DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

Sixth Framework Programme

Project no. 032929

Project acronym: DRY CONTROL

Project title: 'Control Strategies for Rotary Driers Dealing with Vegetal Products'

Instrument: Cooperative Research Project

Deliverable 16 PUBLISHABLE FINAL ACTIVITY REPORT

Period covered: from 1st September 2006 to 31st October 2008
Date of preparation: January 2008

Start date of project: 1st September 2006 Duration: 24 Months

Project coordinator name: José Antonio Alcón Gonzalvo
Project coordinator organisation name: Productos Agropecuarios Hnos.OLIVER

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

INDEX

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

PROJECT EXECUTION

DRY CONTROL EXECUTIVE SUMMARY

PROJECT OBJECTIVES

The present project is proposed with the **fundamental objective** of obtaining desiccated high quality forage and vegetable products (percentage of humidity content, protein and ash) based on an efficient process system, capable of applying only the specific amount of heat necessary at each moment to achieve a uniform final product within an established range of quality.

Dehydration of vegetable products can be very complex given great variations in humidity content. The resulting excessive desiccation of the product not only means a greater cost from energy used, but also degradation of the products nutritional content and weight loss which is seen in the final price of the product and in a reduction in the SME's competitivity.

The following **specific objectives** are also intended to be achieved:

- Develop an automated industrial process capable of rapidly adapting to the specific characteristics of the forage and vegetable products as they enter the process in a continual chain.
- Reduce the energy consumption of the drying process by up to 20%.
- Obtain reliable measurements of the principal variables (humidity and protein) throughout the whole process.
- Obtain perfectly controllable quality with reference to percentage protein and humidity content.

As such, this project proposes the following **operational objectives** to achieve the automatic control in the industrial processes of rotary vegetable product driers:

- Develop a prototype reliable measurement sensor for protein and humidity
- Develop a family of process models and algorithms
- To design a real-time controller system to satisfy the problem specifications

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

1.1 CONTRACTORS INVOLVED

The DRY-CONTROL consortium comprises 3 SMEs from 3 countries & 2 RTD performers.

PRODUCTOS AGROPECUARIOS HERMANOS OLIVER – Coordinator

(http://www.grupoenhol.es)

Productos Agropecuarios Hermanos Oliver, a plant operator and end-user, have co-ordinated the DRY-CONTROL project.

Productos Agropecuarios Hermanos Oliver, the original company behind the current Enhol Group, has always strived to stand as a reference point in the farming sector through its continuous process of innovation aimed at process and end-product quality: natural fodder and seeds.

The Productos Agropecuarios Hermanos Oliver plant is now one of the largest forage dehydration plants in Spain, in terms both of production volume -50,000 mt of alfalfa a year- and the amount of land managed 4,500 Ha of crops.
Productos Agropecuarios was the first dehydration plant to apply a continuous quality control system. The plant now has seven NIR analysers at the beginning and end of the each production line, a PLC network, continuous scales, counter and analyser networks and a supervision system (SCADA).
Energy for the plant is provided by an electric cogeneration plant with a power of 3.8 MW. This cogeneration plant, automated by PLC, has seven natural gas-driven motors with which enough thermal energy is produced to cover the alfalfa dehydration process. The electricity generated is used for own use and any excess is exported to the grid.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

DRTS Ltd

(**http://www.drts.co.uk)**

DRTS Ltd specialises in technology transfer projects. They have particular expertise and experience in University technology exploitation and industrial collaborative research programmes.

They add value by helping our customers manage and build systems and services that enhance the effectiveness and reliability of their operations. DRTS provides core technology and capability that unlocks the knowledge potential of unrealised and under-used data assets. They are committed to systems engineering approaches to problem solving.

They have experience and understanding of both the academic and commercial environments and can help find the right balance between the two. They assist commercial organisations seeking to acquire new technology and carry out technical due diligence.

UST

(http://www.ust-gera.de)

The key business activities of UST include application and development of:

- RFID (radio frequency identification)
- Water treatment by UV radiation

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

Initially both technologies don't meet directly the target of the Dry Control Project. Nevertheless, however UST experiences in the mentioned technologies could be applied for solutions of identification of bales using transponders with integrated humidity sensors to increase the effectiveness in logistic issues.

Cemitec

(http://www.cemitec.com)

Cemitec is an innovative Technology Centre (CIT-Spanish Classification) whose mission is to contribute to the improvement of industry competitivity. It is done by developing R&D projects and Technological Services that promote and provide innovation.

Cemitec is focussed on four Disciplines:

- Fluid Mechanics and Thermal Engineering
- Electronics
- Metallic Materials
- Polymer Materials

Cemitec has major experience in the Fluid Mechanic and Thermal Engineering fields. The main activity is focused on:

- Development of Thermal-Fluid systems:
  - Drying technology
  - HVAC systems
  - Electronic's cooling
- Hydraulic components
- Development of Inkjet Technology Industrial Applications

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

GLAMORGAN

(http://www.glam.ac.uk/soeschool/CEPE)

The Centre for Electronic Product Engineering (CEPE) was established to provide support for enterprise, exploiting electronic technologies in both products and processes. It was awarded the status of 'Centre of Expertise' by the WDA in 1994, and appointed as 'Centre of Excellence' in 2001. CEPE supports industrial clients in Wales and elsewhere in the fields of microelectronics, electronic product engineering, information technology and related fields.

The **services** provided by CEPE include expert advice, feasibility studies, technology transfer, design reviews, product and process development, training and contract research.

CEPE places special emphasis on its role as a **technology transfer centre** to stimulate the use of microelectronics technologies and facilitate their transfer to industry, especially small companies. To fulfil this mission, CEPE actively contributes to regional programmes, national initiatives and European projects. It is widely recognised as a **major driver** of UK and EC microelectronics technology transfer programmes, which makes it ideally placed to locate funding sources for industrial collaboration.

The **Advanced Control and Network Topology (AC&NT) Research Unit** specialises in advanced control theory, technology and applications. The unit is engaged in fundamental theoretical research as well as industrial applications, covering the themes of networked control systems, fuel cell modelling and control, nonlinear identification and control, and multiobjective optimal control.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

ParticRole	ParticType	Partic no.	Participant name	Participant short name	Country	Date enter project	Date exit project
CO	SMEP	1	PRODUCTOS AGROPECUARIOS HNOS. OLIVER	OLIVER	SPAIN	Month 1	Month 26
CR	SMEP	2	DEPENDABLE REAL TIME SYSTEMS LTD	DRTS	UK	Month 1	Month 26
CR	SMEP	3	UMWELTSYSTEMTECHNIK GMBH GERA	UST	GERMANY	Month 1	Month 26
CR	RTD	4	FUNDACIÓN CETENA	CETENA	SPAIN	Month 1	Month 26
CR	RTD	5	UNIVERSITY OF GLAMORGAN	GLAMORGAN	UK	Month 1	Month 26

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DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

1.2 WORK PERFORMED IN THE PROJECT

During the 26 months duration of the project the following work has been performed by the DRY-CONTROL consortium:

WP1 - SPECIFICATION OF THE PROJECT

The SMEs of the consortium, OLIVER, UST and DRTS, have given their knowledge about both the plant and the drying process to the RTD performers of the project, to give them the needed information about the nature and requirements that they will need to solve and improve in the current control system they are using both quantitatively and qualitatively. This has given the required information to RTD performers to start the research and technology development of the project.

WP2 DESIGN AND DEVELOPMENT OF HUMIDITY AND PROTEIN SENSORS

The University of Glamorgan has developed software sensors for measurement of absolute moisture and protein content, which have been integrated in the final real time control system developed in the project. These software sensors give information about the process and the product obtained from measured variables and also from estimated variables.

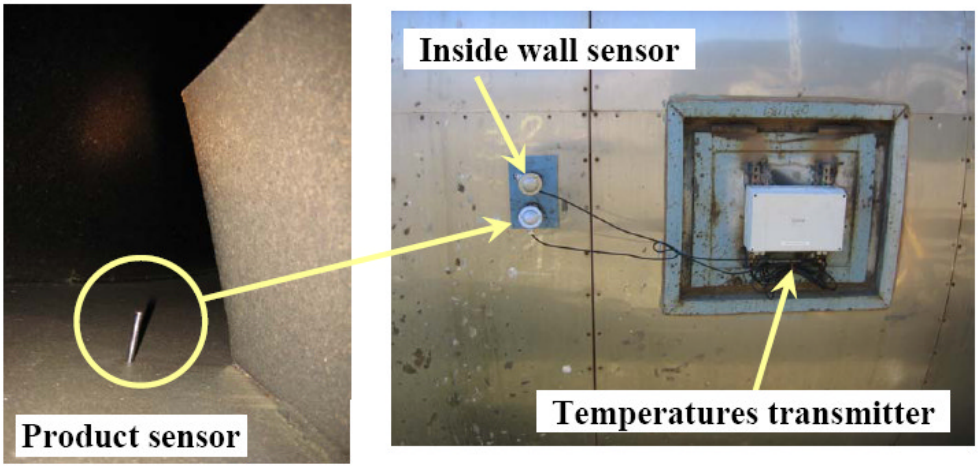


Fig.7. Wireless temperature system and the product sensor inside the drum.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

Fig. 8. Current measured at the receiver located at 50 meters from the sensor.

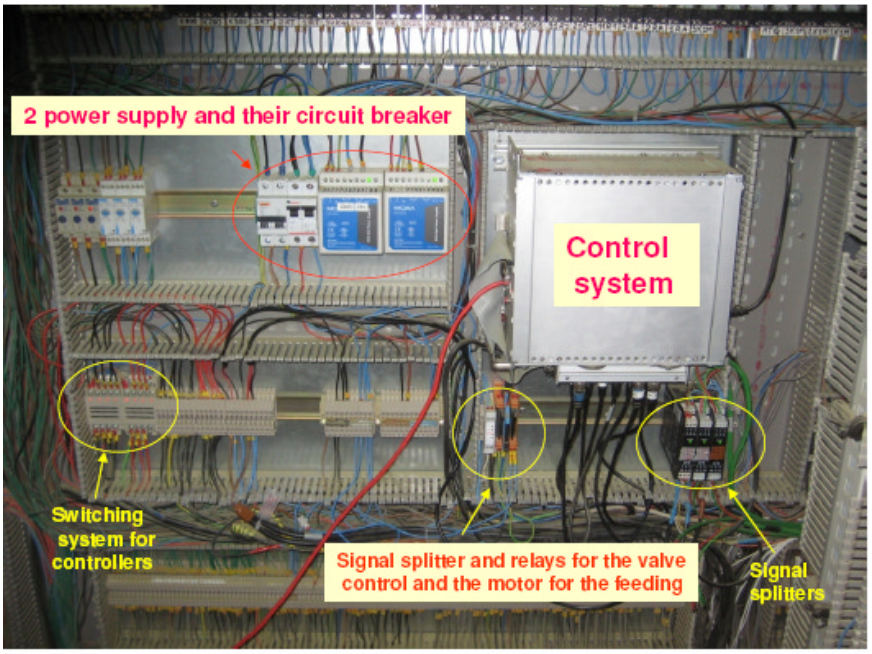
WP3 DEVELOPMENT OF A MATHEMATICAL MODEL OF DRYING PROCESS

The CEMITEC research center has developed a dynamic mathematical model that is able to simulate the he drying process in a rotary drier, being able to determine the transfer processes of mass and heat that take place during the drying process in a rotary drier. This dynamic mathematical model has been validated at industrial level in Oliver plant to check that the values given by the simulator conform to those in reality for the different operating conditions.

WP4 DEVELOPMENT OF REAL-TIME CONTROL SYSTEM

The University of Glamorgan has designed and developed a real-time control system prototype in which both the mathematical model and the software sensors previously developed have been integrated to allow more efficient use of the drying process in all points of the line and to save energy used in the process. Several tests have been made at laboratory and plant level to ensure the achievement of a reliable real-time control system.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products



New control system installed inside the panel with the switch system, relays and the signal splitters.

WP5 VALIDATION OF REAL-TIME CONTROL SYSTEM

The University of Glamorgan with the support of CEMITEC research center has installed the real-time control system in the OLIVER plant in Buñuel (Spain) and has validate it to ensure the robustness of the developed prototype in real conditions of drying alfalfa in the plant. Several validations have been made in real plant to test the reliability of the control system and to monitor the correct functioning with different types of alfalfa, working hours, weather conditions, etc. Furthermore, additional tests have been carried out in Buñuel plant to monitor the energy savings of the new control system compared to the former one.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

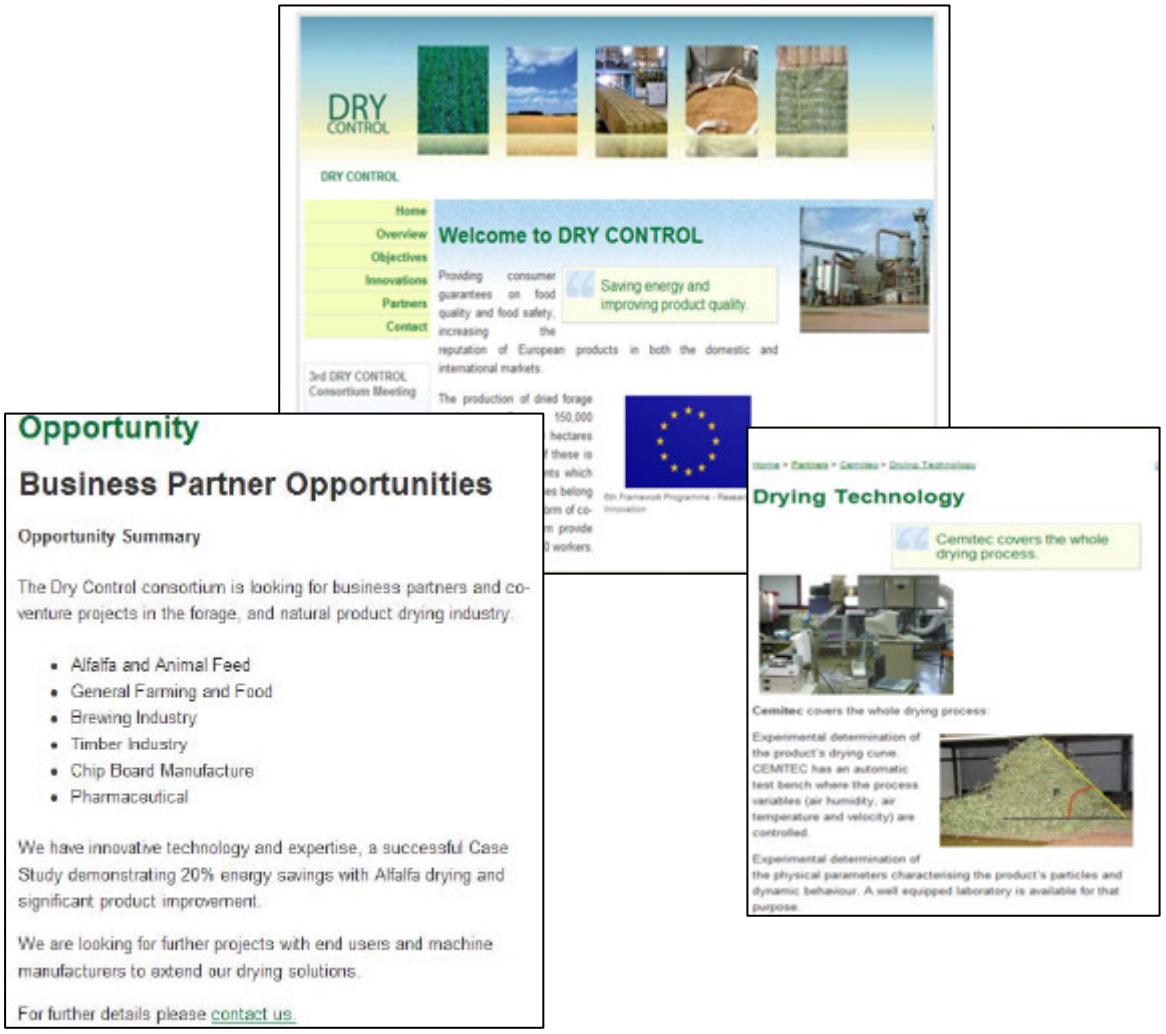
Figure 12: Practical dryer system located in the Oliver factory, Spain

WP6: DISSEMINATION AND EXPLOITATION OF RESULTS

The partner DRTS has been responsible for the development and updating of the DRY-CONTROL website and for monitoring and approval of the different dissemination actions carried out along the project duration.

The DRY-CONTROL website is available for all interested user in the following link:
http://www.dry-control.com/

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products



Furthermoret, DRTS has developed with the inputs from the rest of SMEs of the project the final Exploitation and Dissemination Plan for the project, in which the activities that will be performed once the project is finished to promote the commercial exploitation of the project's results and the widest dissemination of knowledge from the project. The plan is expanded in two directions: towards the marketing activities in order to enhance the commercial potential of the designed control system and hardware, and towards the notification of project's results in the scientific, EC and general RTD sector.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

WP7 PROJECT MANAGEMENT

The project coordinator, OLIVER, has ensured the adequate organisation of the work performed during the project by the different partners, coordinating in a proper way the different tasks. The coordinator has organised periodic consortium meetings to monitor the adequate achievement of the proposed objectives of the project, and for the adequate communication between partners. Important efforts have been made by the coordinator to solve the difficulties arised during the project and to meet the expectations of both SMEs and RTS performers of the project.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

1.3 RESULTS ACHIEVED IN THE PROJECT

1- A **mathematical model** capable of integrating all the described inputs to be processed along with a data base and a rule base, to provide the resulting control parameters of the established outputs which will in turn give the desired set values for the final product with respect to its protein and humidity content.

2- The **development of Adaptive FLC (AFLC) permitting the use of 3 or more control exit signals** instead of only one which in turn also gives greater control of the three controlling variables (rotation speed of the drum, feed of raw materials to be dried and drying temperature –fuel flow-) derived from a greater number of separate input signals (humidity and protein readings, rotation speed, feed of raw materials, drying temperature...).

3- A **control system** for drying processes of organic products capable to control product variables in real time in rotary driers, reducing energy consumption of the plant at least in 20%. This control system is an innovation without precedent in the field of forage dying and Agrofood in general, where these systems have no similar prior developments and have been limited to individual studies which have not permitted the industrial development for the control and automation of the equipment with such precision.

The control system presents the following **advantages**:

- Far greater accuracy to obtain a final product with a previously fixed humidity and protein content.
- Greater stability of the process, with none of the great oscillations in variables experienced with other systems using so many input and output variables.
- More reactive speed of control, responding in real time to whatever variation is observed in the entry variables.
- Low cost of control, given that once the system is developed, given that once the system has been developed, that the software tools have moderate prices and the cont4rol mechanisms will not require specific developments.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

- Real time control of the three process parameters: velocity of raw material feed, drying temperature and drum rotation speed.

DISSEMINATION AND USE OF PROJECT RESULTS

Different important steps have been taken during the course of the project in order to ensure the dissemination of the results achieved in the DRY CONTROL project:

- Preparation of a draft Dissemination and Exploitation Plan is to provide a formal planning document for the project. The Dissemination and Exploitation Plan provides guidance for using and disseminating knowledge both within the project and to those outside it.
- Design and launching of the DRY CONTROL project website
- Dissemination of the DRY CONTROL project website through consortium partners food stakeholders conctact network
- Updating of the DRY CONTROL project website with information on the events and results of the project

The main objectives of the different DRY CONTROL dissemination activities are:

- To raise awareness of the benefits of the DRY-CONTROL innovations to new user communities, ensuring an appropriate message is delivered to each of them;
- To ensure new communities know where and how to get involved in the project so they can be converted to technology and application users ;
- To ensure the availability of appropriate information tools for each target audience and support the growth of user communities;
- To identify and target new user audiences and applications. The challenge is to reach new communities, such as new industrial and commercial groups and branches of government.

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

PLAN FOR USING AND DISSMEMINATING THE KNOWLEDGE

The complete plan for using and disseminating the knowledge can be found attached to this e-mail (Deliverable 14)

The exploitable results that the project has generated are the following:

- The potential innovations are in the modelling and control of drying systems and their machinery for optimal use of energy and final product quality.
- A number of market opportunities exist in a number of market sectors, most notably, farming, brewing, pharmaceutical, and the wood industry.
- The innovations are in the early proof-of-concept stage of delivery. The next stage would be to establish a pre-production demonstrator.
- Collaboration is currently being discussed with the main research partner Cemitec.
- Intellectual property rights are to be discussed and whether there is a business case justifying expenditure.

Exploitable Knowledge (description)	**Exploitable product(s) or measure(s)**	**Sector(s)** of application	Timetable for commercial use	Patents or other IPR protection	**Owner** & Other Partner(s) involved
Optimal design parameters for manufacture of equipment and/or plant settings for particular forage materials – energy saving & efficiency.	*Drying Machines*	*Farming, Pharmaceutical, Wood, Brewing*	*2010*	*A patent is planned for 2009*	***DRY CONTROL SME Partners***
Specialist Controllers for drying of forage.	*Drying Machines*	*Farming, Pharmaceutical, Wood, Brewing*	*2010*	*A patent is planned for 2009*	***DRY CONTROL SME Partners***

DRY CONTROL- Control Strategies in Rotary Driers Dealing with Vegetal Products

- The two innovations actually are linked and can be seen as part of the same process. However the 1st in list of Exploitable Knowledge could only be patented in the US but the control technique could be used to establish a world patent.
- The next issue to consider is whether there is a market for either of these ideas and the information gathered to date suugests that there is. However the only company that could really bring these technologies to the market is Cemitec, or a similar research organisation. Investment would be needed to secure the patents and then to begin to develop prototypes and to begin targeting the market. The kind of figures involved would be around €250k. Some of this money might be able to come from regional funding or other sources but 2 people full-time for about 18 months would be needed to develop and market the technology.
- All DRY CONTROL SME partners have been involved in developing the innovations.