Executive summary:

In the framework of the CLEANFRUIT project the members of the Consortium aimed to provide a non-chemical, conveyorized disinfestation method for fresh fruits and vegetables. The main objective of was to develop a system that can provide an alternative solution for the chemical methods used in storage and quarantine applications.

The scientific and technological development carried out can be divided into the following work packages:

-To develop and to test the radiofrequency (RF) method for the disinfestations of the host commodiites in laboratory environment (WP2).

-The RF sub-system providing the determined RF parameters was designed and manufactured in WP3.

-The mechanical frame of the RF system, the conveyor belt, the washing and drying chambers were designed and manufactured in WP4.

-The process control and safety hardware and software elements were developed in the frame of WP5.

-The integration of the developed modules into a working prototype and the laboratory trials were executed in WP6 and the installation for field tests and the validation/demonstration of the final prototype were carried out in WP7.

The dissemination and the exploitation of the results and the consortium management were executed in the frame of work packages 8 and 9.

The main target of treating fruits against insects was successfully achieved. The Consortium presented the laboratory and field test results in the interim and final reports as well as in the corresponding deliverables.

The main achievements can be summarized as follows:

Three out of the four life-stages of the treated insects (eggs, pupae and adults) could be successfully treated with the CLEANFRUIT prototype, although due to biological reasons the larvae insects could not be treated at a significant level. The treatment efficiency is varied in the function of the life-stages: The killing rate in case of insects in the egg stage is up to 90%

by means of a 1 to 5 minute RF treatment. This value for pupae and adults are 75 and 100%, respectively.

The quality of the treated commodities was tested by means of subjective as well as objective methods and no significant deleterious effects were noticed.

Considering 30 second treatment time (0.4m/min conveyor speed) for apples (one layer of fruits), the throughput of the Cleanfruit prototype is around 3kg/min, or 180kg/hour. The energy cost of the treatment of 1 kg apples is 0.004-0.0057 Euros that is highly competitive with other alternative methods, such as biological disinfestations. Higher throughput can be achieved by simply scaling up the pre-industrial prototype.

As an auxiliary research, tests on mould samples and on fruits infected by mould were carried out. In case of the samples treated more than 2 minutes, the appearance of the developed mould delayed 3 to 4 days. These results were found very promising by the SME partners as this effect can decrease the expensive quarantine time and can also increase shelf life of the products. The consortium intends to carry out further research and development in order to develop a marketable product for disinfestations and decay control.

Project Context and Objectives:

The CLEANFRUIT Consortium recognized that there was clear need for the development of a system for the effective disinfestation of fruits and vegetables at the post-harvest phase so as to provide an effective alternative for chemical pesticides, to increase the storage to market time, and to allow consortium SME members to more easily comply with EU legislation while satisfying increasing consumer demands. CLEANFRUIT aimed to fulfil this need by developing a reliable, non-invasive, rapid on-line disinfestation system using radiofrequency technology that is economical and effective for treatment of a large range of fruit and vegetable produce. The technology developed increases the competitiveness of SME partners by providing them with a low cost, rapid and effective technology to disinfest fruits, reducing the costs associated to pesticide use, as well as the legal and financial liabilities for damage to worker health and non-compliance with environmental legislation. The use of a fumigant free disinfesting system for stored fresh fruits and vegetables also allows SMEs to increase profits by marketing this innovative technology to the growing EU and international organics food sector, as CLEANFRUIT is a non-invasive, chemical-free method that does not damage or compromise fruit and vegetable quality or nutritional value.

The project objectives can be summarized as follows:

SCIENTIFIC OBJECTIVES

-Identify the most important pests that may be harmful to the selected fruits and vegetables at the post-harvest phase, as a base to develop the most appropriate disinfestation system.

-Investigate the electromagnetic characteristics of the selected commodities and their most important and most resistant pests, as well as the required intensity of treatment in order to devitalize insects at all life cycles (eggs, larvae, pupae).

-Gain in-depth understanding of possible effects of high peak power radiofrequency (RF) exposure on fruit quality and nutrition content.

-Investigate the significant effects of RF on the most important pests, focusing on immediate and delayed lethal as well as sub-lethal effects.

-Create a knowledge base for the interpretation of radiofrequency disinfestation efficacy in the function of the operational frequency, peak electric field strength, pulse length, duty cycle and treatment duration.

TECHNOLOGICAL OBJECTIVES

-Develop a flexible RF generator that makes the CLEANFRUIT system able to meet the requirements specified during the system specifications taking place at the beginning of the project.

-Design and build the radiofrequency cavity that provides efficient use of the electromagnetic energy supplied by the generator; the cavity is the part of the system where the treatment is executed thus the geometries and the utilized materials have to be adjusted to the mechanical requirements, as well as the RF specifications.

-Develop a mechanical frame and the conveyor-belt that makes the CLEANFRUIT system robust and reliable and that fits post-harvest conveyor-belt systems. Combined with the RF part, this will form the basis of an on-line post-harvest disinfestation system.

-Develop an easy-to-use process control system, electrical and mechanical monitoring and safety modules and a user-friendly interface.

-Integrate all developed components into a pre-industrial prototype that can be used for testing and validation in field tests.

-Evaluate the CLEANFRUIT disinfestation system in field tests and collect data characterizing its operation. The field test will also be utilized for demonstration purposes.

STRATEGIC OBJECTIVES

-Provide an efficient non-chemical disinfestation method as an alternative to Methyl Bromide and other chemical-based post-harvest treatments as well as commonly used quarantine methods such as cold storage and controlled atmosphere methods. Utilization of the CLEANFRUIT system will result in significant cost, energy and time savings for fresh fruit and vegetable producers

-Gain detailed understanding of the needs of the European fresh fruit and vegetable producing market associated with post-harvest disinfestations, the related legislation and trends, as input for the general system specifications

-Set up a suitable investigation methodology as tool for the SMEs for further development and adoption of the knowledge base in the post project phase

-Ensure that the SME participants will be able to assimilate the results of the project by organizing periodic technology transfer events

-Perform training and dissemination activities by maintaining a project web site, creating a project brochure and a project CD, as well as using the field test as technology demonstrator

-Support the participating SMEs in managing the foreground knowledge, as well as protecting and using the research results to their best advantage

Project Results:

WP1 - Market Research and System Specifications

Task 1.1 - Market Research

A questionnaire was prepared and sent to companies all across Europe dealing with fruit and vegetable disinfestation issues. The questionnaires were sent to over 1000 small and medium sized companies an all across Europe in an interactive portable file format and the filled surveys were automatically sent back to the project's email address (cleanfruit@mfkk.hu). To enhance the efficacy of the survey the form was translated into six languages (English, Hungarian, Latvian, Italian, Spanish and Slovak) and additional telephone surveys were carried out. Based on the results of the market survey the technological system specifications of the CLEANFRUIT system were finalized (Deliverable 5).

Methodology

The questionnaire was prepared with the cooperation of all the consortium members leaded by the SME partner, CHD. The forms in six languages were sent in interactive portable file format to the companies in the European fresh fruit and vegetable sector and the filled form were automatically sent back to the official email address of the project. This method provided high respond-efficacy compared to common email-based surveys.

Preparation of the Questionnaire

A questionnaire and a cover letter were prepared in English. A copy of the questionnaire and the cover letter in English can be found in Appendix I. The form consists of nineteen questions that mainly cover the following topics: The activities and basic facilities of the addressed company, the fruits and vegetables that the company produces, Disinfestation methods currently used by the company, Types of pests that the company's commodities are affected by

Costs of currently used disinfestation methods

Regulations followed by the company regarding disinfestations

Speed of treatments used at the company

Advantages / disadvantages of the currently used methods

A reasonable price limit that the company would pay for a new effective method

The cover letter introduced the questionnaire to the respondent, giving a brief overview of the project and its objective. The questionnaire and the cover letter were distributed among the CLEANFRUIT consortium partners for review and their comments were introduced in the final version. The final version of the document was additionally translated to five different European languages (Lithuanian, Italian, Spanish, Slovak and Hungarian) with the help of the partners.

The questionnaire was also made available online at the following web address: http://cleanfruit.mfkk.hu/.

Dissemination

The targeted group includes companies related with producing, processing, storing and distributing fresh fruits or vegetables:

Orchards,

Green houses,

Storage houses,

Dry fruit (nuts) producers,

Vegetable producers,

Distributors,

Companies conducting research activities in the field of fruit and vegetables business

In total 1050 European companies were selected and contacted all over Europe with the market research questionnaire.

Results of the Market Research

Company profiles

The 1050 sent surveys were distributed among companies having different activities in the fresh fruit industry. These activities are: Fresh fruit production, Vegetable production, Nuts production, Fruit and/or vegetable storage, Fruit and/or vegetable distribution, Fruit and/or vegetable disinfestations,

The exact activity distribution is shown in the cake diagram below:

The survey investigated the facilities of the companies as well. The following facilities were found in the answers: Orchards, Infield, Storage houses, Green houses, Controlled atmosphere rooms, Laboratory

It is shown that the 21% of the companies own orchards and/or storage houses. Besides, infields, green houses and controlled atmosphere rooms are common.

Importance of the problem

It can be seen that there is a well defined need for a system like CLEANFRUIT. 94% the respondents said that there will be costumer interest for the product and 25 % said that a system like this is needed for ages. 69 % of the companies use post-harvest disinfestation methods. The common methods are detailed in the following section. To summarize, it can be stated that the companies show great attention to an alternative for chemical treatments.

Currently used methods

There are several common used disinfestation methods for harvested fresh fruits and vegetables. The four main methods are: Chemical methods, Biological methods, Thermal methods, Controlled atmosphere methods (CO_2, NO_2, etc.)

WP2 Target Specifications and Laboratory Trials

Task 2.1: Typical commodities with the common organisms living in them

Focused fruits and insects focused during the development of the CLEANFRUIT system.

Organisms found in typical European fresh fruits and vegetables

Species of fruit flies

There are numerous species of these insects so it is worth to present a brief introduction to them. Drosophila is a genus of small flies, belonging to the family Drosophilidae, whose members are often called "fruit flies" or more appropriately (though less frequently) pomace flies, vinegar flies, or wine flies, a reference to the characteristic of many species to linger around overripe or rotting fruit. They should not be confused with the Tephritidae, a related family, which are also called fruit flies (sometimes referred to as "true fruit flies"); these feed primarily on unripe or ripe fruit, with many species being regarded as destructive agricultural pests, especially the Mediterranean fruit fly. One species of Drosophila in particular, D. melanogaster, has been heavily used in research in genetics and is a common model organism in developmental biology. Indeed, the terms "fruit fly" and "Drosophila" are often used synonymously with D. melanogaster in modern biological literature. The entire genus, however, contains about 1500 species and is very diverse in appearance, behavior, and breeding habitat. Scientists who study Drosophila attribute the species' diversity to its ability to be competitive in almost every habitat, including deserts

Drosophila melanogaster is very popular in science life, especially in genetics. Most of the genetic laboratories fruit flies are used as investigation object. It is relatively easy to culture them in laboratory environments and the different states of their life-cycle offers good opportunities for numerous research fields.

In the following we present the most typical insect pests on common European fruits:

European apple sawfly (Hoplocampa testudinea)

Tarnished Plant Bug (Lygus lineolaris)

European Red Mite (Panonychus ulmi)

Two-spotted Spider Mite (Tetranychus urticae)

Codling Moth (Cydia pomonella)

Mediterranean fruit fly (Ceratitis capitata)

Drosophila obscura (an abundant European fruit fly)

Navel Orangeworm (Amyelois transitella)

Walnut Husk Fly (Rhagoletis completa)

Peach Twig Borer (Anarsia lineatella)

Usually, these insects settle on the commodities on the orchards and put their eggs in the hidden parts of the fruits. These eggs turn to larvae and start their deleterious activities that can be continued all along storage and transportation. That is why is so important to disinfest the fruits right after harvest.

Microorganisms on fruits

Fungal pests that pose problems without good remedies are: Rhizopus stolonifer and Botrytis cinerea on stone fruit, strawberry, grapes and other soft fruit; alternates on mango, persimmon and tomato; Penicillium species on citrus fruit, pears, apples and many others (effective chemical treatments are available but not desirable).

Insects to be used during the development of the CLEANFRUIT prototype

During the project we will use mainly the above described fruit flies because the members of the consortium and outsider producers find this pest the most important one. As the main problem corresponds to their egg and larva state, we carry out the laboratory trials using these kind of samples.

Life-cycle states of fruit flies

In the frame of the laboratory trials eggs, larvae and adult fruit flies will be treated and investigated. The following properties will be investigated:

In case of adult fruit flies:

mortality,

effects on reproduction,

behavior (the treated ones can slow down, or lost the ability of flying, etc.).

In case of the larva ones

growth (do they attain full growth?),

activity,

metabolism

Task 2.2Electromagnetic characterization of common fruits and vegetables

The objective of this task (Task 2.2.) was to get an in-depth understanding of the electromagnetic parameters of typical European fruits:

Determination of the real part of effective dielectric constant of the commodities

Determination of the imaginary part of effective dielectric constant of the commodities

Conductivity (derived from the imaginary part of the dielectric constant)

Determination of the electromagnetic parameters of common European fresh fruits

The CLEANFRUIT system is based on the radio frequency (RF) core technology. In order to get useful initial data for the design and simulation of the proposed system, the electromagnetic properties of the treated commodities is crucial.

As the cavity is partially filled with the materials under test, the electric field distribution inside the cavity is highly influenced by the materials. This is why we need to know, at least approximately, the complex permittivity (dielectric constant) of the commodities at the frequency range we intend to treat them.

Measurement procedure

In the previous section we presented the theoretical derivation of the complex permittivity from the measured reflection coefficients. Now, we continue with the introduction of the measurement procedure. The commodities were investigated in the 1-80 MHz frequency range at discrete frequencies of 1, 5, 10, 20, 40 and 80 MHz. The samples were loaded into the plastic sample holder in a manner that the materials fit firmly to the coaxial transmission line termination (the open-ended one).

The following commodities were investigated:

Apple, Jonathan, Apple, Golden Delicious, Orange, Persian, Cherry, Walnut, Almond.

The fruits were tailored in order to fill the cylindrical sample holder with as few air gaps as possible, because air gaps increase the measurement uncertainty. The six measurement frequencies were swept through at each samples, and the measurement data were collected by a controller and data acquisition software (HP VEE). The sample holder was cleaned soundly by denaturized water and after each sample. Before the fruit samples, liquid paraffin was measured as a reference material, as its dielectric properties are well known (dielectric constant about 2-2.2 with negligible electric loss). In this manner the measurement was calibrated increasing measurement accuracy.

Results, discussion

The complex electric parameters of the measured materials are summarized in Deliverable 7.

Task 2.3 Preparation of different samples to irradiate

First, the commodities than the pests in larvae, eggs and adult forms are presented. In order to the get measurable results, during the laboratory trials the fruits and the insects are handled and investigated separately. Infested fruits will be tested during the field tests. The deliverable of this task contains photographs of these fruit and insect samples. They can be found in Deliverable 8.

Task 2.4 Pulsed RF experiments

The objective of this task (Task 2.4) is to carry out laboratory trials of pulsed radio frequency treatments and summarize the following:

The experiments began in the low frequency laboratory. The prototype source was quickly available and provided valuable knowledge for creating the high frequency counterpart. Closely following the specification the low frequency source was operating in pulsed mode.

The second iteration was not only operating at higher frequency, but the continuous output power was increased. With the excesses power, the high frequency source was operated in continuous mode, instead in prior experiment's pulsed mode. This opened the possibility to compare the two modes regards to treatment efficiency.

Part A - Low frequency laboratory

Calibration and reference testing were committed before each measurement cycles.

The calibration protocol of the HP4263A LCR meter is further described. The measurement shows the error introduced due to bandwidth limitation. At higher frequency this characteristics must be taken into account, in order to prevent fails readings.

Self calibration - 2 wire open/short cycle, 4 wire open/short cycle

Reference capacitive load 100uF (20%)

Further details can be found in Deliverable 10.

Part B - High frequency laboratory

The results of this task are summarized below and further details can be found in Deliverable 10.

Task 2.5 Examination of treatment effects on pests

Summary

A series of four laboratory tests were carried out in which all life stage of the common fruit fly were exposed to pulsed and non-pulsed RF energy with different parameters (peak power, frequency, pulse length and periodicity).

By varying the RF generator and electrode settings it was possible to obtain significant efficacy against the eggs, pupae and adults of the common fruit fly. Under these conditions there was some slight warming of the surface of the medium in the bottom of Petri dishes or vials, but this elevation in temperature would not have been enough to prove lethal to any of the life stages of the fruit fly. However, good efficacy could not be achieved against fruit fly larvae under these RF treatment conditions.

The details on the statistical analysis of the results can be found in Deliverable10.

Task 2.6 and Task 2.7 Examination of treatment effects on host commodities

The objective and subjective testing of the treated fruit samples was carried out in the certified laboratory of Mertcontrol Ccls. Chemical Laboratory, Budapest, Hungary. The main result is that no significant effects on the host commodities were found. A scanned version of their hardcopy analysis report can be found in Deliverable 11.

Task 2.8 Ozone Production Measurement

The O3 production of the machine was investigated by a measurement device rented from Levegodoktor Ltd, Hungary and recorded the ozone emission of the device. Briefly, no significant change in the ozone concentration could be measured. Details can be found in D12.

Work Package 3 - RF cavity development

Task 3.1 RF generator and cavity design

Not applicable in this period. (Completed in Year 1)

Task 3.2 Power supply design

Not applicable in this period. (Completed in Year 1)

Task 3.3 RF cavity manufacturing

The main objective of this work package was to design and manufacture the radiofrequency (RF) system of the CLEANFRUIT prototype. The design documents were presented in the M12 periodic report and in Deliverable 14 and 15.

Here, we will summary the results of the RF system manufacture and the additional improvements of the cavity, the generator and the interconnections (both RF and control). First, the manufactured components will be described then the reasons and the development of modifications will be discussed. Finally, the integrated RF subsystem will be evaluated.

First, the electrode size was determined in Task3.1, which is documented in Deliverable 14. Above the calculated RF power distribution is shown from front and side view. It is shown by these results that the power concentrates between the electrodes and the power density outside the cavity decreases rapidly. The dimensions of the electrodes are 200 by 120 mm with a thickness of 30 mm.

RF measurements and impedance matching

While the electrodes of the final prototype were manufactured together with the entire mechanical frame and the conveyor belt of the CLEANFRUIT system, RF measurements and adjustments (impedance matching) were carried out by MFKK. For this purpose the following components were purchased and developed:

The first step in the optimization of the RF system was to investigate the RF behaviour of the RF generator-connections-electrodes system. The main parameters to investigate were the generated electric field and RF power between the electrodes and the efficiency of RF power transmission from the generator towards the electrodes. These two parameters were at most importance because the first has direct effects on the treatment efficacy and the second has significant influence on the overall power efficiency.

This part of the research work started with the development of measurement techniques. First, the details of RF power distribution are presented. The most demanding parameters of these measurements are the simultaneous applications of extremely high voltage (up to approximately 10kV), high power (up to few kW) and high frequency (13.5MHz). Most measurement methods are suitable for one of these extremities but not for all of them at the same time. High voltage, high power metering probes are available at low frequencies (typically for the 50Hz mains), while RF field probes are available up to about 50 MHz, but only up to the low kV regime in voltage, and usually for low power applications (~ in the order of Watts).

Other difficulties arose from the operation principal of the RF generator. It works in ground independent mode (the enclosure of the generator is grounded but none of the electrodes is connected to ground), so ground independent differential measurements had to be carried out. Considering ground independency combined with high frequency, high voltage and high power this brings serious health risk issues, so special attention had to be paid on the development of the measurement setups. These safety issues were addressed during the measurements; no health risk situations happened.

At this point it has to be emphasized that during normal operation the equipment has no higher risk levels than any other high voltage equipments. All metal parts reachable by the operator are connected to safety ground. However, the prototype is not qualified by any standard institutes, so special attention has to be paid during operation. These issues were presented to the operators and to all project partners at the final validation and training.

RF power distribution measurements between the electrodes

First, using the wire loop power indicator the actual RF power level was monitored. The wire loop was connected via a shielded coaxial cable to the receiver electronics. This module consists of a capacitive voltage divider, an AC/DC rectifier in Graetz structure and an analogue DC voltage meter. This way the voltage meter itself is immune to the RF leakage, so only the signal collected by the loop and partly the coax cable (due to parasitic effects) was measured.

It has to be noted that this method is capable only for relative measurements since the coupling factor between the RF field and the loop is known only approximately as not such high voltage, high frequency reference signal source was available.

Voltage measurement

It was presented in the previous section that we had developed one useful tool for the relative RF field measurements however the need for quantitative measurements was clear. It was required to underpin the insect and fruit laboratory trials with electric field strength values and for the impedance matching network design and development.

As it was discussed above, the main difficulty during the measurement setup development was to simultaneously handle high voltage, power and frequency. This issue is even more critical when voltage needs to be measured.

The basic concept was to use capacitive voltage division on the electrode voltage and to use the above mentioned DC voltage meter induced by the low level, rectified signal. As the level of voltage division can be calculated, in this way, exact voltages and so exact electric field strength values can be obtained. For the voltage division high voltage had to be used (see the table of components above).

The schematic of the measurement setup is the following:

The aim was to divide the RF voltage between the electrodes ("C_treatment") onto a magnitude of about 1-10V. This voltage level can be easily displayed by the commercial voltage meter. The first divider element is the previously mentioned high voltage, high power adjustable capacitor ("C_meas1"). Determined by the ratio of the treatment capacitor and this divider capacitor, the voltage is in the range of 5-600VAC (according to the value set by the variable capacitor).

This voltage is further decreased by the C_meas2 and C_meas3 capacitors by a factor of 100. This results voltages below 10VAC that can be easily rectified and displayed by the analogue voltage meter. Besides, the capacitance of these two capacitors is below 10pF, so the current in the measurement branch is lower by a factor of 30 than in the treatment branch. Thus the voltage meter has minimal effects on the behaviour of the treatment capacitor.

a)Main results

The main objective of this task was to manufacture the RF cavity, the adjustable impedance matching network and the connection with the RF generator. As it was discussed above, the main steps of the development process were the following:

1.electrode design and manufacturing

2.development of electric field and voltage measurement methods and equipments

3.design and manufacture of the variable impedance matching network

The main results of the actual task can be summarized along these development steps.

1 - The manufactured RF cavity

The electrodes were manufactured of aluminium. Pictures of the prototype electrodes and the cavity are shown in the following:

The electrodes (as a part of the manufacture of the conveyor belt system) were manufactured by Entrasys Ltd., Hungary with delivery in April, 2010. The electrodes are made of aluminium with the dimensions described above. The corners of the electrodes are rounded in order to increase the maximum applicable electric filed strength between the electrodes without arcing.

The conveyor belt frame is also made of alumina, so the separation between the lower electrode and the bottom electrode had to be considered carefully. Finally, it was designed (see mechanical designs in Deliverable 18) to include a polyoxymethylene POM supporting frame section, so all conducting materials are avoided between and next to the electrodes.

The minimal distance between the electrodes and the grounded shielding is at the electrode connectors, which is 10mm. The electrodes are ground independent, so the voltage can be higher between the electrodes than between one of the connectors and the ground.

Naturally, the conveyor belt is placed between the two electrodes. The belt is made of a composite material made of PVC and fibre substrate. This material has low electrical loss ($tg\delta=0.007$) in order to minimize the heating effect on the part of the belt between the electrodes. The fibre substrate is for mechanical stability. The belt has to be tensed at the conveyor wheels in order to precise control.

2 - RF electric field and voltage measurements

First the electric field distribution was measured by means of the loop detector presented in section a). The relative electric field distribution was recorded in discrete points creating a 6x4 matrix. As it can be foreseen, the normal component of the electric field strength is strongest in the middle of the electrode and it is weaker in toward the corners.

The area of the electrode is represented on the horizontal axis and the relative field strength values are shown by the diagram. The ratio of the minimal and maximal field strength is about 70%. From the fruit treatment point of view this means that fruits at the edges of the conveyor belt are exposed 70% weaker treatment intensity than fruits in the middle. This issue has to be taken into account during operation.

This relative measurement method was valuable for two issues: it helped to map the field distribution between the electrodes, and it had vast importance during the laboratory trials with insect. By means of this simple tool the quality of the electrode and impedance matching network settings could be directly monitored. During these trials the main goal was to maximize the electric field at the samples, so each adjustment could be validated by this fast measurement.

The developed voltage measurement method described above was used during the whole impedance matching process and was used to monitor the output voltage on the cavity electrodes. The measurement results are summarized below together with the conclusions of the impedance matching.

Applying this measurement method, the voltage between the electrodes was investigated for different electrode areas and distances. The two measured areas were 225 and 400 cm2 and the distance was varied between 3 and 18 cm. It was shown that for the same distance values, the higher capacitance electrode showed higher voltages than the one with lower capacitance (area).

This symptom can be explained by impedance matching / frequency tuning considerations. The RF generator includes a resonant circuit that has the nominal resonant frequency of 13.56 MHz. This circuit is embedded in the RF power triode's gate loop, thus the amplifier has its peak power output at this frequency when the load impedance has also a resonant frequency at this frequency.

In other words, the maximal output power can get when the impedance of the load (electrodes, tuning elements, leads) is matched to the output impedance of the RF generator. In order to have variable impedance at the load, the two described adjustable capacitors were applied. One in series with the inductance of the leads and another in parallel with the electrode. This way the output voltage, thus the electric field strength between the electrodes was maximized. The output voltage during the impedance matching was measured with the capacitive divider method described above. The maximal electric field strength measured on the electrodes was 8.5kV/cm. Above this value the breakdown of the field strength in form of electric arcing occurred.

By this method the RF performance of the CLEANFRUIT RF subsystem can be optimized for each commodity under treatment. The space density of the fruits on the conveyor belt has also effects on the capacitance of the electrodes, thus it influences the impedance of the load. This effect can be addressed also by means of the variable capacitors.

3 - Impedance matching

The impedance matching method described above was used to optimize the RF coupling between the RF generator and the cavity. The main goal of this development task was to maximize the treatment efficacy and the RF power efficiency of the CLEANFRUIT prototype. For detailed results please refer to Deliverable 32 and 35.

The maximum measured voltage on the electrodes was 25.5kV, which results 8.5kV/cm electric field strength considering the 30mm electrode distance. By the adjustment of the impedance matching components (the two variable capacitors) leads to a variability of about 20%. Considering the same generator and electrode height settings (and same dielectric properties between the electrodes) in terms of electric field it means that the maximal level can be lowered to 6.8kV/cm.

b)Deviations from Annex I

1 - Continuous RF generator

The most significant deviation from Annex I regarding WP3 was that the RF generator installed in the final prototype is a continuous wave generator instead of a pulsed mode power source.

The reason for this modification was described in Deliverables 10, 32 and 35. It was shown during the first three laboratory trials carrying out applying a pulsed mode generator that the treatment efficiency was proportional to the duty cycle. The highest rates were achieved by means of the highest available duty cycle (71%). This value means that in average in 71% of the treatment time, the RF power was on, which means a quasi-continuous operation.

According to these results, the Consortium decided at M9 to continue the laboratory trials and the prototype development based on a continuous mode generator. This decision proved to be very efficient since the first successful treatments were carried out by the 13.56MHz, continuous wave generator.

2 - RF Electric field and voltage measurement

The tasks of electric field and voltage measurements were not explicitly described in Annex I. The complexity of these methods and the development of custom tools however were required for the successful execution of the project. The applied electric field strength was necessary to know in order to underpin the laboratory trials measurement results and to support and monitor the impedance matching development.

3 - Impedance matching network

The task of impedance matching was not explicitly included in Annex I. This development was carried out in order to optimize the RF performance of the CLEANFRUIT prototype in terms of treatment efficacy and power efficiency. The impedance matching network can be used to tune the RF system when the parameters (most typically the treated commodities) change.

Work Package 4 - Mechanical Structure Development

Mechanical frame:

The mechanical frame of the CLEANFRUIT prototype was built form commercial aluminium assembly parts. The reason why this modular assembly system was selected is that with this parts, stable machine frames could be integrated without any additional machine or special equipment. Although the profiles are available in light, medium and heavy duty design, the aluminium material was selected because of its light weight in case of the transportation of the prototype and because of its anti-corrosive property, which can be a real advantage in a wet environment, like fruit or vegetable handling. The aluminium profiles were cut to the designed length and were assembled with the supplied connecting parts. These connecting parts do not only match to each other but are also compatible with other similar products, like tube connection systems, linear units and drive units. This means that the current CLEANFRUIT prototype can be integrated into other industrial applications in the fruit or vegetable processing industry.

Although the original plan was to supply the aluminium frame with 4 legs with adjustable foots, in the meantime of the manufacturing, it turned out that this is not sufficient for the proper stability, therefore the whole system was re-designed into two attachable parts. Now the first part of the frame has 6 legs. The second part of the frame has 4 legs as well as the collector table.

The frame includes the conveyor belt support profiles with plastic support of RF unit and the mechanical support for the belt drive motors and the brush motors.

With the ability to attach and de-attach the system, the biggest advantages of the prototype are the easy assembly and adjustability features. It became obvious at the time when the system was transported to Slovakia for field testing, it was much easier to lift the machine onto the truck with fork-lift. This method also saves space and transport costs either. The height of legs is adjustable to set the optimal angular offset based on the first runs. The metal body of the system need was electrically grounded to ensure safety.

Conveyor belt:

The conveyor belt runs through the whole system and is also detached into two separate sections, parallel to the mechanical frame. The CLEANFRUIT conveyor belt has two pulleys per the two detachable frames, with a continuous loop of the conveyor belt that rotates about them. When the pulleys are powered with the belt motors, the belt starts moving and the agricultural commodities on the belt are moved forward. The powered pulley is called the drive pulley while the unpowered pulley is the idler.

The conveyor belt carries light fruits and vegetables, therefore the belt requirements came from the general food industrial standards. Because of the RF technology and the direct RF contact with the belt, the static electric free belt (which is a conductive material) was disregarded. Instead of that, a green PVC material was chosen, because of the mechanical properties and good price. The material of the PVC belt is easy cleanable, water resistant and it is free from any toxic and unhealthy materials. The belt consists of more layers of material, the under layer of material (carcass) provides the linear strength and shape and the softer over layer (cover) is in contact with the commodities.

The water spraying chamber

The objective of using the washing chamber with clean water is twofold: first, it eliminates the impurities from fruits, therefore it improves the effect of RF treatment with conductive surface water coating. Second, it also cleans the fruits from any contamination (soil, dirt, etc.) that could worsen the effect of the RF treatment.

The chamber is built form aluminium and plastic parts, and held by the mechanical frame of the system. It can supplied directly from the industrial water system or any water tank with a water-pump (installed). The ability of controlling the water spraying chamber is a built-in option in the PLC unit.

Development of safety components:

Emergency buttons

The user of the system has the possibility of interrupting the normal function of the system and process at any time. Consequently, two emergency push-buttons have been placed on the machine to accomplish this task. The first button is placed in the enclosure where the control hardware is situated, as this is compulsory for any electrical installation. Additionally, it was decided to add a second push button to the console for user interface in order to be easily reachable by the operator. Both buttons are part of the control section of the electrical emergency circuit, which drives the emergency contactor.

An RF sensor was developed in the Task 4.5, Design of Safety Components. This sensor belongs to the group of safety measures for CLEANFRUIT machine. It measures potential RF radiation leakage from the RF generator and triggers an alarm when a safety radiation level has been exceeded. If the RF level exceeds the threshold, an alarm signal is triggered and read by the PLC, which automatically enters the emergency mode. As an additional RF leakage protection, conductive chains were hung on the entrances of the RF cavity.

Console for user interface

The user interface is based on an industrial PLC terminal with additional pilot-lamps. The user is able to control the RF unit separately and power down the system with emergency buttons. The RF unit is controlled directly by the PLC during normal operation. Even so it must have the control functions for test or standalone operations. To operate the RF unit it must have the following inputs:

* Power On / Off * RF On * RF Off * Timer Set * RF tuning. It givew the following feedbacks for the operator: * Power On * RF On * Overload

During automatic operation, the PLC controls the safety function. The operator can shut down the machine with the RF Off button or with the main Power Off switch. The control functions are implemented with industrial IP67 standard pressing buttons like Benedict & Jäger BS3D SW/10. The status of the machine is visualized with IP67 pilot lamps like Benedict & Jäger B3R WS/0. A 2-state switch like Benedict & Jäger BC3KN2 is used as Timer On / Off switch.

Coveyor belt control interface

The user interface module is built from commercial parts and the panel is assembled into the electric control cabinet. The main control interface is implemented with a Siemens TD 200 graphical PLC terminal. It is able to control all of automatic functions and settings. The status of the machine is displayed on the operator panel with additional pilot-lamps. The user interface module includes the following functions: * Start process * Stop process * Move conveyor belt without treating * Set process conditions like speed of belt, RF unit On/Off and water treatment On/Off

The user interface can display the following information: * Process status * RF unit status * Safety status. The safety information is displayed on the user interface panel. It gives a warning if the RF unit is overheated, or RF leakage is detected, metal detected on the conveyor belt or the process stopped because of any other reason. The operator is able to stop the process with the 2 emergency buttons in any phase of the operation.

WP5: Process control and monitoring

Task 5.1: Control Hardware development

CRIC has designed, developed and built a PLC based system in which external sensors such as presence detectors and an user interface console developed in T5.3 provide input data to the processor which conduct operation using different actuators such as motors for conveyor or brushes movement or valves for water spraying.

A block diagram is representing the main functions and elements of the control hardware:

The block diagram is formed by the following blocks:

-CPU: it contains the control program developed in Task 5.2

-Sensors - indicators: input and output connections for digital signals.

-Sensors - actuators: input and output connections for analog signals.

-PLC expansion module and communication with RF unit.

-User Interface console: with E-Stop and control buttons, process state lights and a display showing process state and parameters.

-PWM/DC converter to adapt the control signal to the frequency inverter.

-Frequency inverter for motors speed control.

The main part of the task has been the encapsulation of the control hardware in an Electrical Cabinet. A total of three versions have been presented according to needs and variations related to results obtained during the process of the project.

The final version of the electrical cabinet includes the PLC controller and expansion modules, frequency inverter, PWM to DC converter module developed by CRIC for proper communication to PLC-inverter, RF machine drivers, cooling system and safety circuit.

Only the user interface console is outside of the electrical cabinet although it is connected using MPI cable.

Contractors involved: Cric and MFKK.

Task 5.2: Control Software development

CRIC has developed a sequential control program for PLC based control capable of achieving the most efficient throughput of the system ensuring the best disinfestations efficiency.

A first program version has been developed using a prototype built for that purpose.

This version implements the Maintenance mode and its functioning assumes:

- One piece of fruit at a time,

- Constant conveyor speed and

- Piece stops in the RF cavity for radiation.

CRIC has developed an extended version of the program including the Continuous mode for industrial environments. It permits:

- Access of multiple pieces of fruit at a time,
- Variable conveyor speed and
- Conveyor does not stop for radiation making the process more efficient.

The control program has been designed using Grafcet graphical language but implementation was performed using STL language. The main reasons for this selection are the followings:

- Everything that is programmed in LAD or FBD can be also programmed in STL. However, certain things in STL cannot be exactly reproduced using LAD or FBD programming.
- Visually, programs developed under STL programming tend to fit in smaller space comparing to the other two programming languages.
- STL allows inserting explanation comments to each single line.

The process for Grafcet to STL language is explained in detail in the D-27:

Contractors involved: Cric and MFKK.

Task 5.3: Design of a user interface

Based on Task 4.6, CRIC has developed a portable user interface console.

It contains buttons for machine operation,

- Start - Green button
- Reset (alarm) - Yellow button
- Stop - Red button

And lights for machine status feedback

- Normal operation, switched on - Green light

- Radiation and transitions (initialization, alarm recovering) - Yellow light

- Abnormal operation (Alarms) - Red light.

It includes an emergency button for quick stop.

The console includes a multifunction display with a user friendly menu which displays messages about system status, alarm type or stand by.

It permits to consult machine parameters such as Conveyor speed, Radiation time or Operation mode and change them using arrow buttons.

It is possible to read actual value of RF leakage sensor.

By default, the working mode is the Continuous mode but it can be changed to Maintenance mode when necessary.

Contractors involved: Cric and MFKK.

Achievements:

The objectives of the work package have been achieved by the development of the hardware which conducts the operation of the system and monitors the whole process including safety issues.

A process control algorithm has been developed and implemented into the control software that permits easy operation and dual functionality. A maintenance mode has been developed for testing and maintenance purposes, and a Continuous mode is also included for normal production purposes.

Regarding the user interface console, a small and not too heavy component have been developed. It is easy to use and simple but complete in functionality.

Work Package 6 - System Integration and Tests at Laboratory Level

Task 6.1 Prototype assembly

All the mechanical, the RF and control parts were assembled together in order to finalize the construction of the prototype and to validate the design and safety elements.

The first objective was to install the RF generator to the conveyor frame. This was done with connecting the FR generator outputs to the RF cavity input electrodes with copper stripes. Before installing the RF generator, two variable capacitors were included between the generator and the RF cavity electrodes. The objective of including such capacitors was to be able to tune the amount of radiofrequency field inside the cavity, so that the users of the prototype can set calibrated values for treating different kind of commodities and pesticides with different amount of voltages. The capacitors are standing on and screwed to a white plastic panel (330 x 250 x 60 mm), which was made of Polyoxymethylene (POM), an engineering thermoplastic with high heat resistance. The heat resistance skill of the material was needed in case the capacitors are heated because of energy loss in and around the capacitors. One capacitor was installed parallel and the other was installed in series. Electrical specifications of the capacitors: 300 pF (variable between 12 pF - 300 pF), 25 kV, 75 Amps. Mechanical specification of the capacitors: 245 mm (long), 120 mm (diameter).

The second objective, after when the RF generator was fully installed, was to attach the control panel to the frame, this was done with screws that attach the panel box to the side of the aluminium frame.

The next step was the installation of the sensors that give feedback to the controller about the positions of the commodities on the belt. At the time of the installation, the cavity sensor turned out to be too close the RF cavity, where its working could be disturbed by radiofrequency waves, this problem could not be solved with the chains on the cavity entrance, therefore the sensor and its cables were covered with RF shielding material. The rest of the sensor were not shielded, their functioning was not hindered by RF effect.

Additional components, like water pump, the water sprinkler chamber, the brush motors and the conveyor belt motors were also fitted to the conveyor frame with screws. The brush motor is controlled by a relay, the conveyor belt motor is controlled electronically.

The overall dimensions of the prototype is 7000 mm x 2500 mm x 1500 mm, the mechanical, electrical and control components weight is around 800 kg, the power consumption is 400V; 3 x 20A.

Task 6.2 Prototype tests and validation

In order to test and validate the prototype, the system was turned on and was operating for several hours in order to see if there is any malfunction.

The following issues were monitored:

Grounding of the RF generator and the conveyor frame

In order to ensure the necessary safety of the system, careful planning of the grounding was made. The conveyor system and the RF generator were grounded separately. The grounding of the conveyor frame was built in the standard electrical power connection, but for the RF generator with a nominal maximal output power of 5 kWh, a dedicated grounding had to be done. In the beginning, two grounding points were considered, one point at the entrance of the fruit storage room and one point by the default grounding point of the premise.

After the electrical grounding of the RF generator was selected, the RF generator was put on a steel sheet and a grounding cable was attached from the steel sheet to the grounding point of the storage room.

The stability of the RF generator

The RF generator was also operated without load, with half-load and with full load for 1 hour, however no malfunctions were detected. The only detectable issue was the smell that was emitted from the surface of the painted RF inner parts. However this issue did not cause any malfunction in the operation. The emergency button on the RF generator was also tested several times.

Heating of the RF cavity

1-2 degrees of temperature increase could be measured on the different parts of the RF cavity within operation, but as most of them are made of metal and POM plastic, it was not considered to cause a negative safety effect. The RF cavity heating also did not provide any damaging effect on the conveyor belt, which was made of PVC.

Safety measurement of possible RF leaking

A field strength measurement device was utilised to constantly measure the possible RF leaking emitting from the electrodes and the RF cavity. Although the level of field strength was normal around the prototype, it still varied between a certain interval, therefore a special RF shielding was installed around the RF cavity and the electrodes that connect to the RF generator.

Safety RF shielding installation

An additional safety feature of the prototype is the RF shielding covering the electrodes and the variable capacitors between the RF generator output and the conveyor frame. The shield works as a Faraday cage, so no harmful radiofrequency waves can pour out. The shield is attached to the screws of the RF cavity and the screws of the generator. The highest amount of RF activity is inside the cavity, but near to the entrance it is also frequent, therefore chains were attached to the entrances of the cavity to decrease the unwanted RF radiation outside of the cavity and to increase the Faraday effect.

RF control device safety

The control panel safety button was tested several times in order to make the operation of the user interface. There is an emergency stop button on the control panel.

Stability of the conveyor aluminium frame in operation

The additional two legs that were included onto the frame in WP4 turned out to be necessary and useful, because the whole system could be loaded now with more fruits in operation, and the frame is more resistant now against possible vibrations.

Moving parts (motor, brushes, conveyor belt)

The direction of the conveyor belt was not proper as the default setting, therefore it was recalibrated with screws on the beginning of the frame.

After the first assembly, when the design and safety components were tested it turned out that the prototype is ready to be used in real environment. Therefore the CLEANFRUIT system was transported to the premises of CRZ, the Slovakian end-user SME of the project.

WP7 - Field tests and validation

a)Summary of progress towards objectives and details for each task

The main objective of this work package was to install the CLEANFRUIT prototype at the facilities of one of the end users and to carry out field tests with the entire integrated and installed prototype of CLEANFRUIT. In the frame of this part of the project trials were carried out focusing on the treatment efficacy for different types and stages of insects as well as the possible effects on the host commodity. Besides, the prototype was tested for the treatment of mould according to the suggestion of FSRL.

Task 7.1. Prototype installation for field trials

The entire CLEANFRUIT prototype was first integrated for the laboratory tests in Szeged, Hungary in December, 2010. After the system was tested (please refer to Deliverables 31 and 31) it was transported to Prievidza, Slovakia on 21st January, 2011 for the field tests and validation. The prototype was integrated in 3 days in a storage room of CFD. The field tests and the demonstration were carried on 24-26 January, 2011. Details on the field tests and the results can be found below in Task 7.2, here we will focus on the system integration.

First, the components of the CLEANFRUIT prototype were transported to Prievidza, Slovakia at the facilities of CFD. Each sub-module of the prototype was tested and then the entire system controlled by the developed control unit was started up and fine-tuned in order to optimize the operation parameters. The field tests ended up in the demonstration at the final meeting. Here, all partners were present and were given a detailed presentation of the CLEANFRUIT operation and instructions.

The CLEANFRUIT prototype has the following subparts:

-washing chamber

-RF chamber

-two-part conveyor belt

-cleaning brushes

-dryer unit

-product tray

-controller unit

The details of each part can be found in the related deliverables (D23, D28, D29, D31, D32), in section b) the photographs of the installed units will be presented.

Task 7.2.Evaluation of the field tests

Task 2.3, 2.4 and 2.5 include the main steps of the repeatedly executed sets of laboratory trials. In the frame of this task the first step was carried out, namely the preparation of the samples under test. In most of the laboratory trials the insects of different life-stages and the fruits were treated separately. In this way each effect could be investigated more precisely and the RF system could be optimized more effectively considering fewer parameters in the same time.

During this work package seven sets of laboratory trials were carried out by the cooperation of I2L and MFKK. I2L was in charge for the sample preparation while MFKK provided the RF instrument. The treatments were carried out by the experts of I2L and MFKK at the facilities of MFKK. Details on the RF system can be found later in this document under WP3 and in the corresponding deliverables. Here, the most important aspects of sample preparation are summarized.

According to the decision of the consortium partners, the Drosophila melanogaster (common fruit fly or vinegar fly) was chosen to use during the laboratory trials as target insect. However, later on fly larvae and different life stages of Ceratitis capitata (Mediterranean fruit fly) were also used.

A wild-type OREGON R strain of common fruit fly, Drosophila melanogaster, was obtained from the Faculty of Science, University of South Bohemia in the Czech Republic. A culture of this fruit fly strain was maintained in controlled temperature cabinets at the laboratory of i2L-East with a regulated photoperiod (18:6 light/dark cycle) at a temperature of 25±2 C. The rearing medium consisted of corn flower 120 g, agarose 15 g, sucrose 75 g, yeast 60 g, 25ml of 10% methylparaben in ethanol as a preservative, with water to make the volume up to 1.5 L.

In case of all laboratory trials all life stages (see below) were prepared in separated Petri dishes and in vials (adults) on the same rearing medium described above. So, the age of the different samples are the following:

-Day 1: Eggs

-Day 2: First instar larvae

-Day 3: Second instar larvae

-Day 5: Third and final instar larvae

-Day 7: Pupae

-Day 11-12: Adults

The photographs of some samples prepared for the laboratory trials are shown below:

The fruit samples prepared for the investigation of the RF effects on the host commodities

As it was described in the M12 periodic report the results of the first laboratory trials showed that the treatment efficacy (killing rate on insect samples) was higher with increased duty cycle of the pulsed RF generator (please refer to Deliverable 10). Thus the consortium decided to maximize the treatment effect by using continuous RF power source.

Electromagnetic characterization of insect samples

In order to find the most appropriate operation frequency, the insect samples were characterized by electromagnetic measurements (not reported in Deliverables). The dielectric loss of the samples was measured directly by an impedance analyzer (HP4191A) from 1 to 50 MHz. Please see Deliverable 7 for details on the theoretical basis of the electric losses. In a nutshell, the principals are the following: the electric behaviour of materials can be characterized by the complex permittivity.

The permittivity consists of a real ( ) and an imaginary ( ) component. The real component stores the electromagnetic energy inside the medium, while the imaginary part and conductive losses are responsible for the electric losses (heat generated by dipole movements induced by the electric polarization).

The measurement principal was different compared to the fruit measurements. Here by means of the impedance analyzer the capacitance (C) and electric loss (D) of the sample holder capacitor were measured directly. This loss factor arises from the imaginary part and the conductivity of the insects.

The blue lines show the capacitance and the dissipation factor of the empty capacitance while the red lines show the same parameters in case of the filled capacitance. Fruit fly larvae were used to fill the capacitor.

As it is expectable from the theory, the dissipation factor increases with the frequency, no significance resonance can be seen in this frequency range. Taking into consideration the results of the fruit measurements (Deliverable 7.) a compromise had to be found. The ideal operation frequency is where there is significant effect on the fruit flies, while the heat dissipation of the host commodity is at a reasonable level. According to the fruit storage expert partner FSRL, the thermal effects are not as deleterious for the fruits as it was originally stated in the description of work. If the temperature does not exceed 36˚C for a long term, then the thermal effects are rather useful than harmful. In the following all the trials were carried out considering this fact. This enables higher flexibility for the RF development.

The final decision made by the consortium was to use a continuous RF generator at the 13.5MHz frequency band. It promised good compromise for the above mentioned issues; it is in one of the ISM frequency bands, so electrical components could be found relatively easily.

A detailed description and the electric schematics of the 13.5MHz RF generator can be found in Deliverable 9. The generator was designed by MFKK and manufactured by a high power RF expert Danish manufacturer, Techwood. The design relies on vacuum tube technology applying a high power RF triode (3CX2500H3, from Svetlana) and the maximal average output power is 5kW for long term use. Details on the RF modifications due in the second year of the project can be found below in the WP3 report. In the following we summarize the laboratory trials carried out between M12 and M24.

Measurement methodology

In the following we summarize the method of the laboratory trials that was used during all experiments. More details can be found in Deliverable 10 and 32.

Live fruit flies, reared in the laboratories of i2L-East, were transported to MFKK where they were exposed to the corresponding RF treatment. Replicate samples of 20 eggs, 20 third instar larvae, 20 pupae and 20 adults (0-1 day old, sex separated) were either exposed in standardised Drosophila culturing plastic vials (Flystuff Ltd.) on rearing medium, in Petri dishes with a medium of 4% agarose in fruit juice or in Petri dishes without medium (in case of adults). The samples having no medium were investigated only at one set of trials in order to prove that the killing effect on adults is not due to vaporization of medium. The adult samples were put back to vials containing medium right after the treatment. For treatment, the vials or Petri dishes were placed between the electrodes.

Immediately following treatment, the temperature of rearing medium in containers was measured using an infrared thermometer to check for any heating generated by the pulsed RF treatment. Vials or Petri dishes containing treated insects were then carefully labelled, appropriately and securely packaged, and were then transported to i2L-East in České Budějovice where the fruit flies were maintained in a temperature controlled cabinet.

For adult fruit flies (0-1 day old males or females), survival of individual insects in vials or Petri dishes exposed to pulsed RF treatments was assessed daily and compared with survival of insects in the same container type that had not been treated (control replicates). Any changes in the behaviour of RF treated adults were also noted. For pulsed RF treated eggs, hatch was assessed daily and compared with untreated controls. Similarly, survival of pupae was assessed daily in terms of success in enclosion to an adult and survival of larvae was assessed daily in terms of pupation and compared with untreated control replicates.

Mortality of eggs from the first laboratory tests was subjected to an analysis of variance (ANOVA) to test to determine the significance of variations between treatments and controls (untreated). Statistical analysis of other data from the first laboratory tests was not appropriate as tests were not replicated.

Statistical analyses on data from subsequent tests were performed where appropriate to determine the significance of variations in mortality of fruit flies (adults, pupae, larvae or eggs) exposed to RF treatments and control fruit flies that were left untreated.

In the reporting period two laboratory tests were carried out with the methodology described above, while a final test using the integrated prototype was made using more larvae samples (half of the entire amount).

During the field tests and validation mandarin and apple samples with and without fruit fly larvae or mould spores were investigated. Besides, adult fruit fly samples were also treated in Petri dishes. The evaluation of the results was carried out by I2L and MFKK, the results for the different treatment conditions are summarized in the following section b).

The fruit samples were infected by mould spores and insect larvae. In case of the mould investigations the samples were transported back to Budapest, Hungary. The samples were monitored daily, and the area of the developed fungi was logged. The results can be found in the following section.

b)Main results

The main results of this work package can be divided into two parts:

1.the installation of the CLEANFRUIT prototype in Prievidza, Slovakia

2.the field tests in Prievidza, Slovakia and the test evaluations

1 - Installation of the final prototype of CLEANFRUIT

The entire CLEANFRUIT prototype was transported to Prievidza, Slovakia on 21st January, 2011 and installed in 3 days. The equipment was placed in one of the storage rooms of CFD. First, the two sections of the conveyor belts were assembled followed by the placement of the washing and drying chamber, the RF parts and finally the control unit.

Special attention was paid on safety issues of grounding and shielding the high voltage parts of the system. Hence, a new separated grounding was created at the storage in order to minimize the electric hazard and electromagnetic interference of the system.

All the design details of the above mentioned parts were detailed in the corresponding deliverables, here the installed system is presented by means of photographs taken at CFD's facilities.

2 - Field tests and validation of CLEANFRUIT

Treatment efficacy against larvae

As it was mentioned above, the CLEANFRUIT treatment efficiency was tested for both insects and mould. The methodology of these measurements was briefly summarized above, further details can be found in Deliverables 34 and 35. The summary of the measurement results carried out using the integrated and installed CLEANFRUIT prototype can be found in the following.

The treatment efficacy against adult fruit flies shows a very bright view to the potential of the CLEANFRUIT prototype. Above 1 minute of treatment, no survivals were detected. Next, the eggs, pupae and larvae stages of fruit flies implanted in mandarin samples were investigated. First let us discuss the results on pupae: The treatment efficiency is proportional to the treatment time showing that the longer the treatment period is the higher is the efficiency. After a 5 min. treatment the treatment efficiency is above 75% for pupae.

In case of the larva stage the efficiency is not that satisfying. Only a slight effect of mortality can be noted. The efficiency is not obviously proportional to the treatment time (the development ratio of the control is lower than some cases of the treatments). This immunity of the larvae had been noticed already during the laboratory trials, so during the second year of the project special attention was paid on the treatment of larvae. Please refer to Deliverable 35 on this topic.

The treatment efficiency becomes very promising again considering the egg stages. The result shows proportional relationship between the treatment efficiency and the treatment time, although has some abnormality with the samples treated 2 minutes long.

The treatment efficiency could further be improved in subsequent experiment. Never-the-less it is likely that the larva state cannot be fought with this method. However the larva state is only 4 days in the development cycle of the insects. In this way, the quarantine period can be reduced to 4+1 days, which results in a valuable benefit of saving about 10 days in this process. It is worth to mention that the optimal treatment for the egg or pupae stage might be slightly different, so it can be reasonable to develop in the future two sections of treatment regarding these stages.

It is important to mention that the required treatment intervals at a fixed output RF level are set according to these results. However, the throughput of the final product can be increased by simply scaling up the CLEANFRUIT equipment. If the same power level can be radiated between longer electrodes, the overall capacity of the treatment can be increased.

As an auxiliary research, MFKK and FSRL carried tests on mould samples and on fruits infected by mould. In the first case, the developed mould samples were exposed by the Cleanfruit prototype and the reproduction capabilities of the mould was investigated. It was found that the samples treated more than 1.5 minutes were not able to reproduce.

Secondly, infected grape samples were treated for 0.5 to 5 minutes. In case of the samples treated more than 2 minutes, the appearance of the developed mould delayed 3 to 4 days. These results were found very promising by the SME partners as these effects could also decrease the expensive quarantine time and could also increase shelf life. The consortium intends to carry out further research and development in this field, too.

RF Treatments of mould samples

SME partner FSRL had noted a strong additional potential application for the CLEANFRUIT technology. FSRL have been dealing with numerous storage technologies for fruit commodities. Besides insects, the other main target is to control decay in order to increase shelf life. So, they proposed to carry out RF treatment trials on mould samples. Both separated mould samples and fruit samples infected with mould spores were investigated.

The tests were carried out by MFKK with the supervision of FSRL at the facilities of MFKK in Hungary and of CFD in Slovakia. In the first case, the developed mould samples were exposed by the Cleanfruit prototype and the reproduction capabilities of the mould was investigated. It was found that the samples treated more than 1.5 minutes were not able to reproduce.

The first figure refers to the test on separated mould samples. The mould was grown on juice in vials and was treated by the CLEANFRUIT RF module for 1, 2, 5 and 10 minutes. The temperature was measured right after the treatment: a clear correlation was noticed between treatment time and temperature. The highest value was measured in case of the 10-minute treatment: increased to 33˚C from 26˚C ambient temperature.

The methodology was the following: the mould samples were grown by OÁI, Hungary. The samples were exposed to RF at MFKK followed by the investigation by OÁI: samples were taken from the treated mould and the spores were put onto rearing medium of the same composition as the first samples. Then the area of the developed mould samples was monitored. There was a significant effect on the development of the samples treated at least 2 minutes. Above 5-minute treatment times the mould was not able to develop.

These preliminary results were promising to the consortium, so additional measurements were carried out using fruit samples and the mould development was monitored in the following days.

Grape samples were treated for 0.5 to 5 minutes. In case of the samples treated more than 2 minutes, the appearance of the developed mould delayed 3 to 4 days. These results were found very promising by the SME partners as this affects could also decrease the expensive quarantine time and could also increase shelf life. The consortium decided to carry out one more set of trials using mandarin samples injected with grey mould spores.

The three measurements regarding the decay control capabilities of the CLEANFRUIT system were evaluated by fruit storage expert partner FSRL and it was found very promising.

The integrated prototype was tested in Slovakia at CFD's premises but in February it will be transported to Israel to FSRL's facilities in order to carry out more trials on field using different fruits and both insects and microbiological infections.

This auxiliary application of the CLEANFRUIT system strengthened the partners will in continuing the system development in the frame of a future cooperation.

Treatment operation parameters:

Considering 30 second treatment time (0.4 meter/minute conveyor speed) for apples (one layer of fruits), the throughput of the Cleanfruit prototype is around 3kg/min, or 180kg/hour. The energy cost of the treatment of 1 kg apples is 0.004-0.0057 Euros that is highly competitive with other alternative methods, such as biological disinfestations. Higher throughput can be achieved by simply scaling up the pre-industrial prototype.

As an auxiliary research, tests on mould samples and on fruits infected by mould were carried out. In case of the samples treated more than 2 minutes, the appearance of the developed mould delayed 3 to 4 days.

c) Deviations from Annex I

1 - No saline water trials

According to the decision of the Consortium detailed in Deliverable 19 and 23, no saline water treatment was applied in the frame of the CLEANFRUIT project. This method would most probably jeopardize the quality of the host commodity, so this optional process step was removed from the description of work.

Work Package 8 - Technology Transfer and Exploitation

Task 8.1 - Training

Based on the training plan that was prepared in the first year of the project, the training courses were incorporated into the regular project meetings and the SMEs were trained either before, during or after these meetings with Power Point presentation tutorials which served as training material. Pre- and post-validation of the technology were also part of these technology workshops.

The training plan

The receptivity of the training sessions were very positive by the SME members was according to the objectives defined in Work Package 8. All members of the consortium were actively involved in the trainings under the coordination of RTDs and representatives of SMEs.

More detailed information about the trainings can be found in Deliverable 33 - Report highlighting the training activities performed.

Task 8.2 - Dissemination

Project website

On the M18 Barcelona meeting, the SME partners (with the leadership of OSV as Exploitation Manager) agreed that the website did not fully serve the purpose of the project in its condition, therefore they decided to improve the functionality and graphic design of the CLEANFRUIT website. A new web address was bought and designed: http://www.cleanfruit.eu

Preparation of project logo:

A first project logo was prepared and used until further dissemination materials were created. A second version of the logo was prepared by a professional designer, and the concept was accepted by the Consortium as the final version, which was later on used on leaflets, invitations, websites and posters.

Preparation of project brochure (electronic and printed):

The final version of the brochure was printed in 2500 pieces.

Preparation of project poster:

Parallel to the logo preparation, two versions of the poster were made. The first one contained basic preliminary information on the project and the expected results, the second version has information and pictures of the prototype itself.

Presentation of project results in specific conferences:

The first version of the CLEANFRUIT poster was presented at the Research Connection Day on 07-08 May 2009, in Prague, Czech Republic by two MFKK staff, Mr. László Jakab and Mr. András Havasi.

The updated version of the CLEANFRUIT poster with photos of the prototype was presented at the 8th International Symposium on Fruit Flies of Economic Importance (26th September-1st October 2010), in Valencia, Spain. The Consortium members delegated Mr. Attila Uderszky (MFKK) and Mr. Szabolcs Gyarmati (MFKK) to take part in the Conference, where approximately 300 pcs of flyers were distributed.

More than 20 participants queried about the CLEANFRUIT project, considering it worth starting a further cooperation. Compared with available traditional solutions, present stakeholders emphasized the innovative aspects of the project by treating agro-product commodities without chemicals. MFKK started even to have some negotiations with several companies and organizations in Europe and overseas after the conference, as a result of the communication started in the event.

Although the official project duration was already over, thanks to the great interest towards the CLEANFRUIT technology, a project poster was also showcased on the ELTE Innovation Day, held in Budapest, 2011. February 23.

The event focused on the representations of innovative technologies and projects in Hungary, therefore mainly RTD organisations (private and public research institutes, universities were interested in the results of CLEANFRUIT. A large number of project brochures were distributed in the event as well.

Press releases

Press release about CLEANFRUIT in the online version of "Népszabadság":
http://nol.hu/lap/karrier/20090929-nekik_megeri_feltalalni

CORDIS Articles

An article of the CLEANFRUIT project is available on CORDIS under the following link:

http://cordis.europa.eu/fetch?CALLER=MSS_HU_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=012ed7f94d61:2afa:2a42bcf7&RCN=96258

Another CORDIS Article is available:

http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=28&CAT=PROJ&QUERY=012e9c58b42f:044f:679057e9&RCN=96258

Presentations

A Power Point presentation was prepared by the Exploitation Manager (OSV) in order to increase the visibility of the project in related events.

Task 8.3 - Knowledge Management Actions

In the second reporting period, the following results were achieved within this task:

a)Technology watch - All partners were responsible for periodically updating the Knowledge Management database with new findings in terms of relevant research work being performed by other research groups, as well as updating the work already done regarding patent search. This task took account of relevant research activities at national and European level initiatives (e.g. EUREKA and EUROSTARS).

The results of the technology watch are given below within the list of relevant papers/articles/books.

All the results of Task 8.3 are summarized in Deliverable 30: An IPR Protection Report at M18, including the steps taken for filing a patent.

Task 8.4 - Exploitation Potential & PUDF (Plan for the Use and Dissemination of the Foreground)

The activities within this tasks resulted in three relevant articles that were incurred in one report:

Deilverable 37: Plan for the Use and Dissemination of the Foreground.

Joint Ownership and Exploitation Agreement (EA)

It details the agreements between the consortium members regarding exploitation issues. The EA intends to reflect the procedures for defining and handling the background knowledge and its final version encompasses all the conditions and processes on which the consortium will grant further manufacturing and distribution.

The final version of the Joint Ownership and Exploitation Agreement (EA) can be found in Deliverable 37 as Attachment 1.

Business Plan

During the project, the partners analysed the business perspective of CLEANFRUIT product then further detailed the schematic business plan drawn in the DoW. The projected business perspective is based on a detailed, and updated market information, and the results of the R&D activity delivered during the project.

The target group

SME partners, as owners of all the Intellectual Property Rights according to CLEANFRUIT system, defined, and grouped the relevant market actors to be aimed by the product, at the very beginning of the project, as it follows:

-fruit, vegetable (agricultural commodity) growers with own warehouses, cooling houses,

-logistical, transporting, food processing companies,

-agricultural storehouse.

Considering geographical regions, it seems to be more effective to stay in the European market at first, but afterwards, if the system will earn more and more references the Consortium is going to look for ways to reach the market out of Europe as well.

The financial plan

The revenues of the market ready Cleanfruit will come from: sales of the equipment, installation and specification and royalty fee from resellers.

It is a key aspect to distribute the product, and the service related to it at a businesswise price, so the interested partners scoped the product from such an aspect too. To get the most appropriate information about this, the exact field of usage of the system had to be known and the price of maintenance and the changeable parts too. The partners accepted the retail price of the system, (calculating with a profit marge of cca. 30%) will reach up 24.000 EUR. It already contains the installation and the specification fee, which will be charged by around 1,000 EUROS per unit.. As another business line partners agreed to rent out the system at the price of 500 EUR/month, (including a profit marge of 70%).

This revenue in-flow can be only reached, if the consortium is going to be able to start serial production and implementing industrial solutions in the first half of 2015. From year 5 after market entry the consortium expects revenues from royalties in the amount of 5,000 Euros per reseller. The profit reached according to the CLEANFRUIT equipment is going to be shared under the regulation of the Joint Ownership Agreement.

Short term plans for preparation of market entry:

The Consortium decided to look for further and alternative ways of usage of the equipment. All the SMEs, the owners of the project results are involved in the exploitation. After considering the project results, the members agreed in following the policy below:

-By using supports from different resources, the system is planned to be improved, to be able to used more effectively in the original field of usage (pesticide of fruit flies),

-SME partners also accepted to start up a new R&D project after accepting the idea of Ms. Ruth Ben-Arie, which has the goal to use CLEANFRUIT against decay attacking fruits.

-According to this decision of the SME partners, the equipment was transported to Israel, to FSRL's site.

The CLEANFRUIT Consortium decided to further develop the results of the project, with special attention to the experiments with delaying fruit decay. Project partners wish to continue developments based on the outputs of CLEANFRUIT within the framework of new projects, and the follow up projects will be carried out using the partners own resources supplemented with any national or international funds available. The owners of the results keep chasing new opportunities to finish the Cleanfruit application. So far the following opportunities were detected and closer studied:

a)EUREKA/EUROSTARS

b)Demonstration action in FP7

Further details about both research programme can be found in Deliverable 37.

Out of these two research lines, the Consortium decided to prepare and submit a proposal under EUROSTARS for the next deadline of 22 September 2011. Partnership was already confirmed by CRZ, FSRL, ITC, I2L and MFKK. The proposal will have the acronym of "CLEANFRUIT 2" and will focus on the delaying effect of RF treatment of fruit decay.

Potential Impact:

IMPACTS OF THE CLEANFRUIT PROJECT

The economic impacts of the results of CLEANFRUIT could be grouped to the ones which are related to the SME partners involved to this project (DIRECT), and those which are relevant to the future customers, who are going to be targeted with the system developed (INDIRECT). In the following the deeper aspects are going to be introduced of the mentioned.

DIRECT IMPACTS

The SMEs participating in this project could benefit of CLEANFRUIT in two main areas:

1.Implementing the system in their own premises,

2.Selling, or renting out the system to third parties.

1.Implementing the system:

As it was introduced in the previous documents like Description of Work, and proved during the testing phase of the project, the usage of CLEANFRUIT system is a cost friendly, and environmental implementation which gives a competitive advantage to its' users.

To prove this statement it is necessary to get familiar with the background related to it. The usage of chemicals in agriculture is getting more and more unacceptable in the European Union. The main reason of this is the obvious dangers caused by unpredictable side effects. So one hand, the market of chemical free fruits, and vegetables is growing constantly in the EU, and also in the US. Chemicals are not only used in the growing phase, but also in the storehouses because there are lots of organisms which could damage, or totally destroy the goods stored. Using chemicals is also very costly, and if it is not used in the good phase, it's not going to reach its' goal at all.

The dilemma is understandable:

-On one hand members of the target group should use toxics to protect their crops, which will repulse the organic market, and means an extra profit to them, which reduces their profit,

-On the other hand if they don't fight against the pests, they can lose also the "traditional market", which still does not pay attention to the presence of the toxics.

Of course there are solutions to protect the crops held in the storehouses. In the United States it is common to cool down the whole premises (below +4-5 oC) which puts a stop to all the relevant pest attacks, but still not protects against fungi, and costs a lot too, because using an enormous amount of electricity.

CLEANFRUIT is a cost friendly alternative to all the mentioned solutions, for the end users. SME partners joined this project because they believed that it is a good way to solve the problems mentioned, and wanted to be the part of this promising opportunity as end users, or as resellers. The fact that they plan to deliver further field tests related to it, and improve the system itself shows that they consider CLEANFRUIT useful and worth investing in it. After the improvement is going to be over, all the partners plan to implement it, because they consider it as a good tool to reach more profit, to gain more customers, and grow their companies, in every meaning: manpower, machinery and market.

2.Selling, or renting out the system to third parties

All SME partners are owners of the project results, so (according to the Joint Ownership Agreement) all of them will benefit somehow from the commercial use of it. A market scope was done related to the project, and considering the results of it, the following scenario looks feasible:

The figures included in the business plan are promising. These numbers look capable to ensure the growth of the SME partners of the project, which will mean more profit, more workplaces, and a bigger market for them.

INDIRECT IMPACTS

The growing market of organic products is a good target to aim on, because it provides a stabile role in the more-and more competitive food industry. The European society is open to such sustainable solutions which are not endangering their health. It is enough to think about the food issues which shocked the public in the close future, and the process that even the great chains which are 100% profit focused opening to the healthy food options. Free range chicken, organic fruits and vegetables now could be found in almost every store, in a growing number. Generations are growing up who have the chance, (even if they live a big city and have no chance to "meet" the source of agricultural products) to choose between organic and chemically treated food. The growing market definitely means growing income to the end user SMEs. One does not have to be an economic to see the good business case in this whole process.

The growing income generates the need for more employees, which is good answer to the problem of unemployment, and the migration from rural territories to urban places, which is usually rooting in the lack of workplaces. It is also considerable, that working in agriculture is also good answer to the problem of the handicapped groups, who suffer a lot from the problem of unemployment, women, (especially after maternity leave), Roma people, physically or mentally disabled and undereducated people.

Creating workplaces, and providing the future of the people living in the country is crucial, because it is a way to put a stop to the demographical problems of Europe too. Many women living in a village has no opportunity to work after having a baby, because there are no local nursery schools, and commuting kills too much time, and there would be no chance to look after their children. Having an opportunity to work locally would help a lot indeed.

In today's Europe most of the Roma people still have to face prejudice, and segregation. Most of them are undereducated, and this of course is not helping them in finding a job. Without a regular income, they obviously have no chance to live a prosperous life. Because lots of agricultural jobs need no special education, many of the representatives of this ethnical minority could provide a normal life to themselves.

Being disabled many times means automatic refusal in the job market. Many opportunities would open up to these people, if there would more positions in agriculture, indeed. Being involved to the growing phase, the gathering and also the storing could help them to live a full life.

Summarising the above, it is obvious that every solution that strengthens the position of enterprises in the agriculture will strengthen the chances of the people living in the rural areas, and also the chances to stop the constant reduction of the European population, and helps to reach the equal chances to all the handicapped groups relevant.

But we should not forget about the industrial fields which are involved to this area by supporting the end users by providing them miscallaneous goods, and services. Farming tools, vehicles, equipment for the storehouses, etc. It is visible, that the role of these industrial actors are also crucial, and because of the growing need for the services, goods will result a higher profit in their companies as well.

And finally, one of the most important advantage of using CLEANFRUIT is the fact, that it does not pollute nature, so it causes no ecological footprints, of which Humanity should get rid of later on. Using pesticides caused, and still going to cause so many harm to the quality of our waters, and soil, which are still not nown fully. The environmental remediation, and the treatment of the people poisoned by the tosxics which are in the food, cost much more, than the profit realized by the farmers who used the chemicals, to get rid of the pests.

DISSEMINATION ACTIVITIES

Considering the relevance of the conferences during the project duration the Consortium decided to participate the following events:

-Research Connections 07-08/05/2009, Prague, Czech Republic, (a poster was created, and it was presented at the Conference)

-8th International Symposium on Fruit Flies of Economic Importance, Valencia (Spain), 26th September-1st October. The members delegated Mr. Attila Uderszky and Mr. Szabolcs Gyarmati (MFKK), a poster was designed and printed, and fliers (300 pcs) as well for the very event.

A number of international exhibitions and fairs have been identified that could serve as optimal ground for dissemination beyond the lifetime of the project.

Nevertheless, the Project web site (cleanfruit.mfkk.hu) already provides general information about the Project, a description of the partners and news.

The website also contains a private section in order to facilitate exchange of information and communication between the partners. At present, all the consortium partners are evaluating opportunities at national and international level for ensuring a swift dissemination of the results, as soon as the results are mature enough for that purpose.

After being informed about the project results, and participating the field test in Slovakia, SME partners declared their plans for disseminating CLEANFRUIT to a wider audience, but in their point of view, further tests are necessary to provide more authorised results to the public. Members of the Consortium all agreed in following the R&D activity according to the Prototype. They also accepted the idea to submit a proposal in the close future, to get financial contribution, to widen the demonstration activity.

EXPLOITATION

The SME partners have initially identified IPR (intellectual property rights) emanating from the project (foreground), and considered either protecting the whole CLEANFRUIT technology or distinct modules that can be related to individual work packages. The areas identified have been:

-The complete prototype of the CLEANFRUIT system.

-The pulsed RF system that will provide a non-thermal disinfestation method for a large scale of fruits and vegetables.

-The prototype will be a flexible device so that it can be tuned to specified commodities and pests.

-This method combined with the conductive solution spraying system.

-The measurement data gained from the laboratory and field trials regarding to different fruit and pest pairings.

The protection of the CLEANFRUIT technology by a patent is the first option that the consortium investigated, considering that patent protection is solid and provides a clear competitive advantage to its owners (the SMEs). At the same time, patents can only be granted for inventions which are new, imply an inventive step and are capable of industrial application. A thorough investigation of the state-of-the-art should be implemented within the next half year to reveal any patents or publications that could destroy the novelty of the CLEANFRUIT technology, as developed in the project.

Trade marks protect the commercial sign under which a product or service is offered on the market. The name -CLEANFRUIT is already used by a web site which offers reviews of the performance of the development work; moreover, the name -CLEANFRUIT for a technology such as the one developed by the project could be considered descriptive and could thus be refused at the trademark examination process. Considering the above, the SMEs are considering looking for an alternative name and logo, should they decide to commercialize the technology, and apply for a Community trade mark in order to identify the technology on the market. The relatively low cost of Community trade mark applications (covering the whole of the EU), as well as the relatively easy application procedures will allow the SMEs to rapidly and effectively protect their commercial sign if the technology is launched on the market.

Finally, an alternative option for protecting the technical aspects of the technology (instead of or complementary to a patent) is the trade secret. According to most national legislations in the EU, trade secret protection applies for information which has a specific commercial value (and that is the case of the CLEANFRUIT technology and the know-how for its operation) and provided that its owner takes concrete steps for protecting the secret. In this regard, all partners of the CLEANFRUIT consortium are aware of the importance of treating confidential information as such; all publication and other dissemination activities are revised by the Exploitation Committee in order to ensure that key information regarding the technology will not be available to third parties; and the Exploitation Committee is ready to provide the partners with a confidentiality agreement to be signed with any third parties (such as potential licensees or collaborators) which may have access to the confidential project results.

The SMEs agreed that it would be more beneficial to wait for more detailed results related with the ongoing project tasks and obtain more detailed knowledge on the technical performance of the product before formulating a much detailed Exploitation Agreement.

As mentioned before, the Consortium members decided to look for further cooperation, so they plan to take part in new, common projects, to find more fields of usage for the system, and more possi bilities of financing the R&D process.

However, the major initial IPR rules to be stated in the Joint Ownership Agreement have been already discussed by the SME partners and agreed upon:

-The SMEs are the joint owners of all results, information, data and know-how generated by the CLEANFRUIT Project, all in accordance with the rules applicable to the Project.

-Th e SMEs wish to enter JOA to determine their respective shares of the Joint Foreground and the principles for managing the Joint Foreground, including carrying out Further research, Third Party Research and Commercial Use related to the Joint Foreground.

-Th e SMEs agreed to own the Joint Foreground in equal shares.

-The SMEs shall enter into good faith discussions and take such steps as may be required to protect the Joint Foreground by patent, including keeping the Joint Foreground confidential and delaying any publication or other dissemination activity if such activities are likely to prejudice the protection and/or the Commercial Use of the Joint Foreground.

-Each SME may take action for infringement against any Third Parties that infringe the IP rights of the Parties on the Joint Foreground. An SME who takes action for infringement against such Third Parties shall notify the other SMEs of the action that has been brought and the SMEs may mutually agree on additional measures and actions to be taken against such infringing Third Parties.

-Each SME shall have the irrevocable and worldwide right to use the Joint Foreground in all kinds of Further Research activities, including Third Party Research. Each SME is free to undertake Further Research and Third Party Research on the Joint Foreground without notifying or compensating the other SMEs in any way.

-Each SME shall have the irrevocable and worldwide right to carry out Commercial Use of the Joint Foreground, alone or in cooperation with Third Parties, including the right to grant non- exclusive licences to the Joint Foreground (including the right to sublicense) to Third Parties.

-Any SME that intends to carry out Commercial Use shall notify the other Parties in advance.

-Nevertheless, the other SMEs shall not have any right to request compensation for such Commercial Use or to have a share in the benefits generated by such Commercial Use or to object to or to block such Commercial Use carried out by an SME.

-Any SME carrying out Commercial Use in cooperation with Third Parties shall take reasonable steps and sign agreements in order to ensure that the Third Parties will observe and perform all confidentiality undertakings.

-Exclusive licences of the Joint Foreground to Third Parties shall always be agreed and approved by all the SMEs in written.

-Any Enhanced Foreground generated by modifications, adaptations, updates, corrections, upgrades, enhancements and developments of the Joint Foreground shall be the ownership of the SME or the SMEs and/or the Third Parties participating in the Further Research, Third Part research or Commercial Use activities under which Enhanced Foreground is generated, according to their agreement.

-Each SME undertakes to treat the Joint Foreground as confidential and use reasonable endeavours to procure that the same be kept confidential for a period of 5 (five) years as from the Effective Date.

-Each SME may, at any moment, assign its share of the Joint Foreground. Such SME shall inform the other SMEs of its intention to assign its share and the other Parties shall have a right of pre- emption for a period of three months from the notification of the intended assignment.

-The use of a trade mark as a form of legal protection has also been agreed on. It will consist of a distinctive product name and a logo under which partners will be selling the product.

-Potential licenses may be granted for developers of alternative applications.

List of Websites:

http://www.cleanfruit.eu