4.3: Drying model and CFD simulation are finished
M4.4: Upscale tests are finalised

Publications

Amjad, W., Crichton, S.O.J, Munir, A., Hensel, O., Sturm, B. (2018). Hyperspectral imaging for the determination of potato slice moisture content and chromaticity during the convective hot air drying process, Biosystems Engineering 166, 170-183

Crichton, S.O.J., Kirchner, S.M., Porley, V.E., Retz, S., von Gersdorff, G. Hensel, O., Weygandt, M., Sturm, B. (2017). Classification of organic beef freshness using VNIR hyperspectral imaging, Meat Science 129, 20-27

Crichton, S.O.J., Kirchner, S.M., Porley, V.E. Retz, S., von Gersdorff, G. Hensel, O., Sturm, B. (2017). High pH thresholding of beef with VNIR hyperspectral imaging, Meat Science 134, 14-17

Crichton, S.O.J., Shrestha, L., Hurlbert, A., Sturm, B. (2017). Prediction of moisture content and chromaticity of raw and pre-treated apple slices during convection drying using hyperspectral imaging, Drying Technology http://dx.doi.org/10.1080/07373937.2017.1356847

Gersdorff, G., Porley, V., Retz, S., Hensel, O., Crichton, S.O.J., Sturm, B. (2017). Drying kinetics and quality parameters of dried beef (biltong) subjected to different pre-treatments, Drying Technology http://dx.doi.org/10.1080/07373937.2017.1295979

Moscetti, R., Sturm, B., Amjad, W., Crichton S., Massantini, R. (2017). Monitoring of organic potato (cv. Anuschka) during hot-air drying using Vis/NIR hyperspectral imaging, Science of Food and Agriculture, doi: 10.1002/jsfa.8737

Sturm, B., Raut, S., Münsterer, J., Kammhuber, K., Crichton, S.O.J. (2018). Impact of process settings on drying kinetics, colour and chemical composition of hops (cv Mandarina Bavaria), using RGB and HIS imaging, Brewing Science (in preparation)

3.5 WP5

WP5	Quality assessment and quality standards
WP leader: Liliana Badulescu Responsible partners: UASVM	

Overall summary of main results, discussion and conclusions of WP5

The overall aim of this WP was the support of the work packages which dealt with 1. the improvement of process understanding through in depth analysis of changes throughout the drying and chilling/freezing processes, 2. the development of improved process settings and 3. new technologies and techniques as well as retrofits (WPs 2-4 and 6). For this purpose extensive analysis of chemical, microbiological, textural, sensory, visual attributes of products and shelf life tests for the dried and cooled/frozen products were conducted. The results were fed back to the respective WPs and used for process analysis and optimisation as well as the development of non-invasive measurement and control systems using methods of chemometrics.

An extensive yet comprehensive processing and quality guidelines document was produced which was based on the results of the testing conducted in the laboratories as well as practical experience from production audits and discussion with producers at the numerous dissemination events.

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

A- results obtained:

Task 5.1: Determination of the characteristics to be investigated: The characteristics were selected based on information from academic literature and results from WP1. Quality criteria of importance for investigation during the process in the WP 2-4 and WP6 were defined and testing regimes (i.e. technologies and techniques to be used) were collected based on the possibilities each partner had in their own labs as well as the work to be conducted in the labs at UASVM.

Task 5.2: Quality assessment: The products investigated were as follows: fish, meat, fruits (apples), vegetables (carrots, potatoes, and sweet potatoes), herbs, hops. For all listed commodities, analyses have been carried out as appropriate for the commodity:

- Hops: water content, colour measurement, size development, hyperspectral imaging, phenolic compounds, aromas, alpha and beta acid, storage index
- Apples: water content, colour measurement, size development, hyperspectral imaging and NIR spectroscopy, phenolic compounds, soluble solids content, titratable acidity, pH, thermal properties (DSC analysis), enzymatic activity
- Carrots: moisture content, water activity, soluble solids content, titratable acidity, pH and total carotenoid, thermal properties (DSC analysis)
- Herbs: water content, colour measurement, hyperspectral imaging, microorganism count
- Meat: water content, colour measurement, hyperspectral imaging, pH, water activity, toughness, microorganism count analysis, thermal properties (DSC analysis), SEM
- Fish: microorganism count, thermal properties (DSC analysis), lipid and fatty acid contents

Task 5.3: Quality standards: In the course of the project, in context of own investigations, intensive literature studies and practical experience from processors, it became apparent, that raw material quality fluctuates much more greatly than anticipated. Therefore, rather than attempting to present hard numbers in terms of quality guidelines (which would have been impossible), an extensive, yet comprehensive “Processing and quality guideline” document was developed. This document gives deep insight in the impact of all processing steps on product quality for selected products as well as recommendation for the practical implementation of improved ways of product handling, process settings as well as integration of renewable energy sources.

B- fulfilment of objectives:

D5.1: Report written and disseminated to the consortium
D5.2: Database exists (will be transferred into the Data Management System within SusOrgPlus
D5.3: Processing and Quality guidelines are finished

M5.1: Quality criteria are identified, test regime set up and report is written: done
M5.2: All samples are analysed and integrated in the database: done
M5.3: Report on quality standards is finished and disseminated to the stake holders: Partially done: Guidelines exist but are not yet disseminated. The consortium would appreciate the input of the funding bodies before dissemination. Further, it was decided that the processing and quality guidelines will be made available through the dedicate SusOrgPlus website (http://www.susorgplus.eu/) which is currently under construction.

Publications

Shrestha, L., Moscetti, R., Kuhlig, B., Hensel, O., Pawelzik, E., Hensel, O., Sturm, B. (2018). Control of browning development and enzymatic activity on apple slices using physical and chemical treatments, LWT – Food Science and Technology (submitted)

Md Saleh, R., Kumar, A., Kuhlig, B., Hensel, O., Sturm, B. (2018). Investigation of drying kinetics and quality changes in organic carrots (Daucus carota v. Laguna) for optimisation of drying parameters (in preparation)

Cotrut, R. & Badulescu, L. (2016) UPLC Rapid Quantification of Ascorbic Acid in Several Fruits and Vegetables Extracted Using Different Solvents. *Agriculture and Agricultural Science Procedia*, 10, pp.

160-166.
Nicolae, C. G., Bahaciu, G. V., Ţeca, M., Bădulescu, L., Pogurschi, E., & Marin, M. (2017) The effect of frozen storage on lipids and fatty acids content in Atlantic salmon. Case study. International Scientific Symposium "Modern animal husbandry – Food safety and durable development. 19th-20th October, 2017, Bucharest, RO.
Nicolae, C. G., Bahaciu, G. V., Elia, E., Dumitrache, F., Marin, M. P., Pogurschi, E., & Bădulescu, L. (2016). A review of the quality standards for frozen beef meat and fish. The International Conference Agriculture for Life, Life for Agriculture of the University of Agronomic Sciences and Veterinary Medicine of Bucharest, July 2016.
Please note, that some of the publications that are related to the quality assessment, are presented in other WPs as they are contextually more relevant for those.

3.6 WP6

WP6	Cooling/Freezing characteristics and process optimization

WP leader: Michael Bantle
Responsible partners: SINTEF, UNITE

Overall summary of main results, discussion and conclusions of WP6

The main objective of this work package were shelf life and storage tests, quality attributes of organic products in chilled and frozen condition, including super-chilled condition.

Freezing and frozen storage

Among various techniques, freezing is recognized as one of the main processes applied in fruits and vegetables allowing their long-term preservation and storage. Freezing temperatures cause the phase transition of the free and freezable water in to ice crystals, thereby it becomes immobilised, and chemical, biochemical changes are significantly slowed down, and microbial growth is limited, thereby the nutritional and health value could be preserved. However,

Freezing due to ice formation, volume expansion during freezing and recrystallization, could impair cell walls integrity, damage the vegetable structure and determine the lack of product integrity and upon thawing, excessive drainage or loss of shape could occur. Cellular foods in particular in fruits and vegetables that contain large quantities of water in proportion to their weight (85-90 %) are more susceptible than other cellular foods to ice crystal damage. Overall this may affect on one side the texture and sensory properties, and, on the other side, the nutritional and health properties of frozen-thawed fruits and vegetables as in part of their micro-nutrients may be lost in the released water and enzymatic reactions may be favoured due to the damage of the vegetable structure that make easier the activity.

To improve quality of frozen products by inactivating or inhibiting enzymes that may affect quality of the product during freezing, frozen storage and after thawing, pre-treatments of fresh fruits and vegetables are recommended and the most used are blanching (for vegetables) and dipping in solutions containing acids and/or sugars as protecting agents to decrease the pH and/or to reduce the freezable water.

Organic products, compared to integrated or conventional ones are recognized for the absence and/or low presence of phytochemicals and environmental contaminants. Freezing could be an interesting preservative technology applicable more extensively also in the organic food production and currently only scarce are the products available in the market. Several may be the reasons that have limited the application of this technology to organic raw products including the limited information about their suitability to be processed.

In this project a study has been thus developed aimed to evaluate:

- Effect of pre-treatments and, in particular, dipping and vacuum-impregnation by using solutions made of lemon juice. Vacuum impregnation is a new technology that due to a quick pressure reduction could accelerate the penetration of solutes and compounds of interest.
- effect of pre-treatments dipping and vacuum impregnation used as to improve stability over frozen storage time
- Effect of different freezing rates

Superchilling

Refrigeration in the form of freezing and chilling is one of the main processes in the food industry in order to preserve food and extend the shelf life. The refrigeration is mostly performed for products which cannot be dried. In fact most products in a supermarket are either chilled, frozen or dried to a certain extend in order to avoid product degradation and extend shelf life. Storage tests for chilled salmon filets were performed with organic and conventional origin. It was demonstrated that the storage conditions were not resulting in a difference between the shelf life of organic or conventional products. This means that the optimum storage conditions for conventional products can be transferred to the organic sector.
The temperature of a freeze storage for fish was influencing the degradation of the fish lipids. However the influence of the packaging material is dominating. It is therefore recommended to use non-permeable plastic packaging at common freeze storage temperatures in order to sustain a high quality product.
The temperature for chilled products can increase the shelf life quite significantly, when the storage temperature is reduced to almost 0°C. This relation is well known by the food industry.
The investigations performed in this task outlined that organic food sector does not need special refrigerated storage condition. The optimum storage conditions are the same as for conventional food.
Superchilling is in principal a partial freezing of a product when around 5% to 20% of the water is present in frozen state. There is no commonly agreed definition of superchilling in literature and in some publications an ice content of up to 30% was considered as superchilled. The main idea behind superchilling is that the product appear non-frozen despite the presence of ice. Hence, the acceptable amount of ice formation must be considered for each product.
Production of processed organic food is mostly carried out by small and medium enterprises in a pressured marked situation and competing with highly cost efficient large scale producers of conventional products and local ("short-travelled") food producer without certification requirements. The super-chilling concept can be applied for organic meat and fish products, hereby helping the producer to supplying the market with a high-quality organic product. The extended the shelf-life of super-chilled products will be beneficial under storage with respect to production and seasonal variations and transportation in order to reach new and far-distant markets. Strict control of the chilling process as well as storage temperature and time is necessary in order to apply the concept. For these reasons it might be difficult to apply super-chilling towards the end of the cold chain at the retailer or consumer without significant alterations to the cold chain.
Superchilling of organic salmon fillets and pork chop was investigated and the potential of the concept was documented for the organic sector, especially SMEs. Relative shelf life extensions of 14 days compared to chilled product, were documented for both products. The colour of the product showed no significant changes between the superchilling and conventional chilling processes. However, the superchilled products showed an increased drip loss and reduced water holding capacity, which was caused by the partial freeze damage.
The shelf life of the superchilled product will depend mainly on sanitation, processing and cold chain conditions and not on the organic origin of the product.
The performed investigations demonstrated the potential of the superchilling concept for organic products. The needed technology is available at the market and implementation of the technology for the organic production lines is possible.
Thermal properties of food products are one of the most important parameters, which is used for designing processing and storage conditions. The task investigated the following thermal properties of the selected foods:
1. Glass transition temperature. Glass transition is a second order phase transitions, which occurs in food products with a high moisture content at low and ultra-low temperatures. This is solid phase of the material, but the matter is not structured as it happens in the case of crystalline state. Glass transition occurs at conditions, when ice formation is not possible in the system and high viscosity is observed (more than 1012 Pa*s). This state is characterized by low molecular mobility, and it is considered that the product is very stable for long term storage at these conditions. The mechanical structure, on the other hand, is characterized by brittleness and high Young's modulus. The glass transition temperature depends on the chemical composition i.e. average molecular weight;
2. End of freezing temperature. This temperature refers to conditions when the ice formation does not happen in the product when the temperature is further decreased. The formation of so-called maximum freeze concentration solution happens. This temperature helps to understand the preferable storage

temperatures, that is when further decreasing of the temperature do not result in further increasing of the solid fraction and extra stability of the product;

3. Unfreezable water. It is considered, that all freezable water is in the solid state below –40 °C and only unfreezable water remains in the system as a liquid. The unfrozen solution in muscles and tissues is complicated and contains of protein, fats, sugars, salt ions, droplets of fat etc. The amount of unfreezable water is quite significant and reaches up to 40 % from the protein weight (Schwartzberg, 1976). Thus, different deteriorative reactions may occure at temperatures below –40 °C. The knowledge of unfreezable water and end of freezing help to understand amount of ice in the product with respect to the freezing temperature, which is extremely important when designing the freeze-drying methods and storage conditions for foods;

4. Investigation of the fish oil properties. The glass transition of the fish oils was detected at temperatures below –110.0 °C This means that some amount of the fish oil stays in a liquid supercooled state at ultra-low temperatures. The melting of the fish oils will be different due to peculiarities in composition. The determination of a solid fraction in fish oils at different temperatures by DSC is beneficial. It is possible to obtain the melting thermogram during one investigation. Consequently, the solid fraction content can be calculated by the partial integration of the melting peaks.

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

A- results obtained:

Task 6.1: Optimum storage conditions and cryo-protectants:

The perfomed investigations showed that chilling or freezing conditions of organic salmon are the same as for conventional produced salmon. Optimized storage conditions are related to temperature, sanitation, refrigeration system, packaging and cryoprotectant but are not depending on the origin of the product. The shelf life of Salmon shows no statistic relevant difference for organic and conventional salmon.

The second study was carried out on apples obtained by ORG and CONV farming procedures at equal ripeness index. Overall the fresh products showed only limited differences in the organic acids and sugar content correlated with a different rate of the metabolic paths during ripening while the total polyphenols content and phenolics pattern was higher in ORG apples likely due to plant response to biotic and abiotic stresses; ORG apples showed a higher porosity and a slightly higher firmness.

Processing similarly affected both types of apples but, after pre-treatments, freezing and frozen storage (-40°C) ORG apples showed a higher polyphenols content and mechanical strength than CONV (s. Figure 1).

Overall, this part of the study allows confirming the technological suitability of the ORG apples to be subjected to freezing and freezing can preserve the content and quality properties of the initial fresh fruit.

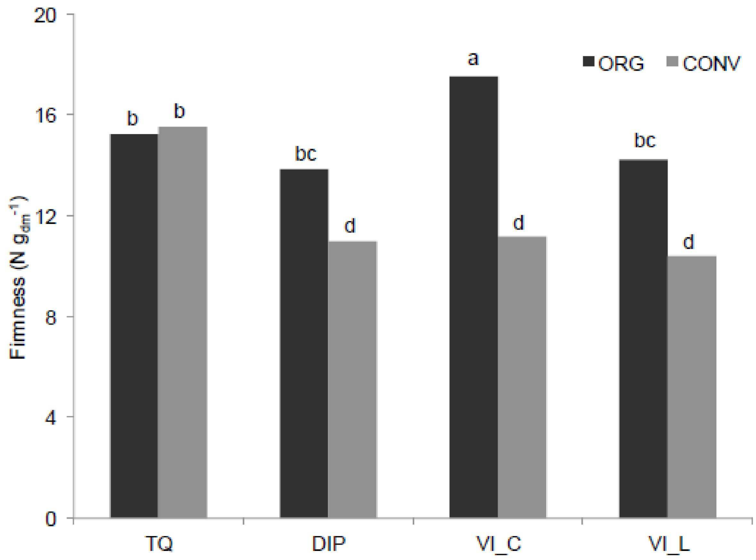


Figure 1. Firmness of organic (ORG) and conventional (CONV) apples. TQ: unprocessed; DIP; dipped in diluted lemon juice; VI_C: vacuum impregnated in water; VI_L: vacuum impregnated in diluted lemon juice. Different letters stand for statistically significant differences at p < 0.05

Task 6.2: Super-chilling of organic food: Organic products have in general the same shelf life as non-organic products as long as they are stored at the same refrigeration conditions in the cold chain. The

superchilling concept was applied for an organic salmon product and on organic pork chop, which are commonly available at the Norwegian and European market. For both products, it was possible to extend the shelf life by 14 days, relative to the shelf life of the product in ordinary cold chain. Similar shelf life extensions are documented of common fish and meat products; superchilled samples have extended shelf life compared to chilled product samples, and thus, and it seems safe to conclude that the results are transferable to organic products. The shelf life of the product will depend mainly on sanitation, processing and cold chain conditions and not on the organic origin of the product.
In order to document absolute shelf life of a certain superchilled product, individual test should be performed on-site. However, the potential of superchilling is clearly that the shelf life of the product can be increased by 14 days which is redoubling of the standard shelf life. The technology can therefore be of special interest for SME in order to increase market availability of their organic products.
The experiments showed a possibility to extend the shelf life of a product which was already 7 days old. This aspect of superchilling was so far not investigated by other researchers. This approach could be of interest extending the market exposure for organic products when it is not possible to sell it within the first days after slaughtering.

Documented shelf life for organic salmon and organic pork products.	**Shelf life normal chilled (+3 °C)**	**Shelf life superchilled (-1.5 °C, 15 % ice)**
Salmon fillets	14 days	28 days (+14 days)
Pork chops	14 days	28 days (+14 days)

R&D has clearly identified the potential of this technology, especially for meat (chicken, lamb, pork) and fish (salmon, cod) products. However, the industry has somewhat overlook this technology, despite the clear benefits, the relative simple implementation also in existing production lines and the high technological readiness level. The first industrial implementations have demonstration positive effects on shelf life, product quality, production yield, energy demand and production costs.

Task 6.3: Determination of thermal properties: Thermal properties of selected organic products were investigated using novel DSC technique and methods of determination. The performed work includes determination of freezing temperatures, glass transition temperatures, amount of ice, and end of freezing point, heat capacity and thermal conductivity for selected cases. One part of the experimental work was devoted to investigate the difference between oils extracted from organic and conventional salmon.
The main aim of the investigation was to understand if the organic food requires any special treatment during processing, when compared with industrially produced foods.

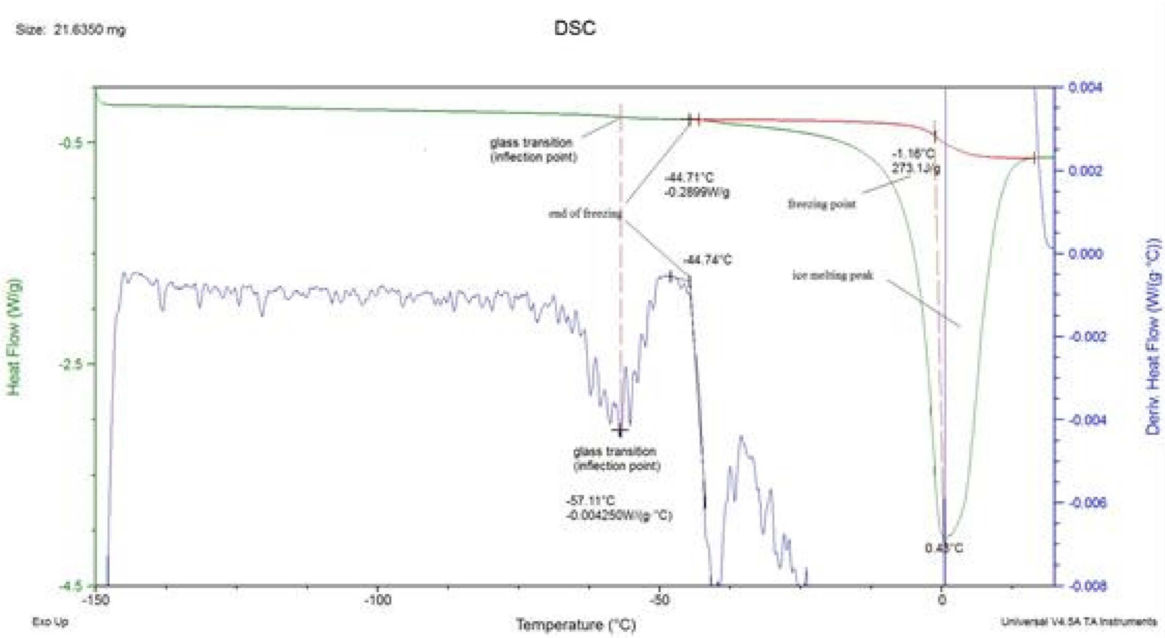


Figure 6.2: Example for DSC results of organic salmon

For the investigated organic products (carrots, apples, salmon fillets and pork chops) no significant difference was found compared to conventional products. Organic salmon oil showed a different melting and freezing behaviour, which can be explained by the different fatty acid composition of the feed.
The performed investigation indicate that organic products can be preserved by the same technologies of the food chain than conventional products.
The determined data from the DSC analysis are available for download on http://orgprints.org/31369/.
An example of the determined thermal properties is given in the following Figure 6.2:

B- fulfilment of objectives: The objective of the WP6 was to investigate and perform shelf life and storage tests, and quality attributes of organic products in chilled, frozen condition and super-chilled condition. The following main activies were performed and objectives achieved:

D6.1 Activities finished, report is written
D6.2 Test on superchilling were done, reports are written
D6.3 Paper based on D6.2 is written
D6.4 Tests in thermal properties are finalized, report is written

M6.1 Shelf life of conventional and organic salmon and apples compared.
M6.2 Superchilling of organic salmon and pork performed, shelf life extension documented. Potential of superchilling technology especially for SME organic producers evaluated
M6.3 Workshop "Novelty Day" on the NBDC 2017 in Hamburg was realized
M6.4 Thermal properties of organic meat and fish determined; difference between organic and conventional fish products evaluated. Correlation to product quality established.

Publications

Bantle, M.; Nordtvedt, T.S.; Claussen, I.C. and Indergård, E. (2016) State of the Art: Superchilling in the Food Processing Industry. 4th IIR International Conference on Sustainability and the Cold Chain, Massey University Auckland, New Zealand, 7-9 April 2016

Neri L., Santarelli V., Di Mattia C., Sacchetti G., Mastrocola D., Pittia P. (2018). Effect of freezing and frozen storage on quality of organic and conventional apples. *LWT- Food Science and Technology. (accepted manuscript)*

Santarelli V., Neri L., Pittia P. (2018). Effect of frozen storage on bioactive compounds of organic and conventional apples. *Food and Bioprocess Technology*

Tolstorebrov, I., Eikevik, T. M., & Bantle, M. (2016). Effect of low and ultra-low temperature applications during freezing and frozen storage on quality parameters for fish. *International Journal of Refrigeration*, 63, 37-47.
Bantle, M., Claussen, I.C, Tolstorebrov, I., Superchilling of organic food – Part 1: Concept, Stator of the Art and Potential for small scale implementation, Technical Report; TRA 7583, SINTEF Energy Research, ISBN 978 82 594 3671 9.
Claussen, I.C., Gullsvåg, P.E., Bantle, M.; Tolstorebrov, I., Kvalsvik, K., Superchilling of Organic Food – Part 2: Storage tests with superchilled organic salmon and pork chops, Technical Report; TRA 7629, SINTEF Energy Research, ISBN 978 82 594 3683 2
Bantle, M., Tolstorebrov, I., Thermal Properties of Organic Food: DSC analysis of apple, carrot, pork, salmon and salmon oil, Technical Report 2017:00021, SINTEF Energy Research, ISBN 978 82 14 06706 4
Bantle, M.; Nordtvedt, T.S.; Claussen, I.C. and Indergård, E. State of the Art: Superchilling in the Food Processing Industry, Feature in The Industry Journal of the New Zealand Refrigeration, Heating, Ventilation and Air Conditioning Industries, August/September 2017, page 19-24.
Gersdorff, Gardis J.E.; Bantle, Michael; Hensel, Oliver; Sturm, Barbara. Drying and Chilling/Freezing of Perishable Foods in the Organic Sector. I: Sustainable Food Systems from Agriculture to Industry Improving Produciton and Processing. Elsevier 2018 ISBN 978-0-12-811935-8. s. 245-274
Quirin Kaliner, Investigation of efficient industrial chilling of Atlantic Salmon, Bachelor Thesis, 26.08.2017, Norwegian University of Science and Technology
Gabriel Dieny, Investigation of efficient industrial chilling of Atlantic Salmon, student project work, 06.06.2016, Norwegian University of Science and Technology.

3.7 WP7

WP7	Value chain management, Life Cycle (LCA) and Life Cycle Cost (LCCA) analyses
WP leader: Girma Gebresenbet Responsible partners: SLU	
Overall summary of main results, discussion and conclusions of WP7 The specific objectives of WP7 include analysis of value chain management, assessing the environmental efficiency (using LCA-life cycle analysis) and economic efficiency (LCCA-life cycle cost analysis) and develop database for future reference. In order to achieve these objectives, intensive studies have been conducted on organic salmon from Norway, organic beef, apple, carrot, and tomato produced and supplied within Sweden. Both primary and secondary data have been used in these studies. It was also intended to study how processing of organic food could influence the environmental and economic performance of the selected organic food value chains. Value chain analysis (VCA) was used to assess the value chains of 5 organic food items indicated above. The value chain structures mapped out in the VCA have been used as basis for LCA and LCCA studies. The major constraints and product losses along value chains as well as opportunities to promote further development of organic food sector have been identified. The role of food processing such as superchilling and drying has been discussed from sustainable organic food production point of view. The environmental assessment of the mentioned 5 organic food products has been conducted using standardized LCA method. The LCA was conducted with in scope of agricultural production up to delivery to consumer gate. Firstly, environmental impacts of fresh products have been assessed. Secondly, the impacts of processed food (superchilled salmon) and dried beef, apple, carrot, and tomato has been studied. For organic salmon case, 1 ton fillet was considered as functional unit (FU). For organic beef, 1 ton fresh bone-free beef at slaughtering house was used as FU for both fresh and dried beef cases. For fresh and dried apple, carrot, and tomato value chains, 1 ton fresh product at farm gate was considered as FU. This enabled to compare environmental impacts of fresh and processed food products. In all cases, energy consumption was assessed using cumulative energy demand approach, which converts all energy inputs from different sources and converts into primary energy and quantifies it. In addition to energy consumption, other environmental impact categories such as greenhouse gas emission, acidification, and eutrophication impacts have been quantified and analysed. The environmental impacts have been quantified and presented at three	

major life cycle stages: *agricultural production, postharvest, and transport stages*.
The cost assessment was conducted for all products described above except organic tomato value chain. In all cases the life cycle costs have been calculated following the same scope of value chain and functional unit described in case of environmental assessment. The life cycle costs have been quantified and presented in Euro per functional unit i.e. Euro per 1 ton of fresh products at farm gate and 1 ton of fillet or beef at slaughtering house. The same FU is considered for processed product cases. The costs have been calculated using year 2016 as base year.
Database has been developed using data compiled for the LCA and LCCA studies. The database includes both input data for LCA study and life cycle impact assessment results (quantified environmental impacts) for all five organic food products described above. Totally, LCA data associated with the 12 value chains including the 4 scenarios of organic salmon supply have been prepared. Similarly, cost data related to 10 value chains have been documented. The data has been compiled in excel based digital files and a brief user manual that guides how to use the data has been prepared.

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

A- results obtained:
Task 7.1 & Task 7.2: Chain Management in the total value chain & Life cycle analysis (LCA): The result indicates that mapping out the value chain structure of organic products facilitates investigation of product value chains using tools such as VCA, LCA and LCCA. The increasing demand of organic food in Europe, the political and financial support for organic and sustainable food production, increasing innovative technologies in processing of organic food create opportunities for improving sustainability of organic food sector.
The LCA results indicated that organic salmon production and greenhouse based tomato cultivation have high energy inputs of 48.4 gigajoule (GJ) and 44.6 GJ per FU respectively (see Figures 7.1 and 7.2). Organic beef value chain has highest greenhouse gas emission with 12 964 kg CO2 equivalent per FU for fresh beef case. Open field carrot production and supply has the least emission (121 kg CO2 equivalent) and energy consumption of 2.6 gigajoule per FU considering fresh product cases. Food processing (superchilling and drying) has reduced the environmental impacts at transport stage. Fresh organic beef value chain has highest acidification and eutrophication impacts (see Table 7.1) followed by organic salmon value chain. The remaining product value chains have relatively insignificant acidification and eutrophication impacts.

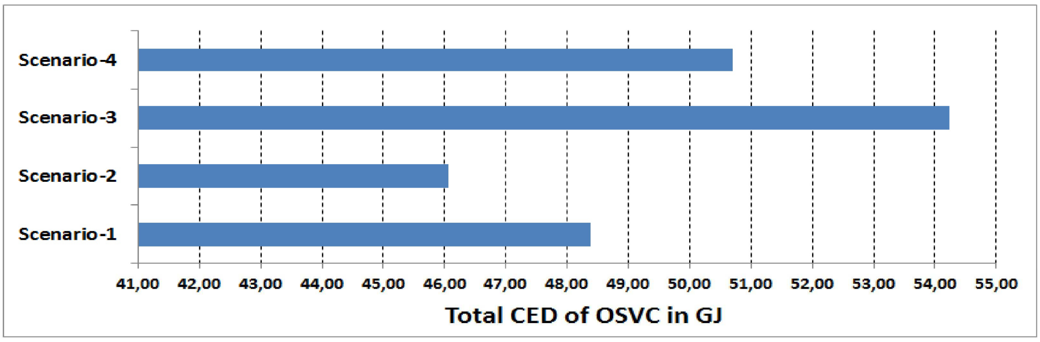


Figure 7.1: Comparison of energy demand for different scenarios of organic salmon value chain (OSVC) in gigajoule (GJ) per functional unit i.e. 1 ton of fillet. Scenario-2 and scenario-4 represent superchilled salmon fillet. Scenarios 1 and 2 represent case of distribution within Norway while scenarios 3 and 4 represent export from Norway to France.

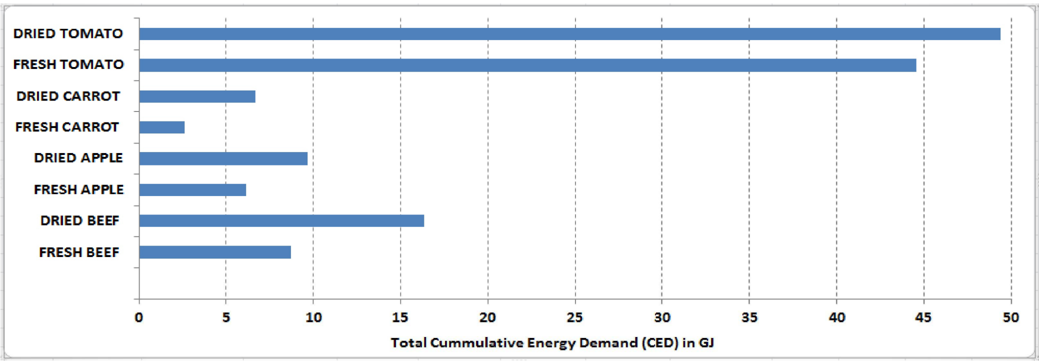


Figure 7.2: Comparison of total CED for fresh and dried organic beef, apple, carrot, and tomato value chains per FU.

Table 7.1: Acidification and Eutrophication impacts for beef value chain. Values are provided per FU

Impact category	Unit	Cattle Breeding	Processing	Transport	Total
Fresh Beef					
Terrestrial acidification	kg SO2 eq*	91.017	0.127	0.179	91.323
Freshwater eutrophication	kg P eq	0.027	0.006	0.006	0.039
Marine eutrophication	kg N eq	56.926	0.007	0.009	56.943
Dried Beef					
Terrestrial acidification	kg SO2 eq	91.017	0.359	0.086	91.462
Freshwater eutrophication	kg P eq	0.027	0.022	0.002	0.051
Marine eutrophication	kg N eq	56.926	0.034	0.005	56.965

*-Equivalent

Task 7.3: Economic analysis: The findings of LCCA study indicate that the share of agricultural production is high in most cases. Organic salmon and beef meat value chains have highest costs while carrot has the least cost (see Table 7.2). In salmon and beef production cases feed production and supply incur significant costs. Improvements at farm stage could lead to cost effectiveness of organic food value chains and promote sustainable organic food production method.

Table 7.2: Summary of life cycle cost (LCC) at different stages and their contribution to total cost per functional unit

Organic food value chain	Unit[a]	Farm stage	Post-harvest processing stage[b]	Transport stage	Total
Salmon supplied within Norway (with normal cold chain)	€	6213	475	27	6715
Salmon supplied within Norway (Supper-chilled)	€	6213	494	18	6725
Salmon exported to France (with normal cold chain)	€	6213	475	106	6794
Salmon exported to France (supper-chilled)	€	6213	494	71	6778
Fresh beef meat	€	6326	14204[c]	1550	22080
Dried beef meat	€	6326	14752[c]	885	21964
Fresh apple	€	1865	482	42	2391
Dried apple	€	1865	643	27	2537
Fresh carrot	€	*830*	*358*	*189*	*1377*
Dried carrot	€	*830*	*384*	*111*	*1325*

[a]-The values are given per functional unit but not per ton of final product; [b]-It includes packaging at this stage; [c]-Esimated based on average 4.4% operating margin at processing and retail levels which could be higher in some cases.

The study enabled to understand the influence of the food processing (superchiling and drying) process on energy consumption and environmental impacts, and costs of organic food product value chains. Both superchilling and drying processes increase the environmental impact and cost at postharvest (processing stage) due to additional energy and labor used when compared with fresh product value chains. However, superchilling and drying could reduce transport demand and related fossil fuel use, cost and environmental impacts of transport stage.

Task 7.4: Data base development: Database compiled from LCA of 12 organic food value chains and LCCA of 10 value chains could contribute to increase the database on environmental impact and cost of organic food sector. These findings could be used as important benchmark for further investigations of organic food products in Europe in general and Sweden and Norway in particular. In addition to improving energy efficiency at farm stage and post-harvest stages, introducing renewable energy is important where it is applicable, to improve the sustainability of organic food value chains. Reducing the use of non-renewable fossil energy and maximizing the use of renewable energy sources could lead to sustainable development of organic agriculture sector.

B- fulfilment of objectives:
The major objectives of WP7 have been fulfilled. The following studies have been conducted on 5 selected organic food value chains.

D7.1 Activities completed and report is written
D7.2 Activities completed and report is written
D7.3 Activities completed and report is written
D7.4 Activities completed and report is written

M7.1 Report on value chain management is written
M7.2 Report on LCA is completed
M7.3 Report on economic analysis (LCCA) is completed
M7.4 Data base is set up

Publications

Bosona, T., & Gebresenbet, G. (2018). Swedish Consumers' Perception of Food Quality and Sustainability in Relation to Organic Food Production. *Foods*, *7*(4), 54.

Bosona T. and Gebresenbet G. (2018). Life cycle analysis and life cycle cost analysis of fresh and dried organic carrot value chains. *Frontiers in Sustainable Food Systems (Manuscript-Abstract submitted).*

3.8 WP8

WP8	Dissemination and Training

WP leader: Paola Pittia, UNITE
Responsible partners: all partners

Overall summary of main results, discussion and conclusions of WP8

Aim of this WP was to disseminate the results of the project to the scientific community and the main stakeholders of the agri-food chain involved in the organic sector. A further aim was to develop training material to allow the upgrade of the technical and scientific competences of the workforce in the organic agri-food sector and chain including professionals, farmers, processors

The dissemination tasks were started and developed with some delay due to the overall delay of the project activities. All partners have contributed at different level to this WP.

The project partners were properly and adequately committed in the dissemination of the project activities at national and international level by using all the tools planned in the project proposal by scientific publications, organisation of conferences, workshops, seminars, oral and poster presentations at conferences.

The results of the project research activities have allowed to publish so far already 13 publications papers in international journals and one book chapter, while 4 additional journal papers have already been submitted and 15 are under preparation.

Partners attended conferences and presented the project general aims or specific project research results. As additional dissemination tool, internships, bachelor, master and PhD theses were included: these publications are the result of the involvement of the students in the researches of the partners allowing to enlarge also the dissemination of the project activities to an unexpected target group (students). The students were involved into lab work, however, also the work on stakeholder farms was enabled. Overall 36 thesis reports were prepared or are under preparation, so far.

As regards the training materials and tools, partners have been involved in the organisation of workshops within a national or international dimension. One (out of the two) workshops in Italy on the topics of the CORE-ORGANIC projects was co-organised by the SusOrganic and Ecoberry consortia thanks to the collaboration of the Italian partners of the two projects (University of Teramo, University La Tuscia, University of Bologna) as pre-conference event at the international FOODINNOVA conference (30th Jan 2017, Cesena, IT).

Moreover, a new e-learning module ("Sustainable processing for organic food products"), has been prepared with the contribution of all the partners containing general contents as well as guidelines for

organic food processing based on the SusOrganic project results. The e-learning module has been uploaded in the e-learning platform of the ISEKI-Food Association that agreed to host this new module by free and contribute, in collaboration with the University of Teramo (IT) to keep it active and updated. This module will be made available for free access to any interested trainer of the SUSORGANIC project and any trainee upon request.
Social media have been used only to a limited extent being all partners more committed on the research tasks. One Facebook page has been set but not kept updated. On the other side a SUSORGANIC project page has been set in Researchgate with over 30 followers and 277 reads (last update: April 2018).

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

A- results obtained:
Task 8.1 Stakeholder Involvement: The partners set up a database including all the relevant stakeholders in organic processing (associations, food producers, organic certification bodies, etc.) to ensure the distribution of project results to the target group which is the processors. Overall, 75 stakeholders were defined (Germany 13, Italy 13, Norway 31, Sweden 16, 2 European).
Task 8.2: Dissemination events: Project related results were presented at 15 international conferences. Some events have been already defined at the beginning of the project, others were chosen during the development of the project. A big success was the contributions of 6 partners of the consortium at the "Novelty Day" session at the NBDC 2017 in Hamburg (see. M3.3) with overall 10 presentations reflecting the wide range of the project to an international auditorium.
Task 8.3 Articles and publications: Project outcomes have been published in 13 articles in international journals, further 4 are submitted and 15 are under preparation. 1 book chapter was published in an international technical book. Several publications are authored by partners of different institutions, which shows the very good collaboration of the project consortium. Regarding stakeholder articles, several press releases were published in the national languages by the participating universities press departments and, taken up by several online magazines and newspapers. Further, stakeholder magazines ask for contributions to appropriate issues. The project was mainly enriched by including students in the project activity and this activity was used as both training and dissemination of the project thereby an increased impact of the project was achieved. Wherever possible, topics for theses (bachelor, master, PhD) were announced by the partner institutions to reach the students, but also interested students from other universities. Moreover, 33 students were enabled to work on own topics related to the project, which leads to lab based work, but also to collaboration with processors on farm, e.g. in the sector of herb drying. Results directly fed back into the project, especially in terms of challenges the producers have to deal with. Besides graduating students, interns and students working on projects relevant for their studies were involved.
Task 8.4 Development of courses and training material: The e-learning course "Sustainable processing for organic food products" consisting of 8 modules and 15 topics has been prepared with the contribution of all partners and uploaded to the ISEKI-e-learning platform: https://moodle.iseki-food.net/course/view.php?id=59. The e-learning has been translated in the partner countries languages where necessary (Germany, Italy, Romania) and distributed to relevant stakeholders as training courses for organic processors.
Task 8.5 Project website and social media: The website is up to date (http://projects.au.dk/coreorganicplus/research-projects/susorganic/). While initially a Facebook web page was set up (https://www.facebook.com/SusOrganic/) it was not further developed and updated as the stakeholder reach was practically non-existing. This activity was replaced by the increased number of seminars and workshops held. Further, the project partners were sharing the project research results and develop a network of scientists. Thus, the project has launched a SusOrganic page on Research Gate (https://www.researchgate.net/project/SusOrganic-Development-of-quality-standards-and-optimised-processing-methods-for-organic-produce) with higher commitment and involvement of all the partners.
Task 8.6 Seminars/workshops for farmers and processors: Project outputs were disseminated by workshops and seminars held by all the partners including presentations at sector-specific fairs and conferences and university events open to students, farmers and processors members of associations and research institutes. Overall, 22 workshops, contributions to workshops and seminars were held (12 national, 10 international), s. 5.2.4, 5.2.5

B- fulfilment of objectives:
Overall, the objectives, milestones and deliverables have been achieved. Main commitment has been given on the skill development of students, publication of the scientific results, the organisation of the workshops at national and international level and the preparation of the e-learning module.

D8.1 done
D8.2 done
D8.3 done
D8.4 partly achieved
D8.5 done
D8.6 done
D8.7 done
D8.8 Website: http://coreorganicplus.org/research-projects/susorganic/
D8.9 partly achieved, Research Gate instead of Facebook
D8.10 done

M8.1 Stakeholder lists for all countries exist: database created
M8.2 List of events exists: database created
M8.3 Stakeholder articles were only published in Norway (2) and Germany (1), however, the information about the project was spread through several newspapers and websites. Compensating, M8.4 (s. below) was fulfilled twice
M8.4 Overall, 17 journal papers (13 accepted, 4 submitted) and 1 book chapter have been submitted successfully (7 were planned)
M8.5/M8.6 finished, uploaded as ISEKI online course and delivered (translated) to the stakeholders
M8.7 Web site launched and up to date: http://coreorganicplus.org/research-projects/susorganic/
M8.8 A project profile was set up on Research Gate und kept updated: https://www.researchgate.net/project/SusOrganic-Development-of-quality-standards-and-optimised-processing-methods-for-organic-produce
M8.9 Overall, 22 seminars/workshops have been held for the stakeholders, further the project or project outcomes were presented on 15 events (international conferences and fairs).

3.9 WP9

WP9	Project Management and Coordination
WP leader: Barbara Sturm Responsible partners: Uni Kassel	
Overall summary of main results, discussion and conclusions of WP9 The aim of WP9 was the project coordination and management. Communication via email worked very well and conference calls were held bi-monthly. The kick of (UNI Kassel)-, and the first interim meeting (UNITE) have been held successful and a cost neutral extension was supported by all partners afterwards. In addition, the project coordinator participated in the CoreOrganicPlus meeting (October 2016, Romania). The second interim meeting took place from 15-16th February 2017 in Kassel, the final meeting was held from 16-17th November in Bucharest.	
Report on the results obtained (A), and fulfilment of objectives (B) **A- results obtained:** **Task 9.1 Project coordination and management:** The overall project coordination was carried out by Uni Kassel who took care of internal project monitoring, controlling, and risk management. An e-mail communication structure was provided (susorganic-partners@uni-kassel.de). Bi-monthly project conference calls were organised to facilitate the communication on progress and support a sense of community. The role of the coordinator within this project was: (a) Preparation, organisation and chairing of the project meetings; (b) Control of work content in each work package with specifications and	

schedule; (c) Project monitoring using predefined indicators to follow up performance and impact; (d) Reporting. **Task 9.2 Project meetings:** Four general project meetings of all partners including the kick-off and the final meeting were planned and conducted. The final meeting was held three month before the end of the project as a working meeting for evaluation, so that the action-items decided on this meeting can still be executed within the project. The coordinator has attended one meeting (Romania, October 2016) organised by the CoreOrganicPlus Coordinators. **Task 9.3 Communication structure:** Each work package leader worked closely with the project coordinator and the other project partners. The work package leaders were responsible for the coordination of their respective work packages and the related reporting. Stakeholders were involved where possible in order to strengthen the output of the project. **B- fulfilment of objectives:** D9.1 Done D9.2 Done D9.3 Done M9.1 Meetings are held, minutes are written M9.2 Communication structure (email and conference call) was carried out M9.3 Midterm report is written and accepted, final report is written and submitted

4. Milestones and deliverables status

Deliverable No.	Deliverable name	Link to the document	Planned delivery month1)	Actual delivery month1)	Reasons for changes/delay and explanation of consequences
D1.1.	Report on technologies used and the market situation	Internal	15	15	
D1.2	Report on commonly used process settings in drying and cooling/freezing for selected products	Internal	15	15	
D1.3	Report on customer expectations	Internal	15	15	
D2.1.	Adapted drying device	Internal	18	18	
D2.2.	Report on drying behaviour of selected products	Internal	21	21	
D2.3.	Report on the impact of drying on quality characteristics	Internal	24	24	
D3.1	Technical modification of a drying chamber for scientific investigations of drying processes on the basis of apple slices.	Internal Report (Christian Kopp)	12	33	Delay due to extended project period
D3.2	Mass transfer in 3D food	Internal Report	18	18	

	structure	(Simon Danco)			
D3.3	State diagrams in low temperature and atmospheric freeze drying of organic fruit products	Proceedings, Nordic Baltic Drying Conference, Hamburg	24	30	Delay due to conference date
D3.4	Low temperature and thermo-physical properties of brown seaweeds (Saccharina Latissima)	Proceedings, Nordic Baltic Drying Conference, Hamburg	33	30	
D3.5	Performance simulation on a heat pump drying system using R744 as refrigerant.	http://orgprints.org/30672/	33	15	
D4.1	Measurement hardware set up	Protocol/description in the relevant papers	18	18	
D4.2	Programmed controller and programming guideline for users	Protocol	30	30	
D4.3	Drying model and CFD simulation	Protocol	30	30	
D4.4	Report on verification test	Protocol	33	33	
D5.1	Report on quality parameters commonly linked to the food products and matrix of parameters to be measured within the project	Report	12	20	
D5.2	Database with all results of the conducted quality assessments	Database	33	33	
D5.3	Report on quality standards	Report	33	33	
D6.1	(1): Freezing and frozen storage of apples (2) Superchilling of organic food. Part 2: Storage test with superchilled organic salmon and pork chops	http://orgprints.org/31514/ (2)	18	19	
D6.2	Superchilling of organic food, Part 1: State of the Art and potential for small scale implementation	http://orgprints.org/31538/	21	15	
D6.3	State of the Art: Superchilling in the Food Processing Industry	http://orgprints.org/30673/	24	24	

D6.4	Thermal properties of organic foods	http://orgprints.org/31539/	12	24	Delay, because it was not possible to publish the data as paper
D7.1	Report on value chain management	Report	36	36	
D7.2	Report on LCA	Report	36	36	
D7.3	Report on LCCA	Report	36	36	
D7.4	Report on database	Report	36	36	
D8.1.	List of stakeholders	Database	12	24	Update during the project
D8.2.	List of events where the project will be presented	Database	12	12	
D8.3	At least one oral presentation per partner	http://orgprints.org/view/projects/SusOrganic.type.html + s. 5.2.3	36	36	Project extension
D8.4	2 stakeholder articles per partner	Article	36	36	Partner contributed and participated to a different extent to this task. Italian (UNITE, UNITUS) and Romanian (USAVM) partners committed more on the organisation of workshops for the stakeholders. German partners focussed more on seminars for stakeholders
D8.5	1 journal article per partner	http://orgprints.org/view/projects/SusOrganic.type.html	36	36	
D8.6	E-learning material	e-learning	30	36	Dependent on D8.7
D8.7	Training material for stakeholders	Training material/guidelines	36	36	
D8.8	Website	Website	12	12	
D8.9	Regular updates in the social		36	36	Facebook was not updated after its setting. ResearchGate was set and kept updated
D8.10	Workshop/seminar organised in each country	Workshop	36	36	5 workshops, not all countries involved due to different

					capabilities to reach sector specific stakeholders
D9.1	Minutes of the project meetings are written		36	36	
D9.2	Communication structure		03	03	
D9.3	Progress and final reports		36	36	

Milestone No.	Milestone name	Planned delivery month[1)]	Actual delivery month[1)]	Reasons for changes/delay and explanation of consequences
M1.1.	Technologies used and market situation are analysed and reported	15	15	
M1.2	Commonly used process settings are analysed and reported	15	15	
M1.3	Expectations of consumers are identified and reported	18	18	
M2.1.	Drying devices are adapted and fully functioning	21	21	
M2.2.	Drying tests are finalised	24	24	
M2.3.	Quality changes and interdependencies between the process settings are analysed and evaluated	12	20	
M 3.1	Determination of drying behaviour finished	18	30	The milestone was postponed due to extension of project period
M3.2	Dynamic model verified	24	24	-
M3.3	Dissemination workshop NDC realized	33	30	-
M3.4	Energy efficient drying process verified	33	12	-
M4.1	Measurement hardware is working	18	18	
M4.2	Controller is identified, programmed and guidelines are written	30	30	
M4.3	Drying model exists, simulation of drying behaviour and heat and mass flow are finalised	30	30	
M4.4	Upscale tests are finalised	33	33	
M5.1	Quality criteria are identified, test regime set up and report is written			
M5.2	All samples are analysed and integrated in the database			
M5.3	Report on quality standards is finished and disseminated to the stake holders			Partially done: Guidelines exist but are not yet disseminated. The consortium would appreciate the input

				of the funding bodies before dissemination. Further, it was decided that the processing and quality guidelines will be made available through the dedicate SusOrgPlus website (http://www.susorgplus.eu/) which is currently under construction
M6.1	Performance and evaluation of the storage tests	18	19	
M6.2	Evaluation of the super-chilled concept for organic food	21	15	
M6.3	Dissemination workshop NDC realized	24	24	
M6.4	Determination of thermal properties	12	24	
M7.1	Report on value chain management	36	36	
M7.2	Report on LCA completed	36	36	
M7.3	Report on Economic analysis completed	36	36	
M7.4	Report on database completed	36	36	
M8.1.	Stakeholder lists for all countries	24	24	Updated version, extension of the project
M8.2	List of events exists	12	12	
M8.3	Stake holder articles are published	36	36	Not completely reached, however, compensated by other means of stakeholder engagement, i.e. seminars and workshops
M8.4	journal articles are submitted	36	36	
M8.5	E-learning material is available	36	36	
M8.6	Training material exists	30	30	Incorporated in the guidelines and the e-learning material
M8.7	Web site launched and up to date	36	36	
M8.8	Social media profiles are generated and up to date	2, 24	12, 24	Delay in selection and setting, change of social media and virtual networking environments, RG instead of facebook, twitter etc.

M8.9	Seminars in all participating countries are held	36	36	
M9.1	Minutes of kick-off and general project meetings	36	36	
M9.2	Communication structure	03	03	
M9.3	Progress and final reports	36	36	

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.
N/A

5. Publications and dissemination activities

5.1 List extracted from Organic Eprints

4.1.1. Journal publications

Amjad, W., Crichton, S. O. J., Munir, A., Hensel, O., & Sturm, B. (2018). Hyperspectral imaging for the determination of potato slice moisture content and chromaticity during the convective hot air drying process. *Biosystems Engineering*, *166*, 170-183.

Bosona, T., & Gebresenbet, G. (2018). Swedish Consumers' Perception of Food Quality and Sustainability in Relation to Organic Food Production. *Foods*, *7*(4), 54.

Crichton, S.O.J.; Shrestha, L.; Hurlbert, A. & Sturm, B. (2017) Use of hyperspectral imaging for the prediction of moisture content and chromaticity of raw and pretreated apple slices during convection drying. *Drying Technology*, online, pp. 1-13.

Crichton, S.O.J.; Kirchner, S.M.; Porley, V.; Retz, S.; von Gersdorff, G.; Hensel, O.; Weygandt, M. & Sturm, B. (2017) Classification of organic beef storage conditions and maturation stage using VNIR hyperspectral imaging. *Meat Science*, 129, pp. 20-27.

Crichton, S.O.J.; Kirchner, S.M.; Porley, V.E.; Retz, S.K.; von Gersdorff, G.J.E.; Hensel, O. & Sturm, B. (2017) High pH thresholding of beef with VNIR hyperspectral imaging. *Meat Science*, 134, pp. 14-17.

Moscetti, R.; Haff, R.P.; Ferri, S.; Raponi, F.; Monarca, D.; Liang, P. & Massantini, R. (2017) Real-Time Monitoring of Organic Carrot (var. Romance) During Hot-Air Drying Using Near-Infrared Spectroscopy. *Food and Bioprocess Technology*, 10 (11), pp. 2046-2059.

Moscetti, R.; Raponi, F.; Ferri, S.; Colantoni, A.; Monarca, D. & Massantini, R. (2018) Real-time monitoring of organic apple (var. Gala) during hot-air drying using Near-Infrared spectroscopy. *Journal of Food Engineering*, 222, pp. 139-150.

Moscetti, Roberto; Sturm, Barbara; Crichton, Stuart O.J.; Amjad, Waseem & Massantini, Riccardo (2017) Postharvest monitoring of organic potato (cv. Anuschka) during hot-air drying using Vis/NIR hyperspectral imaging. *Journal of the Science of Food and Agriculture (J Sci Food Agric)*, online, pp. 1-11.

Raponi, F.; Moscetti, R.; Monarca, D.; Calantoni, A. & Massantini, R. (2017) Monitoring and optimization of drying fruits and vegetables process using computer vision: a review. *Sustainability*, 9 (11), pp. 1-27.

Retz, S.K.; Porley, V.E.; von Gersdorff, G.J.E; Hensel, O.; Crichton, S.O.J. & Sturm, B. (2017) Effect of maturation and freezing on quality and drying kinetics of beef. *Drying Technology*, 35 (16), pp. 2002-2014.

Stan, A., Bujor, O.C. & Badulescu, L. (2017) Extraction of phenolic compounds from organic dried apples: comparison between conventional, microwave-and ultrasound-assisted extraction methods. *Journal of Horticulture, Forestry and Biotechnology*. 21 (3), pp. 8-14

Tolstorebrov, I., Eikevik, T. M., & Bantle, M. (2016). Effect of low and ultra-low temperature applications during freezing and frozen storage on quality parameters for fish. *International Journal of Refrigeration*, 63, 37-47.

von Gersdorff, G.J.E.; Porley, V.E.; Retz, S.K.; Hensel, O.; Crichton, S.O.J. & Sturm, B. (2017) Drying behavior and quality parameters of dried beef (biltong) subjected to different pre-treatments and maturation stages. *Drying Technology*, 36 (1), pp. 21-32.

4.1.2. Conferences

Bantle, Michael; Kvalsvik, Karoline H. and Tolstorebrov, Ignat (2016) Performance simulation of a Heat Pump Drying System using R744 as refrigerant. 12th IIR Gustav Lorentzen Conference on Natural Refrigerants GL2016, Edinburgh, UK, 21-24 August 2016

Bantle, M.; Nordtvedt, T.S.; Claussen, I.C. and Indergård, E. (2016) State of the Art: Superchilling in the Food Processing Industry. 4th IIR International Conference on Sustainability and the Cold Chain, Massey University Auckland, New Zealand, 7-9 April 2016

Cotrut, R. & Badulescu, L. (2016) UPLC Rapid Quantification of Ascorbic Acid in Several Fruits and Vegetables Extracted Using Different Solvents. *Agriculture and Agricultural Science Procedia*, 10, pp. 160-166.

Crichton, S., Münsterer, J., Kammhuber, K., Sturm, B. (2016). Measurement of hop moisture content and chromaticity during drying with VNIR hyperspectral imaging, CIGR – AgEng 2016, Aarhus, Denmark, 26.06.-29.06.2016

Crichton, S., Sturm, B., Hurlbert, A. (2015). Moisture content measurement in dried apple produce through visible wavelength hyperspectral imaging, 2015 ASABE Annual International Meeting

Nicolae, C. G., Bahaciu, G. V., Ţeca, M., Bădulescu, L., Pogurschi, E., & Marin, M. (2017) The effect of frozen storage on lipids and fatty acids content in Atlantic salmon. Case study. International Scientific Symposium "Modern animal husbandry – Food safety and durable development. 19th-20th October, 2017, Bucharest, RO.

Nicolae, C. G., Bahaciu, G. V., Elia, E., Dumitrache, F., Marin, M. P., Pogurschi, E., & Bădulescu, L. (2016). A review of the quality standards for frozen beef meat and fish. The International Conference Agriculture for Life, Life for Agriculture of the University of Agronomic Sciences and Veterinary Medicine of Bucharest, July 2016.

Stan A., Dobrin A., Zugravu M., Bezdadea-Catuneanu I., Iancu A., Lagunovschi-Luchian, V., Badulescu L. (2017) Perception and preference of the Romanian consumers regarding organic vs. conventional products quality – survey study. International Symposium Young People and Agriculture Research, Timisoara, Romania, 23th November 2017

Sturm, B., Münsterer, J., Kammhuber, K., Crichton, S. (2016). Impact of bulk weight on drying behaviour and hop quality after drying, CIGR – AgEng 2016, Aarhus, Denmark, 26.06.-29.06.2016

Tolstorebrov, I, Eikevik, T.M., Bantle, M. (2017) Low Temperature Drying and Thermo-Physical Properties of Brown Seaweeds (Saccharina Latissima). 2nd Nordic Baltic Drying Conference 2017, 7.-9. June 2017, Hamburg

Von Gersdorff, G., Crichton, S., Retz, S., Hensel, O., Sturm, B. (2016). Drying of fresh organic beef with different pre-treatments, International Drying Symposium (IDS 2016), Gifu, Japan, 7-10 August 2016

4.1.3 Technical (stakeholder) reports (also public available here: https://www.sintef.no/en/publications):

Bantle, Michael; Claussen, Infrid Camilla and Tolstorebrov, Ignat (2016) Superchilling of organic food. Part 1: Concept, State-of-the-art and Potential for small scale implementation. SINTEF Energy Research, Norway.

Bantle, Michael and Tolstorebrov, Igant (2017) Thermal Properties of Organic Foods. SINTEF Energy Research and Norwegian University of Sciences and Technology.

Claussen, Ingrid Camilla; Gullsvåg, Per Egil; Bantle, Michael; Tolstorebrov, Ignat and Kvalsvik, Karoline H. (2017) Superchilling of organic food. Part 2: Storage test with superchilled organic salmon and pork chops. SINTEF Energy Research, Norway.

5.2 Additional dissemination activities

5.2.1 Journal publications (Peer reviewed):

Neri L., Santarelli V., Di Mattia C., Sacchetti G., Mastrocola D., Pittia P. (2018). Effect of freezing and frozen storage on quality of organic and conventional apples. *LWT- Food Science and Technology.*

Shrestha L., Kulig B., Moscetti R., Massantini R., Pawelzik E, Hensel O., Sturm B. (2018). Control of browning development and enzymatic activity on apple slices using physical and chemical treatments. *LWT- Food Science and Technology.*

Santarelli V., Neri L., Pittia P. (2018). Effect of frozen storage on bioactive compounds of organic and conventional apples. *Food and Bioprocess Technology*

Tolstorebrov, I, Bantle, M., Eikevik, T.M. Sturm, B., Shokina, Y. (2018). Towards understanding the atmospheric freeze-drying process of organic apples by analysis of thermophysical properties and drying kinetics, *Drying Technology (accepted manuscript)*

5.2.2 Book Chapters

Gersdorff, G., Bantle, M., Hensel, O., Sturm, B. (2017). Chapter 7: Drying and chilling/freezing of perishable foods in the organic sector, in Sustainable Food Systems from Agriculture to Industry: Improving Production and Processing, Elsevier. Authors Team Acknowledgement: http://scitechconnect.elsevier.com/sustainable-food-systems-from-agriculture-to-industry/

5.2.3 Conferences

Sturm B., Pittia P. (2016). Development of quality standards and optimised processing methods for organic produce: the SUSORGANIC project, 4th ISEKI-Food Conference, Vienna (AT), 6-8 July 2016.

Badulescu, L. (2017). Presentation of the SusOrganic project, Hortus Florshow Romania and Horticulture Days Bucharest - XIV edition, UASVM from Bucharest, 4-7 May 2017

All partners (10 project related presentations): Novelty Day at the Nordic Baltic Drying Conference 2017, Hamburg, 7th June 2017 (https://www.tuhh.de/spe/ndbc-2017/outlinedates/novelty-day.html).

Massantini, R. & Moscetti, R. (2017) “Drying behavior of organic apple and carrot by using k-means learning” & “Real-time monitoring of apple during hot-air drying using NIR spectroscopy” at AIIA2017 - Italian Society of Agricultural Engineering 2017, 5-8 July 2017, Bari, Italy.

Massantini, R. & Moscetti, R. (2017). Poster presentation about SusOrganic activities from UNITUS at Maker Faire 2017, 1-3 December 2017, Rome, Italy

5.2.4 Seminars

Sturm, B: Seminar Hopfentrocknung (Hop drying), Biolandwoche Plankstetten, 1st-4th February 2016

Sturm, B: Seminar Streuobsttrocknung (Orchard fruit drying), Biolandwoche Plankstetten , 1st-4th February 2016

Sturm, B: Seminar Kräutertrocknung (Herb drying), Österreichischer Bergkräutergenossenschaft (Austrian Mountain Herb Association), Hirschbach (AT), 15th March 2016

Sturm, B: Seminar Hopfentrocknung (Hop drying), Hopfenerzeugerverband Elsass (Hop producer association Alsace), 12.07.2016

Sturm, B: Fraunhofer-Institut für System- und Innovationsforschung ISI, Prozesstechnik-Forum Energieeffiziente Trocknung (Process Technology Forum Energy Efficient Drying), “Steigerung der Energieeffizienz beim Trocknen durch Mess-, Steuerungs- und Regelungstechnik“ (Increase of process efficiency in drying through measurement and control technology) , 09.11.2016

Sturm, B., Gebresenbet, G. Bosona, T., Massantini, R., Moscetti, R. (2017). "Seminar: New techniques and technologies used in organic horticulture”, November 15, 2017 in Bucharest, Romania

Sturm, B: Themenabend Heilpflanzen und Lebensmitteltrocknen - effizient und mit neuester Technik (Herb and Food drying – efficient and with newest technology), BOKU Wien, Austria, 01.02.2018

Bosona, T. and Gebresenbet, G.: Improving sustainability of organic food: environmental and economic aspects. SLU Uppsala (SE), 12th January 2018

Sturm, B: 2 seminars at “Gesellschaft für nachhaltige Entwicklung (GNE)” (training institute)

- 11.12.2016 CPA/KUR/Praktikum- Program
- 22.09. and 23.09.2016 CPA/KUR/Praktikum- Program

Sturm B.: 1 seminar at DAAD Winter Alumni School 2018 at University of Kassel regarding sustainable food processing

5.2.5 Workshops

5.2.5.1 Project related/supported workshops:

1. "*Strategies to improve quality of organic products: an European perspective*", organised by the University of Teramo (IT), Teramo (IT), 3rd March 2016.
2. *"Strategies to improve quality of organic food products: an European perspective"*, co-organised by University of Teramo, University La Tuscia and University of Bologna (IT), in collaboration with the Ecoberries project, Cesena (IT), 31 January 2017
3. "*Strategie innovative per il miglioramento della qualita' e sicurezza dei prodotti biologici*" (Innovative strategies for the improvement of the quality and safety of organic products), Organised by University of Teramo and University of La Tuscia (IT), Teramo (IT) 10th November 2017.
4. *"Novelty day on sustainable organic foods – Drying and processing"*, organised by SINTEF (NO) and University of Kassel (DE), Hamburg (Germany), 7th June 2017
5. *Organic agriculture in Romania*", organized by the University of Agronomic Sciences and Veterinary Medicine, Bucharest (RO), 16th November 2017.

5.2.5.2 Workshop contributions:

Research for sustainable organic farming – System perspectives, stakeholder, cooperation and communication; December 9, 2015 in Stockholm, Sweden. Gebresenbet, G., & Bosona, T.

21st Workshop on the Developments in the Italian PhD Research on Food Science, Technology and Biotechnology, Napoli-IT, 16-18 Sept 2016 Raponi, F., Moscetti, R., Massantini, R.

Workshop: Strategies to improve quality of organic products in a European perspective, Cesena (31st January 2017) Pittia P.

Workshop: Alimentația sănătoasă și diete special (Healthy and special diets), April 8, 2017 Liliana Badulescu

Management of innovation in the agricultural & food system of the Mediterranean region, 1 June 2017, Foggia, Italy "Quality and drying behavior of organic fruit products", Massantini R., Moscetti R.

XXII Workshop on the Developments in the Italian PhD Research on Food Science, Technology and Biotechnology, Bolzano-IT, 20-22 Sept 2017 Raponi, F., Moscetti, R., Massantini, R.

UASVM conference at INDAGRA (agricultural fair), 26-27.10.2017, Badulescu, L., Stan, A., Lagunovschi-Luchian, V., Asănică, A

5.3 Further possible actions for dissemination

- List publication/deliverables/activities arising from your project that you are still planning in the future

  15 journal papers are in preparation and will be submitted within 2018 (internal list)

  5 papers for oral and poster presentations have been successfully submitted to IDS 2018 (International Drying Symposium) in Valencia/Spain, 11-14th September 2018

  Members of the consortium will attend the 6th ICOAS (International Conference on Organic Agriculture Science), in Eisenstadt/Austria, 7-9th November 2018

- List publications/deliverables arising from your project that Funding Bodies could consider disseminating

  Project start information at forschung-oekolandbau.info: http://www.forschung-oekolandbau.info/en/nachrichten-archiv/nachricht/article/susorganic-im-rahmen-von-core-organic-plus-gestartet.html, September 2015

  Project description (German) at FISA online (http://www.fisaonline.de/index.php?lang=dt&act=projects&view=details&p_id=8284)

  Project description at sinab.it: http://www.sinab.it/ricerca/susorganic-development-quality-standards-and-optimized-processing-methods-organic-produce

  Press release University of Kassel: "Schonende und energieeffiziente Verarbeitung von Biolebensmitteln" (Gentle and energy efficient processing of organic food), September 2015

Press release ISEKI-food: „SusOrganic: A project to increase sustainability and product quality in production of organic food" (https://www.iseki-food.net/webfm_send/2290)

Article in HNA (regional newspaper, Germany: „Das Trocknen frisst viel Energie" (Drying consumes lots of energy), October 2015

Article in Agrarzeitung.de (online magazine, Germany): "Qualitätsverluste vermeiden" (Avoidance of quality losses), September 2015.

Article in gaertner-und-florist.at (online magazine, Austria): "Uni-Projekt "SusOrganic" zur Verarbeitung von Bio-Lebensmitteln" (University project „SusOrganic" concerning the processing of organic food), September 2015

Article in ScienceDaily.com: "Organic food to have longer 'life' with superchilling technique", June 2015

Article in Clean Energy Project (Online magazine, German): "CoreOrganic Initiative" (http://www.cleanenergy-project.de/cleantech/wissenschaft/6887-core-organic-initiative), September 2015.

Report in Ökologie und Landbau (stakeholder magazine for organic production, German): „Schonend und effizient Verarbeiten" (Gentle and efficient processing), Sturm, B. & von Gersdorff, G., January 2016.

Press release University of Kassel: Erfolgreiche Zwischenergebnisse des SusOrganic Projektes" (Promising first results of the SusOrganic project), March 2016

Reportage at Lumea Satalui TV: https://www.tv.lumeasatului.ro/reportaje/1413-susorganic-un-proiect-pentru-dezvoltarea-agriculturii-ecologice.html

Press release in Agricultura 365 (Romania): „Procesarea produselor ecologice" (Processing of organic products), January 2018.

– Indicate publications/deliverables that could usefully be translated (if this has not been done, and indicate target language)

5.4 Specific questions regarding dissemination and publications

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

– List the categories of end-users/main users of the research results and how they have been addressed/will be addressed by dissemination activities

On and off farm processors/associations: seminars, workshops and training in the respective languages, e-learning course (ISEKI Food Association e-learning platform), processing and quality guidelines and production and energy audits

Scientific community: presentation at conferences, organisation of the SusOrganic event in the framework of the NBDC 2017 in Hamburg (Germany), scientific publications

Students: involvement in project research activities and thesis writing

Suppliers of equipment: Newsletters, website, personal contact; direct contact the results of the project are relevant for suppliers of processing and measurement and control equipment in terms of offering improved technologies

General public: better understanding of organic and sustainability aspects. Newsletters, articles in consumer journals, Facebook, twitter

6. Project impact

Due to the set-up of the consortium who are mainly not historically linked to the organic sector, there were a few problems with the initiation of the project in terms of stakeholder engagement. This however, was overcome very quickly in the first phase of the project. The specific dissemination activities were as follows

- Seminars: 9 held in 6 countries, relevant participants were on farm processors of fruits, herbs and hops.
- Workshop: 5. One, out of them, in Italy co-organised together with the EcoBerries project. Overall successful attendance by organic food producers, scientists, students, representatives of organic certification organisations, processors of organic food stuffs
- Conference papers: A total of 20 presentations at 11 conferences were given to scientists and representatives from relevant industries
- Consumer articles: see 5.3
- Conduction of energy and production audits: A total of 12 audits were performed with herb and hop producers
- Design of new driers and optimisation of existing devices: 2 new driers were designed for herb producers in Germany, one device optimised
- Close collaboration with the Bavarian State Office for Agriculture: Conduction of drying test on a pilot plant level, definition of improved process settings, co-authorship of the new guidelines for hop drying (in progress) for the organic and conventional sectors

The consortium looks back to collaboration with organic association who already showed interest in upcoming activities. Further, technology companies and processors, who were part of the past project will support future challenges that might occur. During the SusOrganic project, the consortium got aware of the main challenges in the processing sector through processors, technology suppliers and associations, which was a great support and enabled the consortium to work more on a practical than on a theoretical level.

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

The organic food market in Europe is very fragmented whilst at the same time being much interwoven in terms of trade between the different countries. A product might be processed in one country but needs to meet the consumer expectations in another. At the same time, many problems occurring within the sector are very similar irrespective of product or location, particularly when the market is broken down by technologies in use rather than origin or commodity. Further, what might be a problem in one country, potentially has already been solved in another. Thus, it is of utmost importance to investigate the procedures in the different countries to get a better understanding.
Further, on a national level it is very difficult to form a consortium with such a variety of backgrounds and find a funding stream that is suitable for the conduction of work with the scope of SusOrganic.
Most results of SusOrganic are relevant for the whole of the EU. National projects do not offer the same degree of dissemination, technology and knowledge transfer and training possibilities as an international one. In the SusOrganic project, the seminars and trainings built on one commonly defined base which is relevant for all countries and thereafter were adjusted accordingly to the particular needs of the respective country. The e-learning material ("Sustainable processing for organic food products") on the other hand were developed by the contribution of all the partners and delivered in English and then translated into every language of the participating countries once the approval of the funding bodies is received. To achieve the same impact, national projects would have to duplicate if not triplicate work and thus, would be very resource and finance inefficient.

8. Suggestions for future research

Future research ideas were integrated into the SusOrgPlus proposal. The project, funded by the Core Organic Cofund started on the 01.05.2018.
Future research efforts should be put into assessing ways on how to engage stakeholders who can not be reached by the usual dissemination activities. From the experience of the SusOrganic project it is usually those participants of the market who would need the support the most are not participating. Conversely, the average participant in the dissemination activities is already aware of many aspects relating to improving their production.