Technical Actions

The following has been done and achieved:

A1. Selection of fruits and vegetables for trials: Action A1 had two objectives: the first was to select fresh fruits and vegetables to be studied. To this end, partners Kölla and Lafuente elaborated in September 2014 a preliminary report, which constituted the base for the selection of the following 6 products: Broccoli, Spinach, Strawberry, Stone fruit, Mandarin and Grape. The second objective was to decide the most effective atmosphere of conservation for each of them. To this end, laboratory tests on all the selected fresh products were carries out. PCTAD has characterized the products based on the following characteristics: Respiration rate and ethylene production; sensitivity to the development of different kind of damages; tolerance toward different concentration of O2 and CO2; definition of the most adequate permeability conditions; sensitivity to the development of moulds and presence of external ethylene. The Action was concluded in September 2015.

A2. Development of protocol to organize testing of the Freshbox container: The objective of Action A2 was to develop different protocols describing the methodology and processes to be applied in laboratory for the chemical-physical and microbiological analysis of the different products, as well as to real transports. To this end, the following procedures/standards were developed: Protocol to evaluate the quality of fresh produce; protocol for an adequate samples management and accurate checking at laboratory and during transportation; and a Quick visual quality evaluation charts (realized for all products: broccoli, grape, spinach, mandarin, strawberry and stone fruit). The Action was concluded in September 2015.

A3. Functional requirements analysis of the Freshbox container: The main objective of this action was the preparation of the procedures to develop and produce the Fresh Box. Tasks that were developed in A3 were specially focused on including all the relevant requirements in the production steps of the lid and container in order to give to the Fresh Box the expected functionalities. Those included: definition of the basic issues for the Fresh Box design; definition of the materials to be used for the Fresh Box; detailed definition of the steps to be followed for the production of the Fresh Box. The Action was concluded in April 2015.

A4. Functional requirements analysis of the Integrated Sensors Kit: The key objective of this action was to define the requirements and specifications needed to develop and produce the Integrated Sensors Kit, to be used to monitor some of the key physical parameters inside the Fresh Box's container. In the interest of efficient development, the Integrated Sensor Kit was sectioned into three independently developed sections (Sensors; Communication Protocol; Product Casing) yet their functional interdependencies was also considered at all times. For each section ITT-IMaR, based on consortium inputs, drafted detailed reports making recommendations on components to

be used, and also dimensions of the final prototype to be used during the trial period. In some cases a number of components, as opposed to a single one, have been recommended and in other cases a final decision has been referred to the testing and integration phase. The Action was concluded in July 2015.

B1. Produce the Freshbox: The main objective of this action was to implement the Fresh Box concept based on the "Protocol for developing and producing the Fresh Box" prepared in action A3.

AITIIP completed the first step of the protocol, focused on the design of the technological solutions to be integrated in the Fresh Box (including Macro perforations; Ethylene absorbers; Antimicrobial releasers; Sensor Kit), within February 2015 . Regarding the production of the container, the first step was the introduction of the designs in the CAD (Computer Aided Design) software, for 3D data. At this stage it was important to analyze the geometry of the elements and the specific needs of the processes of transformation of plastics (injection and thermoforming). The second step was the development of process simulation with CAD software, which provided the instructions to be introduced into the CAM (Manufacturing Aided Design) software guiding the machinery. Once all the different components were generated, the molds components were produced and assembled. The mould was then tested in Austria to modify parts of the mould for the lid and container. After the testing of the prototypes was completed and the definition of the final injection conditions set, the manufacturing process took place at AITIIP facilities. A trial phase was needed in order to test the assembly of the lid and container in order to achieve a perfect fit, since material shrinkage is different for each piece. By the end of March 2016, the Fresh Box was ready as scheduled to be used for the transportation tests (Action B4).

B2. Produce the Integrated Sensors Kit: A number of iterations of development/beta sensor boards have been developed by ITT-IMaR. The original prototype, named 'Waspmote' was configured to monitor and record temperature and relative humidity. The next iteration in the development of the prototype device was an IMaR designed sensor controller (referred to as *Oxy2*) using CO2, O2, humidity and temperature sensors, communicating via Bluetooth classic. This was developed to meet the testing timescale for live testing in a Freshbox with sample fruit and vegetables. Both units were delivered for testing to Aiitip in October 2015. Iteration then prosecuted with: the *Oxy3,* including a new location for the accelerometer and humidity sensor; the *Oxy4*, with a low-energy Bluetooth; and the Oxy5, which was the final prototype that was reproduced as the Integrated Sensors Kit. All sensors were low-energy. A companion Fresh Box app was also developed to facilitate data analysis and visualization post transport trials. The 18 foreseen Integrated Sensors Kits were delivered to AIITP in July 2016.

B3. Perform Freshbox laboratory test with selected fresh produce: The lab validation tests of the Fresh Box began in June 2015 (with stone fruits) and ended in March 2016, with strawberries. The main objective was to check if the atmospheres selected for each

case and the active compounds chosen were effective to prolong the shelf life of the 6 products studied in the project. During this action, simulations of the distribution and commercialization have been performed in PCTAD facilities with the prototype of Fresh Box and sensors developed by Aitiip and IMar, respectively. During transport simulation studies, the quality of 6 fresh products and %O2 + %CO2 monitoring have been done. Also, the extra shelf life days with Fresh Box transport has been calculated. It resulted that using the Fresh Box for broccoli and mandarin might not be efficient for short transports, as they already have good shelf life in normal transportation, while moderate to high commercial advantages applies to all the other fresh products studied.

B4. Perform Freshbox transportation test with selected fresh produce: The main objective of action B4 was to validate the final Fresh Box prototype through real transportation tests from Spain to Germany and vice versa. These tests were performed between April and November 2016, with the participation of some external transport companies involved by Kölla and Lafuente. As a consequence of the conclusions drawn under the previous action, it was decided to exclude broccoli and mandarin from the testing, substituting them with raspberries and mushrooms, with higher added value. During each of the 18 transports performed, the quality of the products was evaluated at origin and destination using the protocols developed during action A2. A control pallet allowed to assess the benefits of the Fresh Box against the conventional transports. To validate the different prototypes, different Fresh Box containers with lids with various permeabilities were used. Also, the tests allowed to validate the sensors developed by IMaR. Registers of the data monitored through the sensors and of the quality parameters were sent by PCTAD and Kölla to Aitiip, with the aim to keep on improving the design of the container and get to the final one. Environmental impact indicators (Co2 emission savings due to the lighter container, reduced fuel consumption and minor food waste) were also calculated for each product.

C1. Technical monitoring: The technical monitoring of the project tasks was done by regular contacts of the consultant and PCTAD staff with all partners (meetings, e-mail, telephone, videoconference, etc.), and examination of outputs. The first part, summarized in the first monitoring report, started yet from initial 2015 and concerned the preparatory and the trial phase, until the Integrated Sensors Kit trials. The second part, corresponding to the second monitoring report, kicks off from the transport trials and covers also the technical monitoring of the tasks related to the environmental and socio-economic impact assessments.

C2. Final technical evaluation: The data obtained during all different tests has been compiled in a final technical evaluation report by AITIIP, in cooperation with PCTAD, IMaR and Transfer. The report includes all the development steps and results of each test and focuses in particular on the general results achieved after 3 years and on the eventual further improvements. In brief, it was concluded that the Fresh Box container serves as a valuable instrument to conserve fresh produce quality, by prolonging shelf life and therefore reducing food loss along the supply chain. However, it is not equally beneficial

for all types of products, being most advantageous for fruits and vegetables with higher added value and/or higher vulnerability to post-harvest or storage. In these cases, it can prolong commercial shelf life from 4-8 days. Other promising markets application to be explored are the transport of flowers of high added value (as hydrangea, saffron, orchid, tulips) and of aromatic plants. Further adaptation of the Fresh Box to real transport conditions are needed to maximize its potential and support its commercial take up. Among those, it is important to optimize the use of the space (e.g. with foldable containers that can be stacked when empty) as well as the flexibility and interchangeability of the container's lid.

C3. Conclusions & guidelines: The objective of this action was to compile the main conclusions and recommendations obtained during the Life Fresh Box project, both by interviewing the project partners themselves as well as sending a survey to 40 companies involved in the value chain of the fruits and vegetables distribution sector (wholesale, retail, storage, processing and/or preservation and food services for final consumers).

C4. Socio-economic impact of the project: The assessment of the socio-economic impacts of the project, performed with the support of an external expert, started in July 2016 and was completed in April of the following year. As mentioned, the stakeholders surveys and the environmental benefit estimations were analysed in order to investigate, among others: the economic benefits for the distribution and other advantages of Fresh Box use; benefits/costs for final consumer; impact due to CO2 emission saving; indirect impact on the plastic industry; marketing strategy for Fresh Box technology. Results were then presented in a socio-economic report.

D1. Project website: The project website was launched in October 2014, in two languages: English and Spanish. The Facebook subpage was online since the same month, and is managed in Spanish. A YouTube channel was also created. During the project, a total of 77 of our own articles were published on the project website in Spanish with their respective translations available in English. 12 of the articles regarded Cooperation with other European Project activities. 8 Videos have been published, with altogether 406 views. Website traffic was significant reaching, by the end of June 2017, 13,779 unique visitors, exceeding the 2,500 foreseen.

D2-3. LIFE+ Information boards & Layman's Report: Notice boards have been placed at each partner's offices mid-December 2014 and they contain the website URL, LIFE logo, QR code, project logo and brief summaries. Also a large roll-up was created so as to gain people's attention at conferences, presentations or seminars. With the input from the project partners and using the results from the various deliverables, Transfer drafted and designed the Layman's Report. Itt includes a general description of the project's background and objectives and a thorough overview of all the actions carried out and the results obtained, as well as conclusions and comments for future uptake. The English/Spanish report is available at the project website as interactive version. 500 Copies were printed and distributed starting from the project Final Conference.

D4. General Dissemination: External communications addressed to a national or international public included:

- 50 articles published by the press and radio, 46 in Spanish and 4 in English.
- 6 presentations in international congresses/conferences
- 10 presentations to interest groups in Spain and Ireland, totalling an estimated public of over 500 people; over 10,000 people seeing the Fresh Box exhibit at Fruit Attraction 2016.
- 25 polo shirts with project and LIFE logos were worn at many dissemination events
- 200 copies of the project brochure were printed in English and distributed
- 1 Final European Conference with a guided tour to Aitiip's facilities, over 100 attendees.
- 1 Master's thesis by UNIZAR student on the project was approved and published
- Conclusions report and Technical Evaluation report sent to key experts and authorities.

D5. Local awareness: Local awareness raising involved amongst others university and secondary school students, part of the future professionals in the sustainable food production and transport sector. 4 Open days were realised (1 at PCTAD and 3 in Aitiip) with a total of 65 visitors; 2 Educational visits (by PCTAD) with a total of 37 students; meetings with transport companies and fruit producers. 500 Copies of the project leaflets were printed and distributed by partners at dissemination events.

E10. Networking: 12 networking meetings/events took place throughout the project, involving more than 15 other LIFE and European projects. Concrete collaborations occurred with LIFE12 ENV/ES/902 Zero Residues and H2020 SME Instrument Fruit Watcher.

Direct benefits and long-term expected impacts

The project demonstrated that in the majority of the products, the shelf life increased by more than 30%. It appeared to be most beneficial for fruits and vegetables with higher added value and/or higher vulnerability to post-harvest or storage during transport and distribution (especially for long distances). The reduction of food waste highly exceeded the expected percentage of 20%, depending on the kind of product achieving twice or even seven times less food waste compared to conventional containers.

The Fresh Box that were developed resulted to have a weight 17% lower than ordinary containers, while 20% less energy was consumed due to the innovative injection process. During the production process 2.31 Kg CO_2 emissions per container were saved, which was lower than the expected 3,9 kg due to the need to make the FreshBox with 60% PLA (bio-based and biodegradable material) and 40% PE, for reasons of usability. CO_2 emission reduction due to lighter transport was shown to be 3,168 kg per tonne fruit transported.

Food waste prevention is an integral part of the EC's new Circular Economy Package and as well included in the Sustainable Development Goals (SDG). It saves money and lowers the environmental impact of food production and consumption. Thus, the developed innovative post-harvest and packaging technologies to increase product shelf life are clearly responding to EU policy objectives.

Long term benefits of the Fresh Box lay in its use of recycled materials; energy savings in its production; savings on fuel consumption for transportation and significant reduction of food losses, avoiding CO2 generation, depletion of natural resources and high consumption of energy.
Also consumers have advantages from fresh produce being transported in the Fresh Box: their physical, chemical and organoleptical features are of a better quality, because the transport is realized under the most adequate conditions, which delays the senescence process and keeps the initial quality of the fresh produce longer. The use of biodegradable recycled plastic reduces plastic waste, improving the recycling market of plastic in Europe.

After-LIFE activities will foster improvements to the tested prototypes regarding the versatility and reduction of production cost. Moreover, assessments will be made for the most beneficial foods to be transported, ranging from high value fruits and vegetables to fungi, aromatic plants and flowers. Goal is to have the Fresh Box in 2019 on the market.