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PDAPP: DIGITAL SOLUTIONS FOR PREVENTING FOOD WASTE IN THE HORTICULTURAL SECTOR

H. Barco Cobalea
Researcher. F. Espigoladors. El Prat de Llobregat, Barcelona

N. Zurro Sánchez
Project Technician. F. Espigoladors. El Prat de Llobregat, Barcelona

P.Castro Castrechini
Project Technician. F. Espigoladors. El Prat de Llobregat, Barcelona

B. Vidal Monés
Research and Knowledge Officer. F. Espigoladors. El Prat de Llobregat, Barcelona

Raquel Díaz Ruiz
Director. F. Espigoladors. El Prat de Llobregat, Barcelona

A. Ginestá Anzola
R&D Technician. Environment Department. CETENMA. Cartagena

A. Pagán Muñoz
R&D Technician. Environment Department. CETENMA. Cartagena

Álvaro Areta García
Coordinator of Farmers and Livestock Organizations (COAG). Madrid

R. Martínez Vázquez
Urban Ecosystems and Industry Researcher.
EnergyLab Technology Center. Vigo

M. M. Pérez Martínez
Urban Ecosystems and Industry Researcher.
EnergyLab Technology Center. Vigo.

A. Casalderrey Area
R. Martínez Vázquez. Software Engineer.
EnergyLab Technology Center. Vigo

D. Ugalde
CEO. Oreka Circular Economy. Bilbao

Abstract: Food losses and waste (FLW) are a problem that has a negative social, environmental and economic impact. However, there is still a great lack of knowledge and few incentives for its prevention. In Spain, an opportunity for its reduction is opening up through the future law on food losses and waste, which will oblige food companies to have plans for its prevention, among other measures. To facilitate the adaptation of companies to the new law, the PDApp Operational Group has created a consulting service based on digital tools: PDApp. Its platform speeds up the implementation of prevention plans, optimizes decision making and proposes alternatives for surpluses, encouraging exchange and revaluation under circular economy principles. The results of the tests show PDApp's potential to facilitate the adaptation of food companies to the future law, reducing their economic losses and environmental impact.
Keywords: Food losses and waste, Circular economy, innovation, sustainability, Marketplace, prevention, traceability.

INTRODUCTION

The magnitude of the problem of food loss and waste (FLW) along the entire agri-food chain was clearly demonstrated by the FAO study in 2011 (Gustavsson *et al.*, 2011), which concluded that 1 out of every 3 kilograms of food produced on the planet is not consumed by people, is wasted and sent directly to landfill, among other destinations.

First of all, this problem generates a negative impact at the social level, since while generating these FLW figures at the global level, FAO et al. (2025) estimates that between 713 and 757 million people in the world went hungry in 2023, 8.9-9.4% of the world's population. When compared with the 2019 figures, it is concluded that there is an increase of around 152 million people in 2023. If the analysis covers all people affected by food insecurity

on the planet, it would reach 2.33 billion people on the planet, 28.9% of the total.

These negative impacts also have an environmental component, since ADPs not only involve the waste of essential resources for food production, such as water and arable land, but also lead to the emission of greenhouse gases, without these foods ever fulfilling their purpose of feeding people (FAO, 2013)

Another negative impact to highlight would be the economic one, since these discards are foodstuffs that could never be sold by the producer. As an example, we can highlight a study related to the Valencian persimmon (Fernandez-Zamudio *et al.*, 2020) where it was shown that 29.5% of all persimmon produced did not have an adequate economic remuneration to the farmer.

Despite all these impacts, the FLW issue is still little known by the general public, even at the level of management by public administrations (at local, regional and/or national level), as concrete figures on what quantities of FLW are being generated in each territory are unknown (Xue *et al.*, 2017).

To address the FLW in the first stages of the agri-food chain, the consortium of the "PDApp" Operational Group has been created, made up of the entities Fundació Espigoladors, as representative, CETENMA (Technology Center for Energy and Environment), as technical coordinator, OREKA, EnergyLab, COAG and companies from the agricultural sector such as Cooperativa Agrícola Conca de la Tordera, Kiwi Atlántico and Jimbofresh.

This initiative will have a fundamental possible future regulatory support: the future law on food losses and waste (Government of Spain, 2024), which is currently being processed at the national level. This new law could be an element that helps to quantify and understand these figures from the primary to the wholesale sector and, above all, to minimize them. To this end, one of the core elements of the future national law is the obligation to have food loss and waste prevention plans for all food companies, along the entire chain: from production to final consumption.

The "PDApp" Task Force considers that these plans can be a great opportunity for the sector since, firstly, they make it possible to establish diagnoses at the company level that facilitate the identification of possible problems related to food losses and waste and, secondly, to use this information to facilitate decision making and minimize these discards.

In addition, these plans are not intended to be a tedious administrative burden for companies, but represent an opportunity to establish new ways of cooperation between entities, within the current framework of the Circular Economy. In this way, food surpluses or discards that have no value for some companies can be valuable resources for others.

OBJECTIVES

The main objective of this Task Force is to reduce food losses and waste in the fruit and vegetable sector through the development of new services supported by digital tools. In order to achieve this general objective, the following specific objectives have been proposed:

- SO1. Diagnose food losses and waste in the fruit and vegetable sector.
- SO2. Facilitate the implementation of prevention plans for FLW in the primary fruit and vegetable sector.
- SO3. Facilitate decision making for FLW prevention based on sustainability criteria (environmental, social and economic).
- SO4. To provide alternatives for the prevention of horticultural FLW following the hierarchy of food uses adapted to the sector and the territory.

• SO5. Raise awareness and sensitize companies in the fruit and vegetable sector to the importance of reducing FLW and its quantification.

METHODOLOGY

To achieve the main objective of PDApp, a program has been designed based on the development of a total of 7 work packages, which in turn respond to the 5 specific objectives mentioned above. These work packages (WP) are the following:

- **WP1. Platform design and coordination**. This WP is associated with SO2 and SO4. The platform offers two services: on the one hand, the development of prevention plans, and on the other hand, the exchange between entities for the valorization of food. This implies a different user experience, one for the surplus generating companies and another for the receiving entities.

The needs of the sector have been identified and the technical assistance and personalized support for the services have been defined, as well as the professional profile and skills of the people who will fill this position.

Finally, a technical and economic feasibility study has been carried out for the scalability of the PDApp platform and the search for a business model.

- **WP2. Conceptual design of protocols for the elaboration of the Food Loss and Waste Prevention and Reduction Plan and measurement of FLW in the fruit and vegetable sector**. This work package is associated with SO1 and SO2. Through a qualitative assessment, identification of the causes and critical points within the sector, the quantification methodology and protocol for the preparation of prevention plans were developed.

- **WP3. Development of the sustainability tool**. Associated with SO3. The back-end tool developed for the calculation of environmental, social and economic impact indicators is in line with the programming of the existing platform. This part of the tool allows certifying, through the indicators, the impact of the actions implemented by the companies.

- **WP4. Design of a decision tree to structure alternatives for prevention and recovery of existing FLW**. Associated with SO4. The study of existing alternatives from different geographical areas has generated potential options for industrial symbiosis. This makes it possible to put the different agents in contact with each other, thus valorizing their foodstuffs. The generated algorithm allows selecting the destination following the hierarchy of uses, the sustainability tool, characteristics and conditioning factors of the alternatives.

- **WP5. Digital development of the PDApp platform**. Associated with SO2, SO3 and SO4. The development has taken place thanks to the different members of the GO and its collaborators, adapting the programming language to the design of the structure and user experience.

- **WP6. PDApp platform validation.** Associated with SO1, SO2, SO3, SO4 and SO5. Consists in the elaboration of prevention plans and the use of the industrial symbiosis service for the FLW prevention in pilot cases, carrying out exchanges with other companies and social entities, as well as the integration of both services in a single platform.

- **WP7. Dissemination, communication and awareness**. Associated with SO5. The dissemination plan includes a series of dissemination actions in field of "inno-

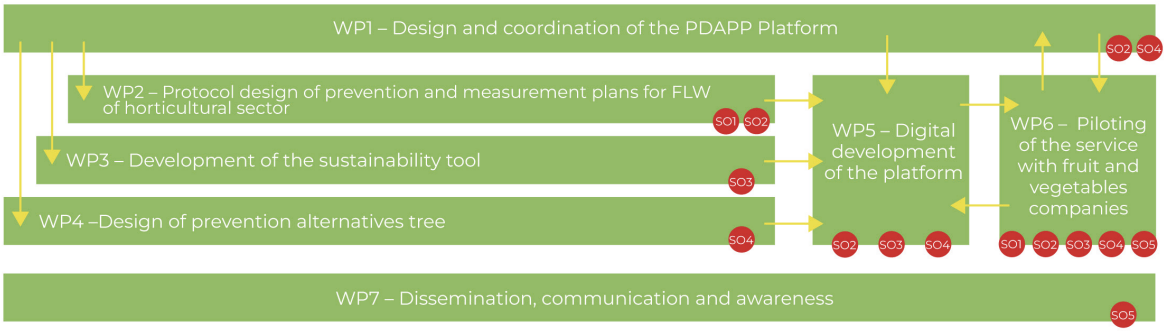

Figure 1. Scheme of the project execution schedule

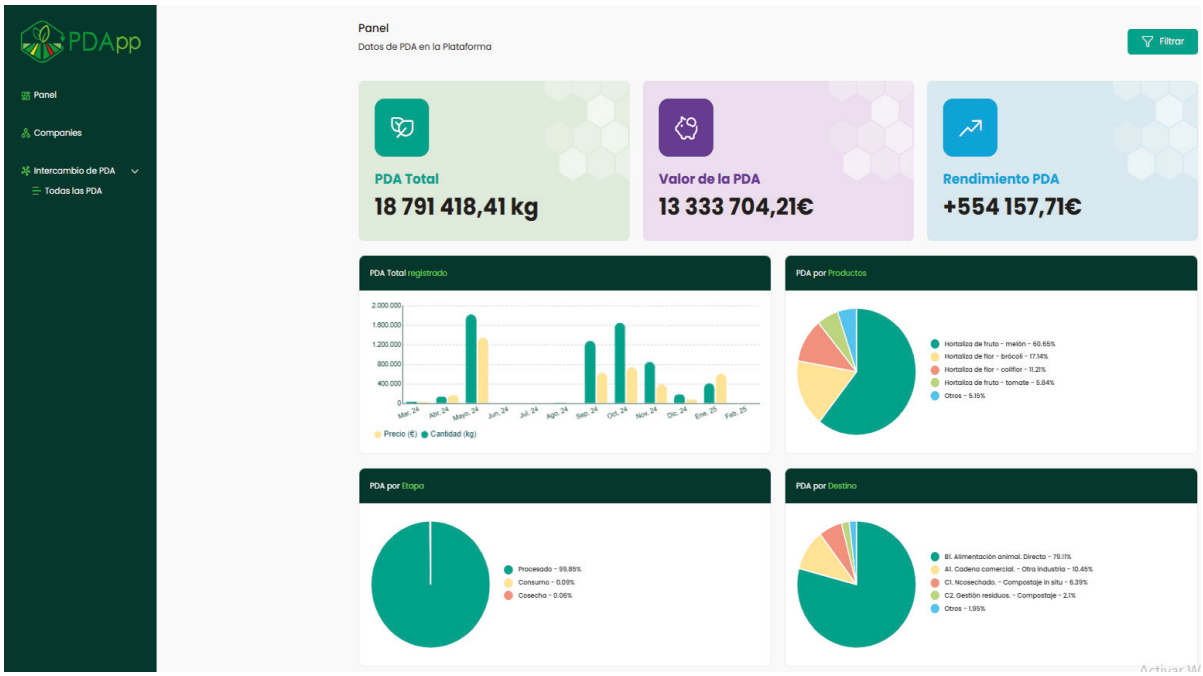

Figure 2. Screenshots of the monitoring system provided by the PDApp tool

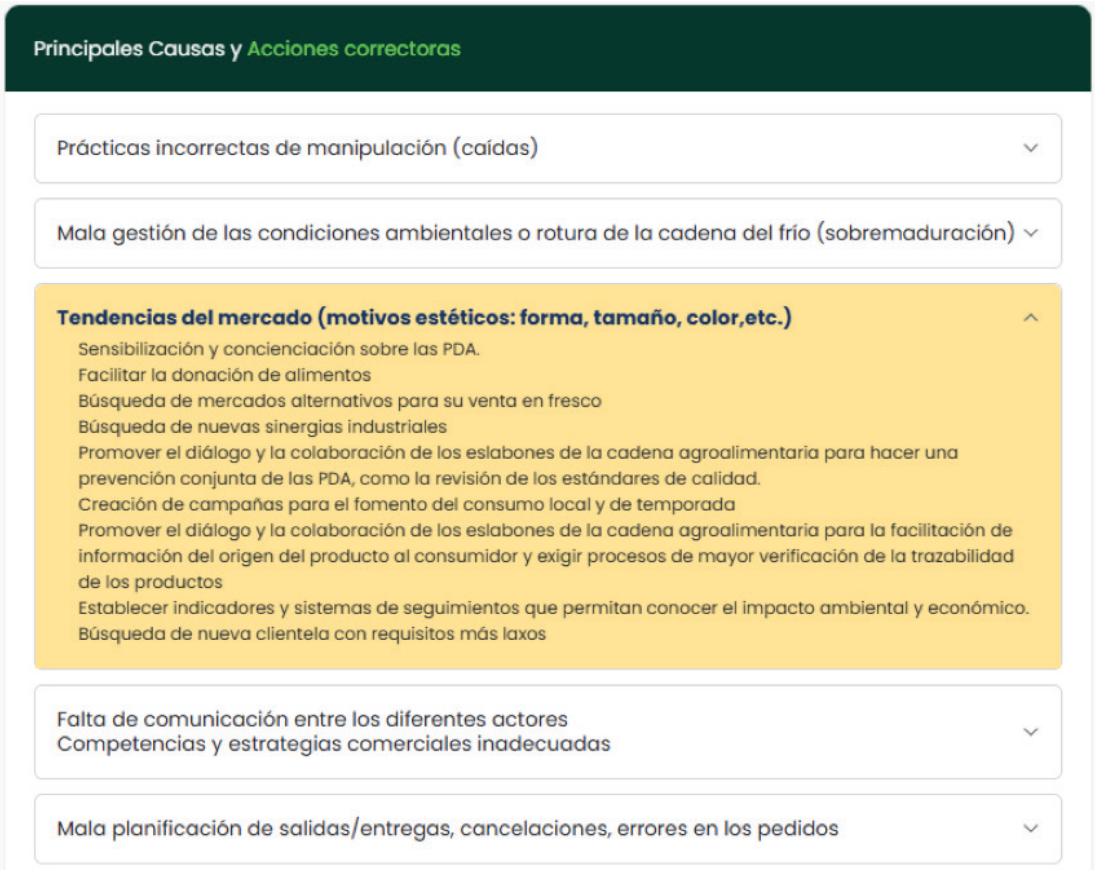

Figure 3. Screenshot of an example of the links between the main causes identified and corrective measures for their prevention provided by the PDApp tool

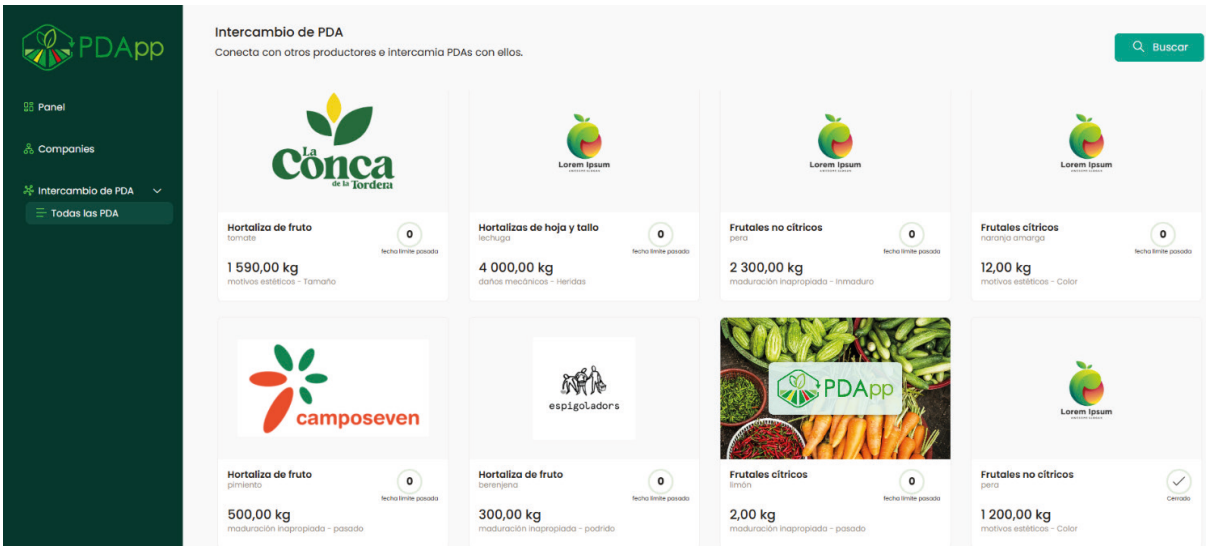

Figure 4. Screenshot of examples of transactions made by the PDApp Marketplace

vation in the agri-food chain" within the fruit and vegetable sector. The priority target audience is farmers and distribution companies, but also all the agents in the supply chain, technological partners, administrations and the general public. The objective is to communicate the EU's commitment to innovation and, in particular, to convey the objectives of the EI-P-AGRI and the commitment of the EU and the Spanish Ministry of Agriculture, Fisheries and Food (MAPA) to these tools. A combination of face-to-face and online communication actions has been planned, maximizing the number of impacts in relation to the investment made.

RESULTS

The Task Force has developed a business advisory service that will be supported by the digital application (PDApp). The PDApp developed facilitates business decision making related to food losses and waste. To this end, this application allows the registration of FLW generated over time. To facilitate the management of this data, a FLW monitoring system has been created in the digital application, simplifying business decision making on this problem (Figure 2).

The PDApp integrates a tool for calculating sustainability indicators based on the Life Cycle Assessment (LCA) methodology. This tool allows companies to quantify their environmental (CO_2 emissions), economic (FLW cost) and social (saved food portions) impact. These indicators are applied both in the initial diagnostic phase and after the implementation of corrective measures, allowing for a periodic evaluation of progress in sustainability.

In addition, the certification system developed within the framework of WP3 allows companies to obtain recognition for their good practices in FLW reduction. This certification is part of a verification model that evaluates the actions implemented and their real impact on waste reduction. In this way, companies can demonstrate their commitment to sustainability and improve their positioning in the agri-food market.

Likewise, thanks to the record kept in the PDApp, it also facilitates the identification of the main causes associated with food losses and waste generated in each of the companies, as well as the provision of solutions to minimize this problem (Figure 3).

This range of solutions provided by the PDApp also includes the Marketplace (Figure 4), an exchange space that facilitates the connection of surpluses with other entities in the sector that can maximize their use, improving the final destination of these discards, in line with the hierarchy of priorities in waste management (De Laurentiis et al., 2024).

This Marketplace system is already in operation and a total of 16,812 kilos have been allocated in 23 exchanges to food processing companies (e.g. the creation of tomato sofrito or zucchini cream) and the donation of 27,951 kilos of food in a total of 51 exchanges with social entities.

The PDApp also provides all the data necessary to generate food loss and waste prevention plans, thus complying with future regulations. Currently, this Task Force is collaborating with companies in the sector that are testing this digital application and communicating with them to ensure that the advisory service can be useful for the sector, facilitating compliance with the future law, but also allowing greater efficiency in the operation of the companies. In fact, as a result of this collaboration, nine FLW prevention plans have been created for companies in the fruit and vegetable sector. Figure 5 shows some examples of surpluses generated in some of the participating companies, so the management of these surpluses and their prevention and/or minimization is the main objective of these prevention plans

Figure 5. Images of some of the participating companies, where the food loss and waste prevention plans have been generated.

CONCLUSIONS

For all these reasons, it can be concluded that these first results of the PDApp are considered promising for facilitating the diagnosis of the problem of food losses and waste throughout the agrifood chain, and especially in the first stages, from production to distribution.

The results obtained so far show that this tool facilitates the implementation of concrete measures for the reduction of FLW in the fruit and vegetable sector. Thanks to the development of this digital application, its usefulness has been proven for data visualization, helping companies to make decisions, and thus allowing the minimization of FLW, either through prevention or by improving the final destination of these surpluses, in line with the waste hierarchy.

The traceability system implemented has significantly improved control over the destination of discarded food, facilitating redistribution and recovery within the framework of the circular economy. The results obtained with the Marketplace show that the exchange of surpluses has made it possible to transform them into new products, increasing their useful life and contributing to the reduction of waste. In addition, the PDApp has enabled the creation of 9 FLW prevention plans for agri-food companies, consolidating its role as a tool for adapting to future state regulations, facilitating their implementation in an agile and effective manner.

The incorporation of environmental, economic and social sustainability indicators makes it possible to accurately quantify the impact of the actions undertaken, facilitating their certification and providing concrete data for the improvement of food waste reduction strategies.

Finally, the development of PDApp has demonstrated the feasibility of a digital tool for the integrated management of FLW, making it an innovative and scalable solution for the agri-food sector. With its implementation, an effective transition towards more sustainable production and distribution models, aligned with the Sustainable Development Goals (SDGs) and the future law on food losses and waste, is encouraged.

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