*Food* ©2009 Global Science Books

# Eco-Efficiency in a Crispy Chips Industry

**Justina Catarino[1*] • Elsa Mendonça[1] • Ana Picado[1] • Paulo Partidário[1] • João Nobre da Costa[2]**

[1] INETI, Estrada do Paço do Lumiar, 1649-038 Lisboa, Portugal
[2] Matutano S.A., Quinta dos Cónegos, Carregado, Alenquer, Portugal

*Corresponding author*: * **justina.catarino@ineti.pt**

## ABSTRACT

Combining economical and environmental efficiencies, eco-efficiency within production processes is a key path where there is a simultaneous focus on waste prevention and on the improvement of resource productivity – by producing more with less, towards sustainable production. To achieve such a goal, a Portuguese crispy chips company implemented a cleaner production approach. That process included the company's background information, a global inventory based on manufacturing diagrams, materials accounting, mass balances for the more representative materials, a synthesis of the production process eco-inefficiencies and its environmental impacts, an identification of ideas to improve the eco-efficiency in the field, and finally a feasibility analysis regarding technical, environmental and economical aspects. Results show that 75% of the starch input was converted into the final product, and that 80% of the by-products and wastes were generated before the frying process. It was also found that water utilization was closely related to the starch path. After a creativity phase where improvement ideas were generated and a feasibility analysis was done, some solutions were implemented. The implementation of improvement solutions resulted in an increase in business productivity that enabled the reduction of energy consumption, water and chemicals inputs, and the volume of sludge. In conclusion, eco-efficiency showed to be of major value to this industry, converting process inefficiencies into economic opportunities with simultaneous environmental benefits, thus fulfilling the industry's objectives towards the challenge of sustainable development.

**Keywords:** cleaner production, ecotoxicity, potato, starch, wastewater

## INTRODUCTION

Considering in general that waste from industrial processes are unused resources that create costs and no added value, combining economical and environmental efficiencies (eco-efficiency) is a key path to producing more with less (Schaltegger and Sturn 1990; Schmidheiny 1992) towards sustainable production. This is the result of an evolutionary process where waste prevention strategies have been focusing on reducing or eliminating contaminant mass-transfer problems, on undesired waste streams and on managing by-products and water reuse, rather than focusing on treatment and disposal options (Mann and Liu 1999; Maia *et al*. 2006). In the long run, prevention strategies are comparatively more cost-effective and environmentally sound than conventional pollution control approaches.

Eco-efficiency strategies enable a simultaneous focus on lower costs and on the improvement of resource productivity, leading consequently to waste prevention (Catarino *et al*. 2007a; Partidário and Figueiredo 2008). Therefore, eco-efficiency strategies clearly contrast with command and control environmental approaches as economic savings are a driver at system level in order to take cost-effective steps. However, looking at the sustainable development process as a whole, such advantage should not underestimate the emergent paradigm on sustainable production. An excessive focus on incremental process efficiency improvements is likely to hinder the rate and direction of the necessary radical changes (McDonough and Braungart 1998) where the lifecycle of products and the whole production-consumption system have to be considered. Eco-efficiency is a useful business management concept that should be considered within the short and mid-term to create more value with less natural resources and wastes.

When applied to the agro-food industry, and more specifically to waste minimization and water use, the eco-efficiency concept provides interesting opportunities (van Berkel and Kortman 1993; van Berkel 1995; Adams and Galy 2007; Thrane *et al.* 2009). At an industry level, eco-efficiency might be implemented in different ways (WBCSD 2000). Material and energy savings, reduction of toxics dispersion in the environment, and improvement of resources recyclability are of particular interest for this study.

This study provides insight into eco-efficiency implementation in a food manufacturing facility in Portugal, which is a crispy chips producer having a business share of 70% on national market and employing *circa* 400 workers. The general flow process for crispy chips production includes the following steps: the potato discharge, washing, peeling, slicing, blanching, frying, quality control and packaging.

Groundwater has been considered a cheap and abundant resource for a long time. In addition, wastewater could also be discharged either in surface water or to the sewer system without excessive costs and restrictions. Currently, however, due both to rain water shortage and to more stringent regulation, deep groundwater is increasingly having restricted use and companies forced to seek for water supply alternatives.

To prevent critical water shortages (Anderson 2002), water savings at a country level are increasingly a policy priority, in order to balance supply and demand, as well as to pollute less and to reduce the environmental impacts of growing populations. At an industrial level (Deul 2002), water has thus become an even more critical resource for many facilities, and a driver for water savings which in turn enables a reduction on production costs and on environmental impacts.

High water consumption in the crispy chips production process occurs particularly in operations such as washing, peeling, slicing, blanching and frying, which are a source of wastewater having high starch content. Those effluents

Received: 29 July, 2008. Accepted: 20 October, 2008.

Research Note

show a Biochemical Oxygen Demand after 5 days ($BOD_5$) up to 7 g/L $O_2$, as well as a Chemical Oxygen Demand up to 10 g/L $O_2$. In those conditions, a wastewater treatment plant (WWTP) provided a two stage treatment on a regular basis, prior to the discharge into a small river nearby. In addition, considering the high volume of water consumed but not embodied in the final product, a significant quantity of wastewater was being produced, carrying raw material-related components such as starch, oil and grease (Catarino *et al*. 2007b).

Having all these issues and operational conditions into consideration, the main project goals were the reduction both of inputs and of process losses (mass, energy), in order to recover by-products, to reuse water and to reduce costs in pollution control, instead of improving the existing "end of pipe" approach.

## METHODOLOGY

### Cleaner production

A global inventory was structured based on the Cleaner Production approach. All the unitary operations were identified as well as the inputs and outputs of materials, energy and water.

All the collected information was treated and gathered according to the Portuguese Cleaner Production Manual – Prepol Manual (Peneda *et al*. 2001). This manual is a dynamic tool aiming to help the company in the knowledge of its process and to become more eco-efficient, by focusing on its materials and energy fluxes in the different unit operations viewing pollution prevention.

The detailed information for each operation was quantified concerning energy, materials, water and emissions and waste management. For this purpose the company listed all the raw materials, components, auxiliary materials, packages, water, energy, final products, intermediary products, waste, emissions, and noise. All of them were characterised (in environmental and economic terms) and quantified thus allowing to build the mass balance as well as to detect the manufacturing inefficiencies. The eco-inefficiencies of the process and its environmental impacts were the starting points for the formulation of improvement proposals. This information enabled the evaluation of the process performance and the identification of areas, activities or operations where attention must be focused. The synthesis of the information gathered until this phase was essential to identify and generate proposals to solve the detected problems.

Viability analysis of those proposals was made concerning technical, environmental and economical aspects.

### Wastewater valorization

Several ideas emerged from the Cleaner Production approach, to improve company's eco-efficiency. In this work we discuss the following ones: getting value from wastewater, recovering by-products and reducing water consumption and organic load of the wastewater (WWTP optimization).

The implementation process of these ideas was performed in four phases: phase 0 corresponds to the initial system before the changes have occurred; phase 1 where the oil recovery occurs without any starch recovery; phase 2 where the starch recovery is performed without any oil recovery; phase 3 corresponds to the recovery of both starch and oil (Catarino *et al*. 2007b).

The starch by-product (60% concentrated) was obtained by slicing and blanching process water pumping, rotary filter screening, tank storing, hydro-cyclones separation (battery of 3 units from RAISIO, Belgium) and vacuum filtration. The oil and grease by-product separation from the final effluent was done by gravity in a tank, removed manually or automatically. Water recovery was achieved in two ways: implementation of a reverse flow where sliced potato wash water (blanching water) was used in the first potato washings and reutilization of treated wastewater for soiled potato washing and for watering and fire systems (Catarino *et al*. 2007b).

All phases were monitored in order to evaluate the changes progressively implemented.

Sampling program was tailored to this situation: samples were taken at the input of the WWTP, by collecting manual grab samples every 30 min. They were kept refrigerated and there was a subsequent preparation of a composite sample representative of one day laboration period of each of the described phases. For this evaluation, starch and oil recovery units were discontinued one day for the situation described in phase 0; for phase 1 only the oil

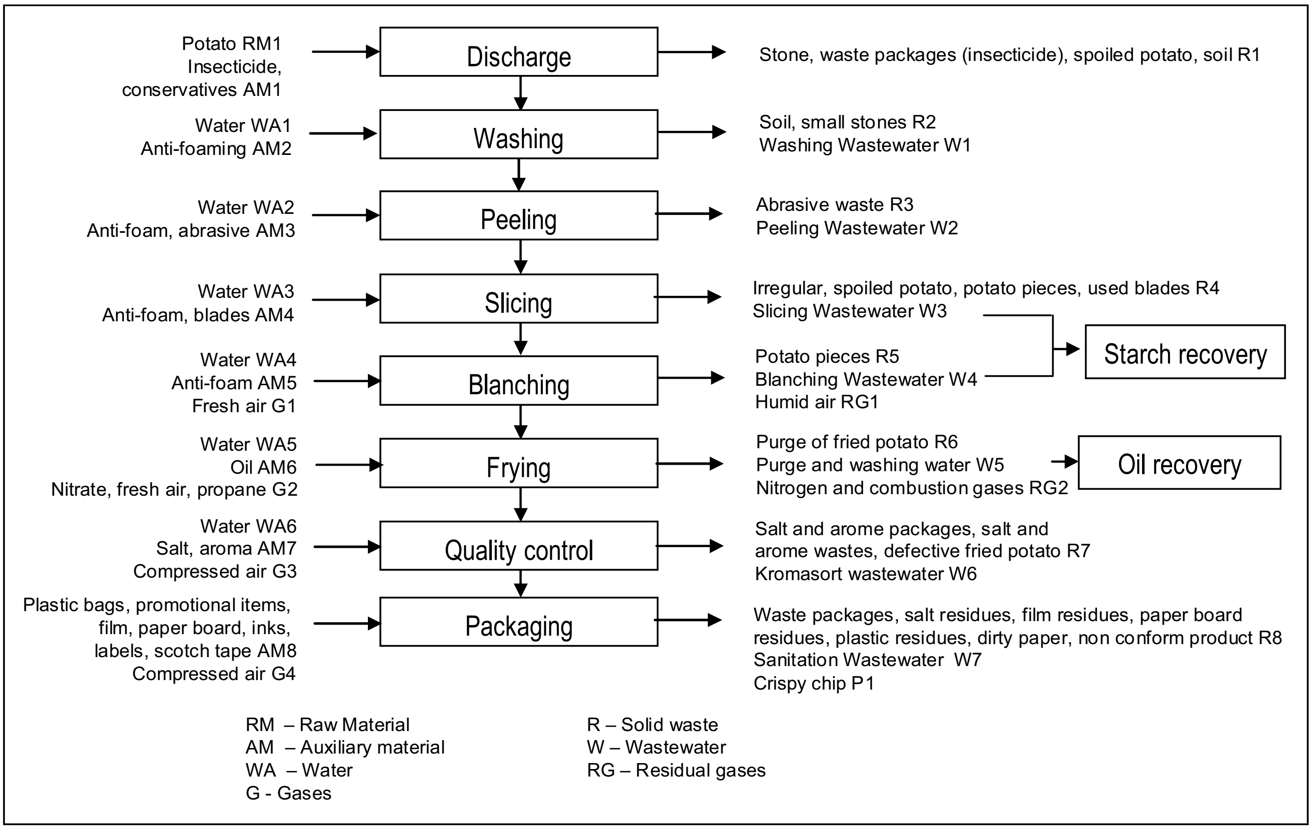


**Fig. 1 Production process phases in the potato chips company.**

recovery unit was discontinued; for phase 2 only the starch recovery unit was discontinued; for phase 3 sampling was done while the two recovery units were running. The four resulting refrigerated composite samples were transported to the laboratory for analysis. For this purpose samples of industrial wastewater were physico-chemically and ecotoxicologically assessed in a previous work (Catarino *et al*. 2007b).

## RESULTS AND DISCUSSION

### Cleaner production

The potato chips production process was divided into several phases (**Fig. 1**) with potato being the main raw material. Potato is discharged from truck and screened for soil and stones. After a first washing, potato is peeled by abrasion and sliced. Sliced potato enters the blanching operation, where starch is released to the water. After a drying step, potato is fried in oil. Then potatoes are salted / aromatized and after quality control sent to the packaging phase.

Process water is obtained from the public system and natural water. The main energy source is propane and electricity, with the company being an intensive energy consumer. Raw materials are potato, vegetal oil, salt and aromas.

Wastewater, composed by soil, potato, starch, anti-foam and greases are treated in a WWTP by activated sludge. Atmospheric emissions come from potato drying, vegetal oil deoxygenating and propane combustion. Solid wastes can be grouped in those related with potato, paper, wasted greases and oils and packaging material.

The synthesis of mass balance performed for starch and water is shown in **Figs. 2** and **3**, respectively. Each year *circa* 7500 t of starch enter the company of which 75% of it is present in crispy chips, the final product. From the by-products and wastes, 80% were generated before the frying process. Accounting for the water mass balance of the company, two inputs were considered: *circa* 180000 t/year process water and *circa* 30000 t/year potato water content. As output there was almost 100% of water as waste. It was also found that water utilization was closely related to the starch path: water and starch are potato components; in addition, in the cleaning process, water transports the starch; as a result, there is a significant content of starch in that wastewater.

After the information synthesis 47 cleaner production ideas were generated: 60% for prevention at the source, 23% for internal valorization and 17% for external valorization. Main ideas that emerged throughout this improvement on the company's eco-efficiency were related to the following aspects: by-products recovery and the reduction of both water consumption and organic load of the wastewater.

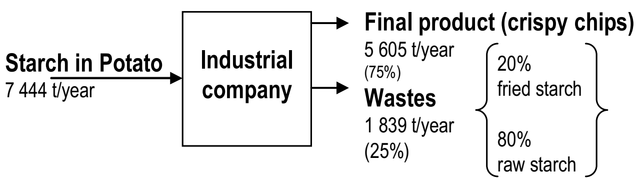


**Fig. 2 Starch mass balance.**

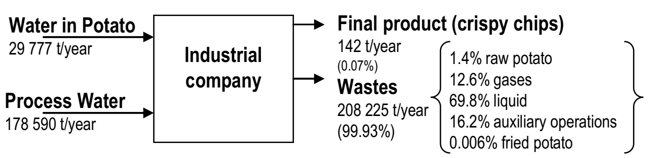


**Fig. 3 Water mass balance.**

### Wastewater valorization

The implementation of the starch and oil and grease recovery processes led to a decrease in the wastewater content in nitrogen, phosphorus, total suspended solids and $BOD_5$

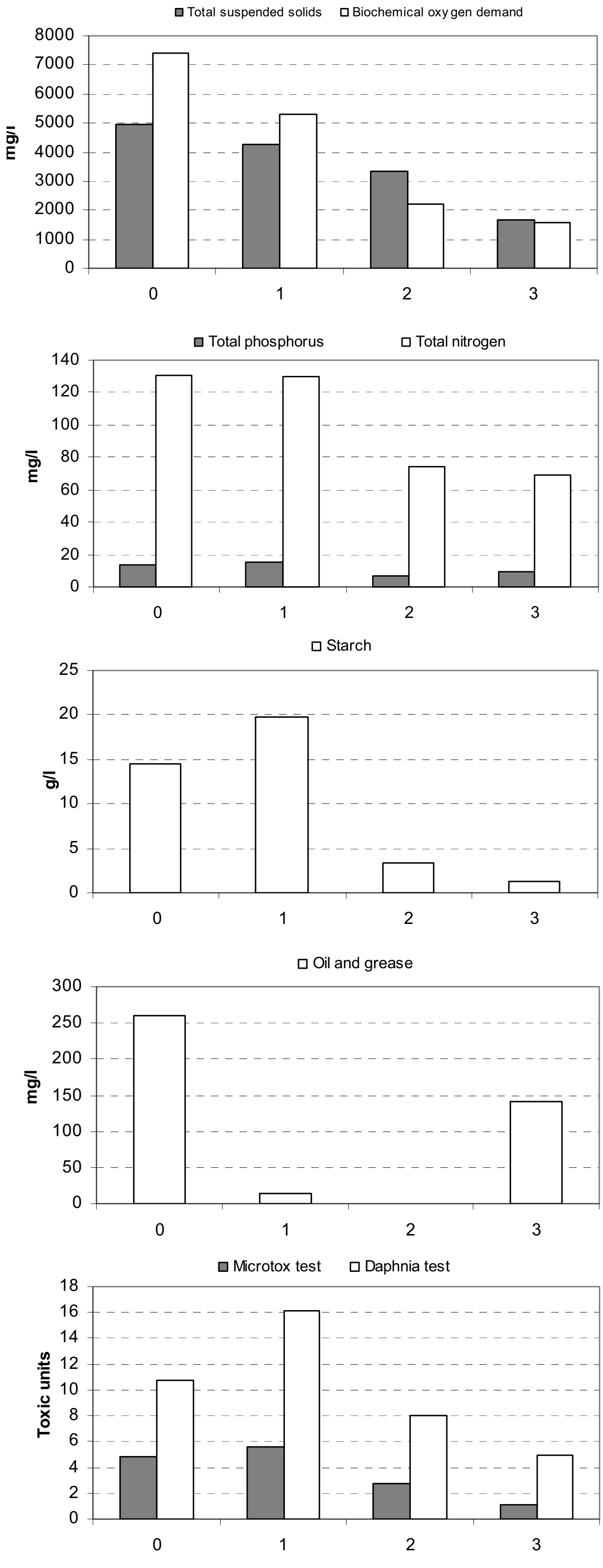


**Fig. 4 Chemical and ecotoxicological parameters for the different phases (0 - initial system; 1 - oil recovery without starch recovery; 2 - starch recovery without oil recovery; 3 - starch and oil recovery)** (adapted from Catarino *et al*. 2007b).

**Table 1** Economic analysis (adapted from Matutano Report).

| Action | Productivity gains (euro) | | |
|---|---|---|---|
| | First year | Second year | Total |
| WWTP optimization | 42405 | 53970 | 96375 |
| Starch recovery | 15985 | 27930 | 43915 |
| Water reduction | 143880 | 159810 | 303690 |
| total | 202270 | 241710 | 443980 |

input to the WWTP (**Fig. 4**). Source separation technologies can play an important role in environmental management (Wilsenach *et al.* 2002; Stypka *et al.* 2003), as proved by the decrease in ecotoxicological effects for the tested species. Direct toxicity assessment approach is an added value in assessing the potential ecological impact of industrial wastewater (Whitehouse 2001; Picado *et al.* 2008). Removal of starch and of oil and grease from wastewater reduced the effluent toxic load (Catarino *et al.* 2007b), resulting in a minor acutely toxic wastewater, according to the classification proposed by Tonkes *et al.* (1999).

The quality improvement of the wastewater allowed facing a new approach including its reuse (in the potato washing area, outside washing, in the watering system and in the fire combat network), in a trend to close the water loop, minimizing natural water consumption. The shutdown of one wastewater treatment stage due to starch and oil and grease removal resulted in a decrease in energy, polyelectrolyte and sludge management costs. Two years after the valorization actions, the residual amount of sludge of 7 kt/year, was reduced of 2 kt/year; the savings in energy costs/t crispy chips were of 33%; wastewater treatment cost was 15 euro/t of crispy chips and it decreased *circa* 30% after the implementation of this approach. These achievements and the valorization of starch as a raw material in the paper manufacturing and of oil and grease in the soap industry contributed to economical and ecological benefits for the industry.

Globally looking at the eco-efficiency aspects the investment costs were 450 kEuro leading to equivalent productivity gains as described in **Table 1**. The payback period was *circa* two years.

## CONCLUSIONS

Cleaner Production approach in the potato chips industry demonstrated to be of major value. A global inventory of the potato production process phases, where all the inputs and outputs of material, energy and water were identified and characterized, allowed building input/output balances and detecting eco-inefficiencies. The detected problems push the industry to generate and evaluate improvement ideas and to take actions toward process changes, leading namely to by-products valorization and water reuse. A technical, environmental and economical analysis of the selected actions showed the improvement of the company eco-efficiency viewing a more sustainable management of production processes.

## REFERENCES


**Adams M, Ghaly AE** (2007) Maximizing sustainability of the Costa Rican coffee industry. *Journal of Cleaner Production* **15**, 1716-1729

**Anderson J** (2002) International guidelines for water recycling. In: Lens P, Hulshoff Pol L, Wilderer P, Asano T (Eds) *Water Recycling and Resource Recovery in Industry*, IWA Publishing London UK, pp 161-178

**Catarino J, Henriques J J, Maia A, Alexandre J, Camocho D, Rodrigues F** (2007a) Manual Valor Sustentável, INETI, 119 pp

**Catarino J, Mendonça E, Picado A, Anselmo A, Nobre Costa J, Partidário P** (2007b) Getting value from wastewater: by products recovery in a potato chips industry. *Journal of Cleaner Production* **15**, 927-931

**Deul AS** (2002) Systematic approach to water resource management in industry. In: Lens P, Hulshoff Pol L, Wilderer P, Asano T (Eds) *Water Recycling and Resource Recovery in Industry*, IWA Publishing London UK, pp 252-270

**Mann J, Liu Y** (1999) *Industrial Water Reuse and Wastewater Minimization*, McGraw-Hill, NY, 523 pp

**Maia A, Catarino J, Rodrigues F, Duarte P** (2006) Eco-efficiency in mineral extractive industry – A strategy to sustainable development. *2nd International Conference on Quantified Eco-Efficiency Analysis for Sustainability*, Egmond aan Zee, The Netherlands, 28-30 June, 34 pp

**McDonough W, Braungart M** (1998) The Next Industrial Revolution. *The Atlantic Monthly* **282 (4)**, 82-90

**Partidário P, Figueiredo J** (2008) Measuring material flows in industrial processes. A key step towards sustainable production. In: Putnik G, Ávila P (Eds) *Proceedings of an International Conference 'Business Sustainability 2008'*, 25-27 June, University of Minho, Portugal, pp 1-5

**Peneda MC, Ventura F, Catarino J, Duarte P, Frazão R, Marçal M, Nogueira A, Rocha C, Trindade P** (2001) *Manual PREPOL Prevenção/Minimização da Poluição nas Empresas*, Caderno INETI, nº4 Lisboa (3rd Edn), 31 pp

**Picado A, Mendonça E, Silva L, Paixão SM, Brito F, Cunha MA, Leitão S, Moura I, Hernan R** (2008) Added value of the ecotoxicological assessment of industrial wastewater in Trancão River Basin (Portugal). *Environmental Toxicology* **23 (4)**, 466-472

**Schaltegger S, Sturn A** (1990) Ecological rationality. *Die Unternehmung* **4**, 273-290

**Schmidheiny S** (1992) *Changing Course*, MIT Press, Cambridge, MA, 414 pp

**Stypka T, Plaza E, Stypka A, Trela J, Hultman B** (2003) Regional planning and product recovery as tools for sustainable sludge management. *Water Science and Technology* **48 (1)**, 11-17

**Thrane M, Nielsen E H, Christensen P** (2009) Cleaner production in Danish fish processing – experiences, status and possible future strategies. *Journal of Cleaner Production* **17**, 380-390

**Tonkes M, de Graaff PJF, Graansma J** (1999) Assessment of complex industrial effluents in the Netherlands using a Whole Effluent Toxicity (or WET) approach. *Water Science and Technology* **39 (10-11)**, 55-61

**Van Berkel R** (1995) Introduction to cleaner production assessments with applications in the food processing industry. *UNEP Industry and Environment* **January/March**, 8-15

**Van Berkel R, Kortman J** (1993) Waste prevention in small and medium sized enterprises. *Journal of Cleaner Production* **1 (1)**, 21-28

**WBCSD** (2000) Eco-efficiency: Creating more value with less impact. *World Business Council for Sustainable Development*, Geneva, 32 pp

**Whitehouse P** (2001) Measures for protecting water quality: current approaches and future developments. *Ecotoxicology and Environmental Safety* **50**, 115-126

**Wilsenach JA, Maurer M, Larsen TA, Loosdrecht MCM** (2002) From waste treatment to integrated resource management. *Water Science and Technology* **48**, 1-9