LIFE Project Number

LIFE15 ENV/GR/000257

LIFE PROJECT NAME or Acronym

LIFE-F4F (Food for Feed)

Data

Action:	B3: Initiating, Operating and Optimising the F4F System
Partner:	ALL PARTNERS
Deliverable:	B3.1 Data, results and feed produced, during the initiating operational period

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1. Initial operation period of the F4F project

The main objective of this period is the operation of the F4F system under real conditions, aiming to determine the operational parameters including performance and operational costs, as well as to identify possible short comings, problems, limitations and required technical additions or improvements to the original idea and set up.

The operation of the F4F system process includes collection and treatment, where evaluation will take place in Actions B4, B5 and B6.

In this action, as the pilot unit of the project has been successfully completed and is fully operational during this period it is anticipated that the other two periods of the project will be completed as foreseen and no delays are now expected by partners.

1.1. Trials by partners before the fully construction of the pilot unit in the facilities of the pilot unit (May 2018 – June 2018):

The pilot unit has been fully completed at the end of May 2018 and the official acceptance by ESDAK was at the end of June, 2018. However, partners at the first days of May and in order to save time and to test the operation of the pretreatment unit equipment started some trials only in the pretreatment unit (as the solar drying unit wasn't still completed). The operation of only the pretreatment unit lasted from the first days of May till end of June, 2018, where the solar drying pilot unit has been officially accepted by ESDAK. From the collection of food wastes collection from the four cooperative with the project hotels during this period about 44tn have been collected.

This action carried out so as composition analyses under real circumstances, hand sorting and physicochemical analyses of the collected first material to take place, after thermal drying of the pretreated product in the facilities of TEIC. The solar drying unit has been completed at the end of May, 2018 and during June 2018 the solar drying turners were also completed.

All trials that carried out during the period before the construction of the pilot unit (trials that partners have implemented the period before the start up of the pilot unit operation) have been analytically described by all partners in their actions respectively.

1.2. Trials in the fully operational pilot unit:

The official first initial operational period of the project started on 1st of July, 2018 until 31st of October, 2018. This is a 12 month delay of the project and a 4 month operation under real conditions. During this period about 105tn of food wastes have been collected from the hotels. In total, from the first days of May till the end of October, 2018 about 150tn of food wastes have been collected and pretreated in the pilot unit. From this quantity the 105tn have been treated in the solar drying unit. During this period, many different drying tests in combination with weather conditions, the use of the under floor heating system and the testing trials on the use of the drying turners carried out. Samples for analyses sent to all partners and two composition analyses carried out in this operational period.

Concerning the drying tests into the pilot unit, from the 1st of July, 2018 till 3 of August 2018 partners have transfered into the drying halls the collected pretreated food wastes from hotels. During this period about 25tn of food wastes have been hand sorted and the first days of August partners have removed about 3tn of solar dried product. This was the first testing period in order partners to check the solar drying procedure. This product hasn't been used by partners.

From the 6th of August partners started the next drying period until 15th of September, 2018. During this period about 42tn of hotels food wastes have been pretreated in the pilot unit. Partners have tested the turners, the drying rate and the optimum management of the drying product. This product also hasn't been used by partners.

From the 17th of September till 17th of October about 26tn of food wastes have been transferred into the pretreatment pilot unit. The drying rate from the drying product of this period is being presented on the following table. This is the final product from the pilot unit which has finally been sent to the partners on 5th of November, 2018 for more analyses. In the Tables below the drying rate in the two different drying turners is being presented.

Table 1. Drying rate in the solar drying pilot unit during September – October, 2018 – Horizontal turner

Drying (days)	1st day 17/09/2018	2nd day 18/09/2018	4th day 20/09/2018	8th day 24/09/2018
Moisture (%)	68%	64%	40%	15%

Table 2. Drying rate in the solar drying pilot unit during September – October, 2018 – Vertical turner

Drying (days)	1st day 22/10/2018	3rd day 24/10/2018	8th day 29/10/2018
Moisture (%)	67%	66%	64%

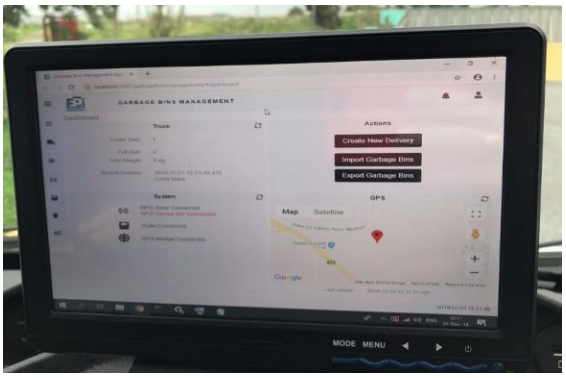
From the Tables above occurs that the horizontal turner has a high drying rate, particularly satisfactory for the management of this specific food waste product. The fact that the product's moisture within a week can be reduced to a final percentage of about 15% is very encouraging, taking into account that this rate was during autumn. Partners are very optimistic about this drying procedure for the next operational period. It also has been proposed by partners to investigate the possibility of thermal drying of the product from a moisture content from 30% to 10-12% at 90° C in order to achieve final product pasteurization and a faster moisture rate reduction.

1.3. Description of the operation and final product

Food wastes collection system: The collection of the food wastes was on a daily basis, except Sundays. The relevant contractor has placed into the hotels' kitchens green bins (70lt each) for the collection of the food wastes, into plastic bags. These bags were removed into brown bins (240lt) and then were transferred into the refrigerator truck. Empty and clean bins were placed in the truck for replacing those used by hotels. The refrigerator truck has a weighting system so as partners to be able to kwon the collected food waste quantity by each hotel per day. After the collection, the contractor from the collection service with the relevant personnel transfers the bins into the pilot unit.

Pretreatment unit: After the collection of the food wastes, each bin was emptied into the pretreatment unit on the conveyer belt, where personnel was hand sorting foreign objects from the food wastes, such as metal, glass, paper, etc. At the end of the belt and after the hand sorting, there is a shredder for the shredding of the food wastes. The pulp after shredding is being collected into an inox hopper and then this pulp is being disposed into a worn which supplies the pump. This pump is being connected with a pipe proper to be used for food. The pulp through this pipe is being transferred into the solar drying halls of the solar drying greenhouse.

In the pictures below the refrigerator truck, the bins, the pretreatment and solar drying unit are being presented.



Picture 1.Refrigerator truck for food waste collection with hydraulic lifting system and GPS

Picture 2. Green bin (70lt) placed in the hotels' kitchens

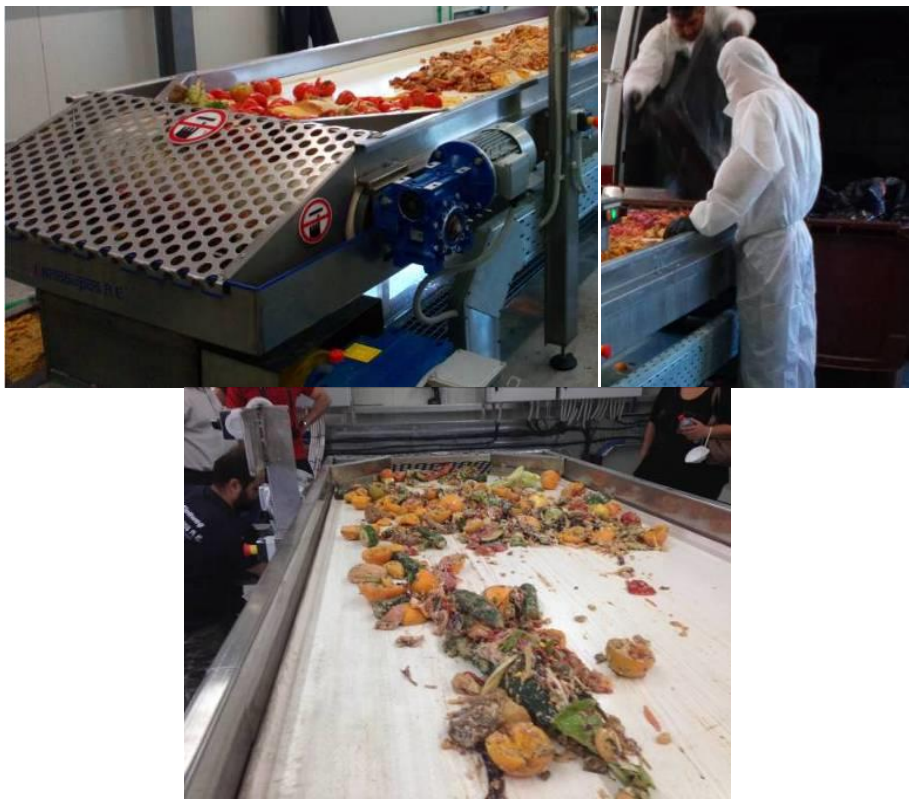
Picture 3. Brown bin (240lt) for the collection of the food wastes from the green bins. This bin is being transferred into the pilot unit.

At the entrance of the truck into the bio-drying MSW unit of Municipality of Heraklion was being weighed on the unit's weighbridge and then parked outside the pretreatment unit of the F4F pilot unit.

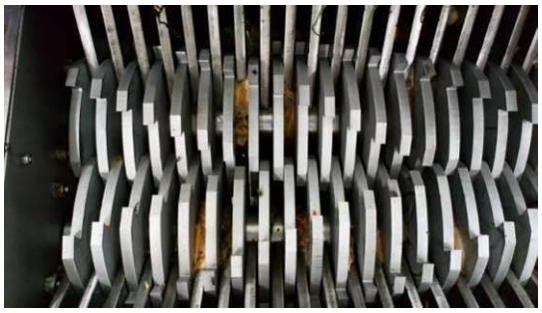
Picture 4. Weighbridge in the bio-drying MSW unit and weight recording unit

Picture 5. Refrigerator truck in the F4F unit

Picture 6. During transferring food wastes from the collected from hotels bins into the pretreatment unit



Picture 7. During hand sorting on the conveyor belt in the pretreatment unit



Picture 8. The grinding, after the conveyer belt

Picture 9.The pulp after grinding

During solar drying of the shredded food wastes: At this stage, the food wastes after hand sorting and shredding they were forwarded through a pipeline into the solar drying halls. The application with the pipeline of the pulp into the drying hall was made by hand in different areas and in different height of this material so as the drying rate to be checked. Moreover, during the reference period the horizontal turner has been checked in different parameters so as to determine the optimal rate of the operation of the turner and to proper program the automation of the turner in combination with the operation of the underfloor heating system and the weather conditions. In the pictures below it is presenting the drying process into the drying halls.

Solar drying unit – operation of the turners: During this first initial operational period of the pilot unit and concerning the operation and optimization of the solar drying turners, tests were carried out in order to investigate the optimum time and operation drying mode. These different trials on the duration of turning, the rate of turning, the height of the drying material and other parameters, with two different types of drying turners (one horizontal and one vertical) were carried out so as the better results for the drying material to be found. The ultimate goal is the best conditions for managing the produced product with the best quality features to be found.

- ✓ **The horizontal drying turner**

This turner was delivered on the pilot unit at the end of June, 2018 and it was fully functional from July, 2018. During the first initial operational period for the optimum programming of its automations many tests have been done. This drying turner has been programmed to execute two different turning systems. The first one was the batch reactor operation and the second one the continuous operation.

According to the **batch reactor operation** the turner from the starting position performs only one function scans once the drying hall and then rises and returns to the original start position. In this way the material moves during drying from the drying hall from the entrance to the end of it. In this way, the different materials per day were not mixed and the drying rate is higher.

In contrast to the previous one, with the **Continuous Operation System** the turner scans along the drying hall from the start position to the end of the drying hall and then vice versa. In this way the different materials (from the different days) remain in the same position within the tank and to some extent they are mixed. The scanning time of the tank for both moves, back and forth, takes place within 30 minutes. The scanning of the tank is repeated per hour. During this operation system the feeding of the drying hall takes place at different points into the hall, manually.

For the movements of the turner an automation program has been designed, based on which the rotor is activated every hour and the running time lasts for about fifteen minutes. This time is required by the turner to scan the drying tanks once.

✓ **The vertical drying turner**

This turner was delivered on the pilot unit at the end of June, 2018. During the first initial operational period for the optimum programming of its automations many tests have been done. The main movements of this drying turner are the following:

- Clockwise movement of the stirring screw (to lift the material upwards)
- Movement of the stirring screw to the width of the drying hall
- Movement of the stirring screw to the length of the drying hall (one step forward, as the diameter of the screw) in order with the combination of all these movements to scan the whole surface of the drying hall.

In order to scan all the drying hall surface this turner needs 3 hours. This procedure repeats after one hour stand by.

A meteorological station has also been installed in the area of the pilot unit, so as meteorological parameters such as temperature and moisture to be monitoring. The recording of these parameters is crucial as the operation of the funs and the windows are related with the weather conditions in order into the solar drying unit the better conditions to prevail.

In the pictures below the operation of the drying turners into the solar drying unit is being presented.

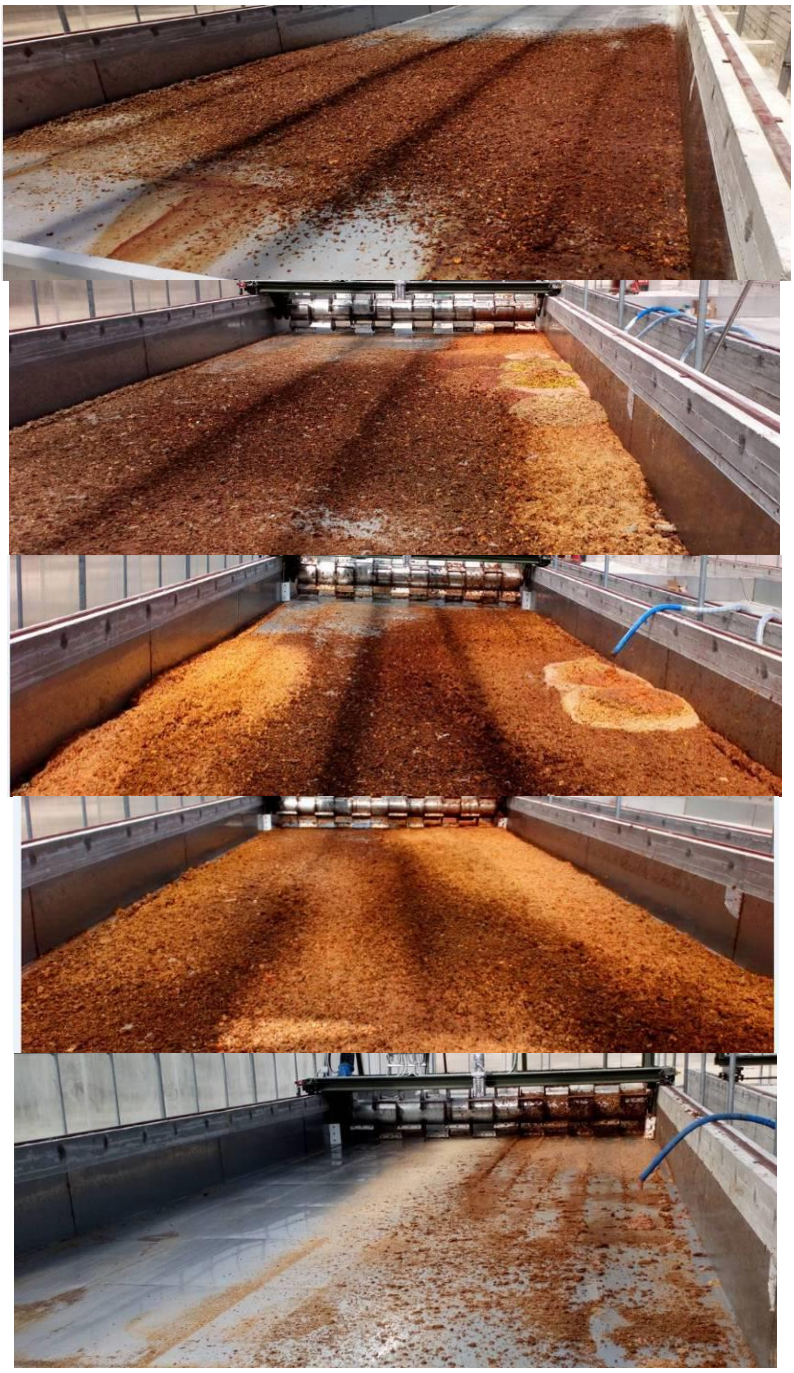












Picture 10. During feeding the solar drying halls in the solar drying greenhouse with the shredded food wastes

From the last and optimum drying tests into the solar drying unit, from 17th of September till 17th of October about 26tn of food wastes have been transferred into the pretreatment pilot unit. The drying rate from the drying product of this period has being presented on a previous Table 1. This is the final product from the pilot unit which has finally been sent to the partners on 5th of November, 2018 for more analyses. From this procedure also occurred that about 1tn of fresh shredded food wastes after drying (15% moisture) is about 250kg. At this final product it was estimated that 5 lt of the dried material was about 3.5kg (0.7 Kg/Lt). From the final product about 100kg have been sent to AUA and 150Kg have been sent to FUB for

more analyses on 5th of November, 2018. This is the SAMPLE code 1(5/11)_final2018.

Picture 11. The final product after solar drying in the F4F pilot unit sent to partners

Picture 12. Packing of the final solar dried product of the F4F pilot unit

Picture 13. Samples from the final product sent to partners

Picture 14. The final product of the first initiating operational period of the LIFE-F4F project

2. Problems encountered during this first operational period and Suggestions for technical and operational optimizations

During this reference period, from the operation of the F4F Pilot all the individual problems that have been arisen were recorded by partners, for both the pretreatment and the solar drying unit. In each case partners tried their bests in order to find out the optimum solutions and suggested technical and operational additions/alterations for the optimum operation of the pilot unit. All partners will try their best so as all the proposed alterations to be concluded until the start up of the 1st full scale operational period, which is expected on May, 2019.

The most significant problems identified by partners during this operational period are being presented in the following paragraphs:

- **The input food wastes purity.** Beyond food wastes, during hand sorting personnel have located materials such as glass, paper, cardboard, toothpicks, plastic wrapping film, etc. All these materials create important problems not only in the final product which cannot be used, but also in the mechanical equipment of the unit. In the picture below materials that are forbidden for the production process of the projects' pilot unit are being presented.

  The training of hotels' kitchen personnel on how to correctly sort at the source their wastes and the proper management of their food wastes (a great deal of attention to what they reject into the project's bins) is a key factor in the optimal operation of the plant and in the production a product with high quality characteristics.

Picture 15. Materials that should not get into the production process of the project.

- **Operation of the pretreatment unit mechanical equipment:** as it was foreseen, into the pretreatment unit there was a hand sorting conveyor belt, a shredder and a pump. However, problems during feeding the pump after shreddering were encountered. These problems were not only due to materials that have passed from the conveyor belt to the shredder (such as small glass items or toothpicks, which couldn't be seen by hand sorting personnel etc) but also due to some food wastes (such as orange, potato and watermelon peels) which couldn't be shredded is items smaller than 1cm. This had as a result blockages and damage to the mechanical parts of the pump to arise. During attempting to solve these problems of the pump, it was found that the shredder couldn't sufficiently graft some categories of some food wastes (orange peel, watermelon, potato, carrot, leafy vegetables etc.). This had as a result difficulties during feeding of the pump, as these large particles pass through the pump, causing blockages. To deal with this problem partners (in cooperation with a mechanical engineer of the pump supplier), it was suggested to add a screw after the shredder in order to better promote the material and feed the pump more efficiently.

Picture 16. Problems during some kinds of food wastes shreddering

Picture 17. Screw placed after the shredder and before the pump

To avoid any blockages of the pump, it is suggested by partners the hand sorted food wastes after grinding to be pulped in order the final product before drying to be as a pulp so as to significantly reduce the granulometry (3-7mm) of the materials. This product texture is much better manageable in the drying unit, homogenous, with better drying rate. Moreover, the use of a screw (which has already added in the main equipment of the pretreatment unit) helps to easily feed the pump with this pulp. The use of the shredder in combination with the pulp and the screw will achieve better uniformity in the final product. It is therefore proposed to additionally add a pulverizer, which will be placed after the shredder. Using the pulverizer, the final material to be dried will have a 3-7mm particle size.

Picture 18. Suggested pulverizer

- **Under floor heating system in the drying halls:** During the reference period and as the temperature of water in the floor heating system which was written down by sensors, it turned out that this temperature was about 45-maximum 50^{o}C. As it has been arisen from trials that partners carried out the previous period (drying rates before the pilot unit construction in TEIC) this temperature for better results (so as not to cause alterations of the product's quality during drying due to microorganisms growth) has to be more than 50^{o}C and about 55^{o}C or 60^{o}C if this is possible. The temperature inside the greenhouse is also among

45-50^{o}C in a shinny day. So, in order to be able to increase the product's temperature partners have to reinforced the underfloor heating system so as to contribute to faster and better drying rate of the material under conditions that will not alter its physicochemical characteristics. For this reason, it was considered necessary a heating pump and 5 more solar collectors to be installed (which were not initially foreseen), in order to enhance the underfloor heating system for better efficiency and acceleration of the materials drying rate.

Picture 19. Temperature indication for both solar drying halls

Picture 20. Heating pump

3. Proposals for the optimization in the construction and operation of the pilot unit

After the completion of the first operational period of the F4F project, in brief, the following are proposed by partners so as to optimize the operation of the pilot unit:

Suggestions for the pilot F4F unit:

- Additional equipment in the pretreatment unit for better grinding. A screw which partners have already added and a pulverizer, following the shredder, which has been routed by partners for the next operational period of the project.
- Additional equipment in the floor heating system (heating pump and more panels). This action has already been routed by partners and the pilot unit the next full scale operational period will be supported by this extra equipment.
- Additional insects' protection (air curtain) in every door or window in the unit. Partners have already routed this action for the next full scale operational period.
- Mechanisms for automatic door closing. Partners have already routed this action for the next full scale operational period.
- Additional thermal drying after the solar drying of the end product, in higher temperatures for pasteurization is being proposed by partners and they will investigate this option. More specifically, they will investigate the moisture reduction rate into the solar drying halls up to 30% and then they will try to use a thermal dryer so as to reduce the product's moisture up to 10-12& at 90° C in order to achieve final product pasteurization and a faster moisture rate reduction
- Use of organic acids for the products' disinfection. Partners will also try to investigate the use of organic acids the next two operational periods of the project.

Suggestions for a full scale F4F unit:

- Refrigerators in all cooperative with the project hotels' kitchens for storing the food wastes
- Different material for covering the drying halls (not inox). Partners already investigate the use of epoxic floor for better heat transmission and better material management
- Optimization of the solar drying turners
- Smaller solar drying halls in the solar drying unit (or separation in apartments)
- Lower height greenhouse

All these proposed alterations are also being presented in the mid term report, in paragraph 6.3. Evaluation of Project Implementation.