Computational tool for the energy performance assessment of horticultural industries - Case study of industries in the centre inner region of Portugal

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Abstract: Food processing and conservation represent decisive factors for the sustainability of the planet given the significant growth of the world population in the last decades. Therefore, the cooling of any food products has been subject of study and improvement in order to ensure the food supply with good quality and safety. A computational tool for the assessment of the energy performance of agrifood industries that use refrigeration systems was developed. It aims to promote the improvement of the energy efficiency of this industrial sector. The computational tool for analysis of the energy profile is based on a set of characteristic parameters used for the development of correlations, including the amount of raw material, annual energy consumption and volume of cold stores. In this paper, the developed computational tool was applied to companies in the horticultural sector, specifically to resale-type companies. The results obtained help on the decision making of practice measures for the improvement of the energy efficiency.

Keywords: Computational tool, Energy performance, Energy efficiency, sustainability, perishable products, horticultural, cold storage, Matlab, GUIDE.

1 Introduction

There are several topics that are targets of research or scientific studies, and both sustainability and food safety are no exception. In the early twentieth century the world population was about 1500 million people, however just over a century the number of habitants increased to approximately 7000 million [1]. Thus, it is clear that the demand for food is increasing and so it becomes imperative to find short-term solutions for the sustainability of the planet, hence putting an enormous strain on the production and conservation sectors of the food chain. In this context, cooling plays an important role, allowing food storage in times of increased production when the market has no capacity for product flow, or just make it available when needed. The refrigeration is a process with the ability to preserve perishable products ensuring that they retain their chemical, physical and nutritional properties but it is also indispensable in the processing of perishable foods such as meat, fish, milk, fruit and so on. The demand of chilled and frozen food has increased substantially, which leads to new requirements for the efficiency of refrigeration systems [2]. Energy represents a factor of greatest importance not only for country's economy, but especially for the well-being of its citizens. In 1971 there was a global electricity consumption of around 439 $Mton_e$, and in 2010 this figure rose to 1 536 $Mton_e$ [3]. This increase is related to the population growth, being the industry responsible for about 35.2% of energy consumption worldwide in 2010. The energy consumed globally for the cooling process accounts for 15% of energy consumption worldwide [1].

Horticultural products, i.e., fruits and vegetables are important elements of a balanced diet and are associated with a healthy lifestyle, due to vitamins, fiber, minerals and sugar that can be obtained from it. Besides that, the high intake of this kind of food helps to reduce the risk of chronic diseases such as diabetes [4], a few cancers (mouth, larynx, oesophageal, stomach, pharynx and lungs) [5] and cardiovascular health problems [6,7,8].

According to the European Food Information Council (EUFIC), there are different definitions of fruit and vegetables since some countries might consider dry fruits as the same kind of food (statistically). In a general way, potatoes are not considered as a vegetable to statistical results. Note that the World Health Organization (WHO) recommends eating more than 400 grams per day of fruits and vegetables, excluding potatoes and other starchy tubers such as cassava [9]. Unfortunately there is no information regarding the consumption of this food group, however based on the vegetable supply in Europe, it can be stated that its consumption has increased over the past four decades (FAO). Actually, the average fruit and vegetables intake (excluding juices) in Europe is 220 grams per day and 166 grams per day respectively, which leads to a total of 386 grams per day [10]. Austria and Portugal are the countries that show highest intakes of fruit and vegetables, while Spain and Iceland show the lowest values.

Thus, is important to develop studies and tools to improve the efficiency of these processes in order to ensure a better sustainability of this industrial sector. Although it can be highlighted that there are a few studies or projects developed in this area, more specifically in the creation of computational tools for the analysis of several points related to the cooling processes (whether the level of energy consumption, environmental impact, among others). In this regard, Gogou *et al.* [11] describe the FRISBEE (*Food Refrigeration Innovations for Safety, Consumers Benefit, Environmental impact and Energy*) project, which considers the development of a software tool for the evaluation of quality, energy and environmental impact of the European cold chain. This program has the ability to predict the temperature of chilled or frozen products on certain circumstances and to calculate the validity/quality of particular food at different stages of the cold chain. An internet platform was developed to conduct the surveys which has more than 5500 records [11]. The data entered on this platform is organized according to the following fields: phase of the cold chain, temperature range from food storage, characterization of food, type of food, food product, packaging, and country of origin. This computational tool is innovative not only by their own concept of allowing simulating certain behaviours of the cold chain in Europe, but mainly because it has three very important fields in cooling: chilled product quality, energy consumption and environmental impact. FRISBEE covers five categories of foods, including fruit, meat, fish, dairy products and vegetables [12] and its main objective aims to collect data of different stages of the cooling process using the online platform. The FRISBEE CCP (Cold Chain Predictor) [13] is the computational tool developed, which performs simulations on specific conditions defined by the user, constructing graphs representing the variation of the temperature over time and estimating the remaining shelf life of the product. These simulations are performed based on the method of Monte Carlo [11] generating distributions of time/temperature for every stage of the cold chain and the selected product. The results represent realistic behaviour scenarios of food products and based on these it is possible to take corrective actions in order to optimize the efficiency of the cold chain ensuring product quality. In this same context, Foster *et al.* [14] describes the ICE-E (*Improving Cold Storage Equipment in Europe*) project [15] devoted to the creation of tools with the same goals: reduction of energy consumption and greenhouse gases emissions through the application of more efficient equipment, taking into account the energy and environmental standards of the EU [16]. The database of this project includes not only small businesses but also large multinationals, with data collected through an online platform. The ICE-E does not analyse the quality of chilled products with the respective indicators of safety and quality [17] being this the main difference between the presented projects. It should be noted that both projects developed freely computational tools to be used by any owner or employee of a company in the sector in order to perform an energy characterization of his company and to determine the achievable savings if their consumption is exaggerated. In addition, Eden *et al.* [15] describes the CHILL-ON [18], which is a project developed in the same area and with similar concerns. However, it is noteworthy that this project focuses on the quality of chilled products, mainly fish and birds, making a deep study in terms of microbiology. It includes a computational tool, QMRA (*Quantitive Microbial Risk Assessment*) [19], which is combined with the principle of the Hazard Analysis and Critical Control Points (HACCP) to enable the improvement of quality and safety of food in a preventive approach. More specifically, this tool allow to estimate the risk of pathogens growth based on the temperature, chemical and nutritional characteristics of food. As result, the SLP (*Shelf Life Predictor*) [20] was developed with the ability to predict the remaining shelf life of foods. Apart from the quality and safety of foods, this tool allows to track (traceability) products in order to know its real time location in so that the consumer can make use of reliable information about the foods origin and to overlook the manufacturing process from the beginning to the end. Furthermore, the development of new technologies in the field of refrigeration is also covered by the CHILL ON project such as the introduction of "smart labels": TTIs (*Time Temperature Indicators* or *Integrators*) [19]. Combining this technology with RFID (*Radio Frequency Identification*), it became possible to send an electronic and optical signal through a wireless connection directly to a software that calculates the remaining shelf life.

Butler *et al.* [21] describes another European project, NIGHT WIND, which can also be related to these topics being the reduction of power consumption its main objective. The concept of this project is very simple, and it consists in making use of the existing cold storages as "batteries" that will store cold air [21], in other words, energy. It is proposed the creation of a control software of cold stores temperature taking into account the price of electricity and the daily consumption profile of the company. It can be stated that the compressors will work during periods in which electricity is cheaper (usually at night), accumulating energy as cold air (temperature below -20°C) to use it rationally during peak hours [22]. However, this procedure is executable only in the facilities with enough cold storage capacity to store the energy demand of the next day.

2 The energy performance assessment in Portuguese industries

The abovementioned projects covered the development of computational tools aimed to improve the energy efficiency of cold stores. Although, Portuguese companies had not been included in the databases. In this context, a project was developed in Portugal directed to the identification of the energy consumption profiles of the agrifood industry and the promotion and development of actions that contribute to a real improvement of energy efficiency and the competitiveness of this sector. The work developed and presented in this paper is part of an activity of the project and its main objective is the development and implementation of an analysis algorithm to be validated with companies outside the visited/studied sample of companies. It is considered a tool to support strategic decisions in the companies allowing the estimation of their energy performance and pointing practice measure that lead to an effective improvement of energy efficiency. Note that this project is not aimed for the energy characterization of the cold stores in general, but to the characterization by sector, including meat, fish, milk, horticultural (fruit and vegetables), wine and vineyard and distribution sectors in order to obtain real data that can be inputted in the model/algorithm.

It should be noted that in the case of Portugal, in 2011, the number of small and medium enterprises was around 1.112.000, providing employment to about 78.5% of the employed Portuguese population [23], a factor that characterizes the Portuguese economy. Furthermore, according to a study conducted by the OECD (Organization for Economic Cooperation Development), Portugal was considered in 2005 as one of the countries whose population had fewer qualifications, being positioned at the same level as Brazil and Turkey. The study surveyed individuals between 25 and 65 years of age belonging to the labour force, and 59% of them had qualifications below the sixth grade [24], while in Denmark, also a European country, this figure was only 1%. This situation was taken into account for the development of computational tools, given the lack of literary skills of part of the Portuguese population. Thus, the computational tool created is extremely simple, intuitive and easy to understand in order to be accessible to all employees in the refrigeration industry regardless of their qualifications.

After an intensive collection of field data of a given sample of companies, analytical correlations were developed based on the work of Nunes [25] and Nunes *et al.* [26-28] to predict the average energy performance in the horticultural industry in Portugal. Considering the correlations for different sectors of agrifood industry, a computational tool was developed that allows the estimation of the energy consumption of a particular company against the national average. Depending on the results, the tool also provides practice measures to improve the energy efficiency. Thus, it can be used on energy-decision making process. This work introduces the tool in the horticultural (fruit and vegetables) sector, more specifically, for the industry of fruit resale.

3 Computational tool for the prediction of energy performance

3.1 Overview

The computational tool, Cool-OP (*Cooling Optimization Program*), was developed in MATLAB using the GUIDE (*Graphical User Interface Design Environment*) tool [29] that allows the creation of multiple windows that graphically illustrate the results. This toolbox is used by advanced programmers giving them the ability to create the graphical layout of the program more easily than using the old methods. It consists in usual programming code to define the position of the GUI. The GUIDE has facilitated graphical programming allowing to reduce the working time to develop the graphical interface. Using this application it is possible to create windows of the desired size, adding various interactive icons of user interface with the program, from buttons to static boxes or dynamic text, and many others as shown in Figure 1.

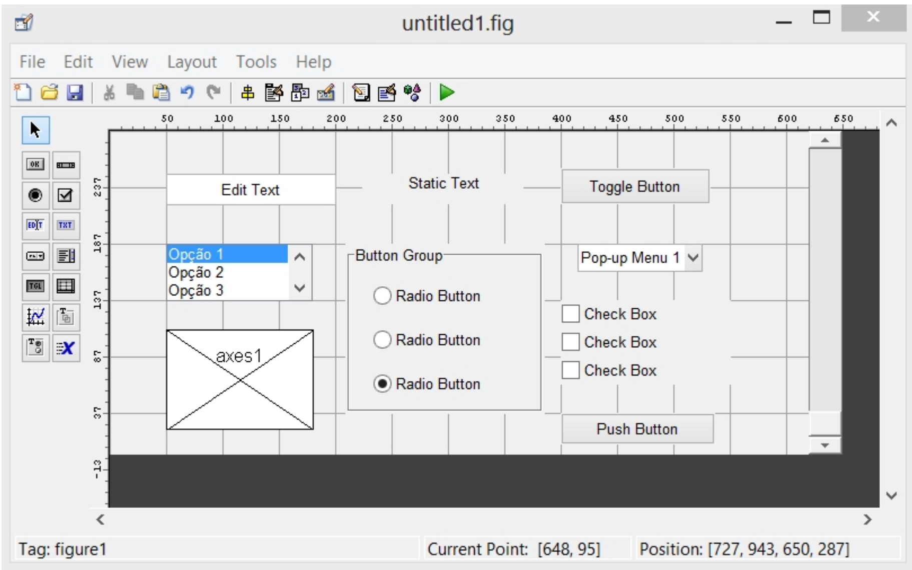


Fig. 1. GUIDE interface software in MATLAB.

It is important to note that all files created by GUIDE are .fig format and they must have an associated .m file where a function is assigned to each graphical component. Some of the features of this toolbox allow the programmer to display static text and other components such as images, graphs or tables, without the need to have any dynamic function. By other hand, editable text boxes can have two distinct functions, such as reading a value or text that is entered by the user, or displaying information based on the .m file associated. Regarding the axes, these are always used as a reference to insert an image or to plot a graph. Besides that, the programmer can make use of many other graphical components such as radio buttons, checkboxes, pop-up menus or list. Finally there are the usual buttons, which are normally associated with a link to a different window or action such as closing a window, for example. Each component has always a *tag*, or a label that will be identified in the source file (.m) by creating a *callback*. Thus, every GUI component has a *callback* that consists in a function that will control its behaviour according to the respective programming code when the event occurs. This event may be the click of a button, the selection of an option from a menu or inserting a text or number. For example, consider a .fig file with a button that starts the plotting of a graph. When the user clicks the button, the software reads the *callback* function associated to the button, performing its action according to the code written.

It should be noted that all GUI components are configurable through the Property Inspector (see Figure 2). Consider a push button as an example. As expected, it is possible to change the button size, type, font colour and size, text alignment, background colour, among others. But beyond that there are some editable programming parameters such as the value assumed as default of *pushbuttons*, the setting of shortcut keys to trigger buttons, the name that identifies the .m file, the automatic or manual creation of *callbacks*, and a few others.

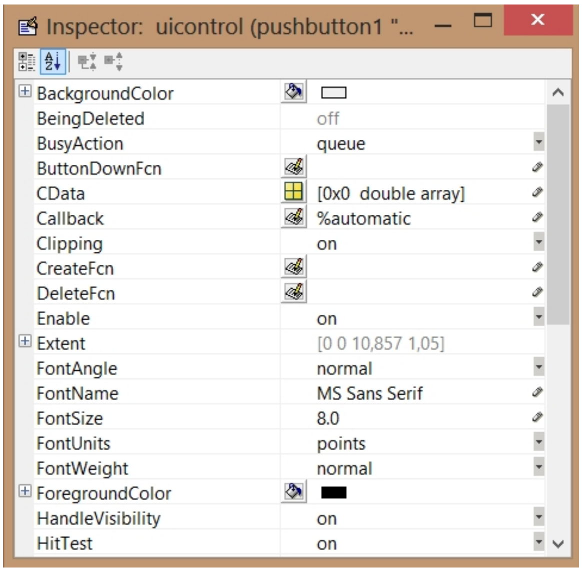


Fig. 2. Property inspector of the pushbutton component from GUIDE.

The Cool-OP windows here developed using the abovementioned programming concepts. Besides these programming details, it is important to highlight that the code was converted to an executable file (.exe) that can run in any computer.

This computational tool predicts the current state of the energy consumption in a company and suggests a few practice measures to reduce this consumption. The correlations used in the tool were developed statistically and are focused on several key parameters that characterize companies of agrifood sector, including: the quantity of raw material processed, power consumption and the total volume of cold stores. The energy consumption parameter includes not only the energy consumed for cooling or processing products, but also other energy consumption related with lighting, heating, office, etc. Since the correlations, that are the core of the algorithm, were obtained through real values collected in companies, it becomes imperative to define the variation domain of each parameter to provide valid predictions. These restrictions on utilization of the computational tool are given in Table 1. As it can be seen, the energy consumption parameter is not limited to a domain, since this is the main evaluation parameter which characterizes the company.

Table 1. Application domain of each of the parameters of the computational tool.

Industry	Raw Material [ton]	Chambers volume [m^3]
Fruit Resale	100-1800	50-1000

3.2 Inputs/Outputs of the computational tool

Cold stores are responsible for about 60-70% [30] of total consumption. This computational tool aims to promote the implementation of energy efficiency practice measures by the knowledge of the overall energy performance of a company in the agrifood sector, as well as its relative position to the national average. The tool presented in this study considers improvements on its previous version developed by Santos *et al.* [31-32] and Neves *et al.* [33] and it contains the correlations for horticultural companies located in the central region of Portugal [25]. Initially, a window containing a brief description of the tool is displayed, informing the user about the necessary input data (inputs) to perform the simulation in the following steps (see Figure 3).

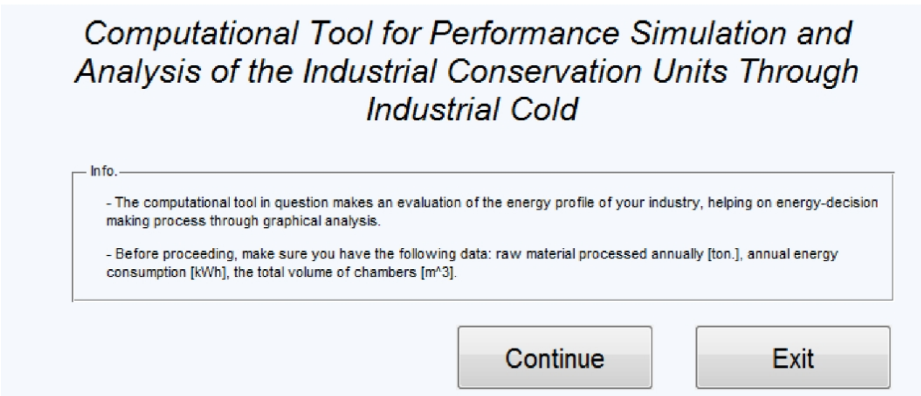
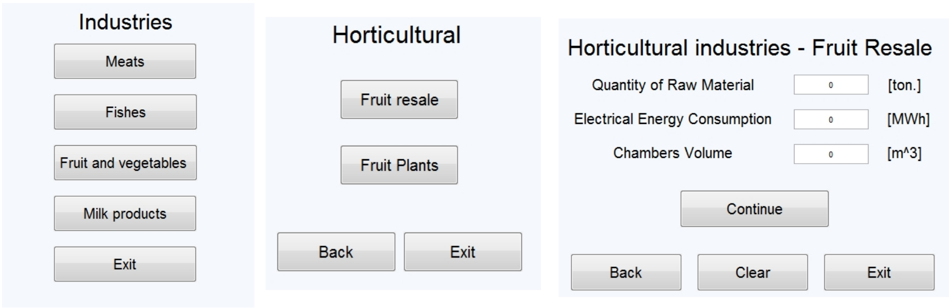


Fig. 3. Cool-OP: Opening window.

In the next menu, the user can select which industry fits the company to be analysed (see Figure 4-a)), including meat, fish, horticultural (fruit and vegetables) and dairy products. Within each of the different sectors there are many subcategories. In the specific case of the horticultural sector or Fruit and Vegetables industry, there are (1) fruit resale warehouses and (2) fruit plants as shown in Figure 4-b). This paper focus on the former subcategory.

Thereafter a window appears in which are introduced the values of the parameters that characterize the company: amount of raw material processed annually [ton], annual electricity consumption [MWh] and the total volume of cold stores [m^3]. Notice that it's always possible to return to the previous menu or close the window using the respective buttons for navigation. Any of the subcategories of agrifood industries opens a similar window requesting the same data, changing only the title (Figure 4-c)).



a) Menu window.

b) Menu window of Horticultural sector.

c) Input window of the parameters of the company.

Fig. 4. Cool-OP: Windows to input the company parameters.

After the correct introduction of the data according to the International System of Units (SI) and within the valid variation domain of each parameter, pressing the button "Continue" gives access to the general results that summarize the current state of energy performance of the company. In this window (see Figure 5) the tool immediately processes the information previously entered, generating graphs that relate the evaluation parameters of the company.

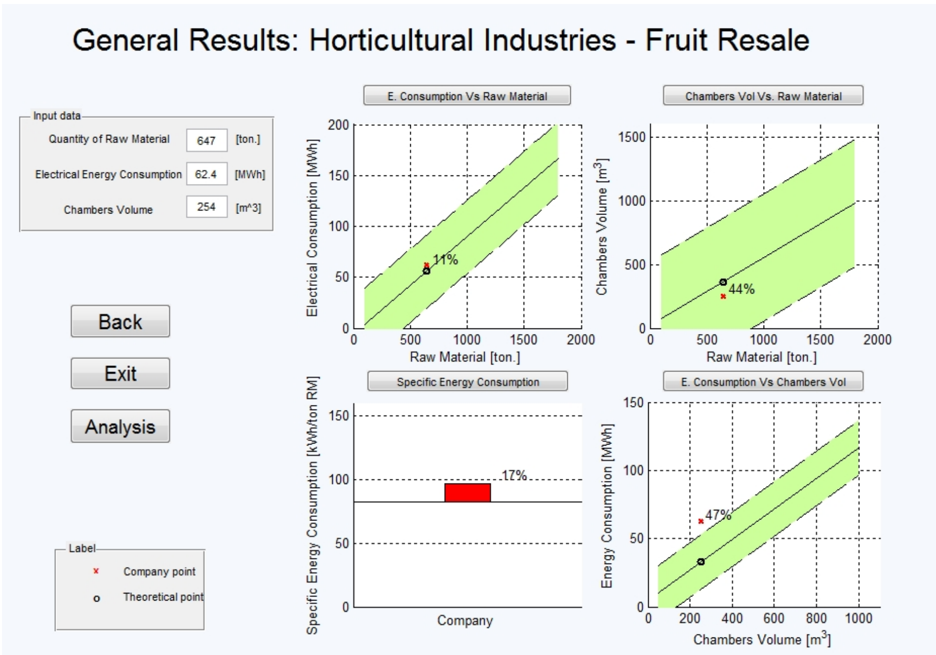


Fig. 5. Cool-OP: Window with the overall results (example of simulation).

All graphs have a green shade which represents a confidence level of 95% of the experimental values used to create the statistical correlations. In addition, it is also shown in each graph the percent deviation of the point under consideration (Company point – red dot) against the Portuguese national average (black dot). If the user wants to analyse a particular graph, he/she can press the button above it to open a new larger window.

4 Case study

4.1 Company presentation

A company was randomly selected to validate the tool, hereinafter referred to as Company A for reasons of business confidentiality. The company has not been part of the statistical data used in the development of the correlation.

This company is in the fruit resale sector and began operating in 2010. It has 10 workers and according to the Portuguese legislation it is classified as a small enterprise. Annually it processes about 900 tons of horticultural products, particularly vegetables (200 ton), pear and apple (350 ton each). Its facilities are equipped with cold rooms with a total volume of approximately 294 m^3 and its total covered area is 400 m^2. The values used to run the simulation are shown in Table 2.

Table 2. Values of the parameters used to evaluate the company energy profile.

Parameters	Values
Quantity of raw material [ton]	900
Electrical Energy consumption [MWh]	46.8
Cold Chambers total volume [m^3]	294

The cold chambers are built with sandwich panels, insulated with polyurethane and the floor is in concrete. Figure 6 shows one of the cold chambers of Company A. Note that the insulation of the evaporators tubing in made with neoprene in both chambers. Regarding heat sources, lighting is obtained through fluorescent lamps and there are, in average, about 10 person per hour inside the chambers. There are both manual and automatic doors that allows access to an antechamber before entering the chamber itself. Since it is a recent company it hasn't invested in any equipment in order to improve the energy efficiency and the refrigerant fluid used is recent and updated. With regard to the refrigeration system it is a direct expansion system and the condensers are defrost by an electrical resistor.

Fig. 6. Case study: Inner vision of a cold chamber of Company A.

4.2 Analysis and discussion of results

The predictive values of energy performance of Company A are shown in Figure 7. It is stated that the company has a specific energy consumption below average, characterizing it as competitive business.

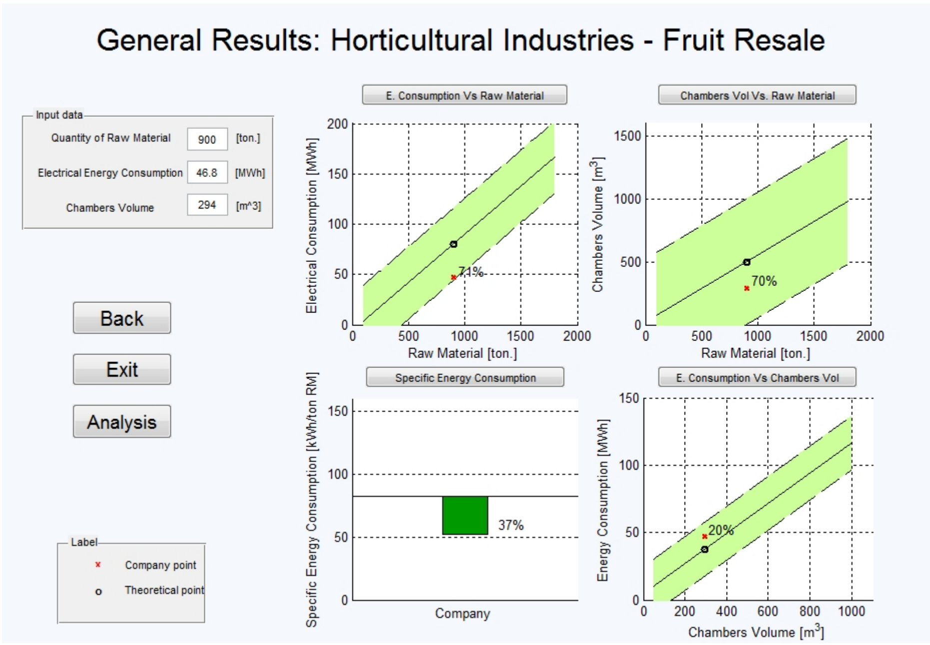


Fig. 7**.** Case study: Simulation results of Company A.

The first graph (left upper side of the tool window of Figure 7) compares the electrical consumption with the raw material processed by the company. Its value is 71% under the national average, which is a good result meaning that most of similar companies with the same energy consumption can only process about 600 tons of raw material. The second graph (right upper side) shows a similar result, although it compares the cold chambers volume with the quantity of raw material. Despite a value 70% under the average, which might lead the user to think that the chambers are under dimensioned, it means that the company as a stable volume of business all over the year making good use of the chambers storage space. The third graph (left bottom side) is related to the Specific Energy Consumption (SEC) and it can be considered as the most conclusive graph of the computational tool. It relates the energy consumption with the quantity of processed raw material. In this particular company, the SEC is 37% under the average, approximately 52 kWh/ton, allowing the user to conclude that it is a competitive and well sustained company with advantage against the majority of the other companies in the same business sector. The fourth and last graph indicates an energy consumption value 20% above the average regarding the chambers volume. There are many factors related to the variation of this relationship. In this case study, it is due to the fact that there are in average ten person per hour inside the cold chambers (significant heat load), and despite having an air conditioned antechamber, there are always significant losses that lead to an increased energy consumption since the compressors will work more time in order to compensate the temperature increase.

It is important to highlight that all predictive values are within the confidence interval of 95% (shaded green). However, in the fieldwork were identified practice measures that will improve the energy efficiency of the company, such as the replacement of fluorescent lamps by LED lamps, the use of curtains to reduce the heat entrance in the cold chambers when the door is open, among others.

It is noteworthy that these conclusions are indicative and allow managers of agrifood companies to be aware of the positioning of their company in relation to the national average in terms of energy efficiency. However, any change in the company or in the processes should be based on a detailed *in-situ* study about the energy consumption of different devices that are part of the production and cooling processes, taking into account the various inefficiencies that may exist. Nevertheless, the results obtained by the computational tool for the prediction of the energy performance of horticultural companies are in line with the failures or inefficiencies detected in fieldwork.

5 Conclusions

This paper presents a version of the computation tool for the prediction of energy performance aimed for the horticultural sector. The main workflow of the tool is presented. In order to demonstrate its applicability, a case study of a randomly selected company in the fruit resale subcategory was presented. From the graphical analysis of predicted results are presented some conclusions about the positioning of the company's performance in relation to the national average. The Cool-OP computational tool allows to perform an evaluation of the energy performance of companies in the agrifood sector comparing parameters such as raw materials processed, energy consumption and volume of cold stores with national averages so that the user has the ability to conclude which are the possible weaknesses or strengths of its company. The graph of specific energy consumption is very conclusive since it relates the energy consumption per ton of raw material. However it should be mentioned that the developed tool only aids in the analysis of the energy performance, so it is necessary that the user has sensitivity to identify possible problems of technical origin on the company facilities. Thus, the analysis does not eliminate the need for a more detailed study to determine the particular conditions that can be improved. This conclusion arises from the comparison of results obtained from simulations and results from audits to the respective companies. It became clear that they had adequate working conditions and a proper maintenance of the equipment, such as the compressors, the refrigerant pipes and their proper insulation, and the quality and maintenance of refrigeration chambers.

The current state of computational tool allows the user to manually enter the data of annual energy consumption, raw material processed annually and volume chambers. With these performance predictions, the user can decide how to improve the energy performance of his company. The practical application of this tool demonstrates its usefulness in helping decision-making in the implementation practice measures for the improvement of energy efficiency. This tool includes other correlations for other agrifood sectors, such as meat, fish, milk, vine and wine and distribution. Moreover, taking into account the sector of the company under analysis, it will provide automatic suggestions for the improvement of energy performance. Changing the linear correlation values, this tool can be used in any country, since the production process and storage conditions may differ depending on the food product.

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References

1. Pachai, A.C.: From Crandle to table – cooling and freezing of food. In: 2nd IIR International Conference on Sustainability and the Cold Chain (ICCC 2013), pp. 2-4. Paris, France, April (2013).

2. Laguerre, O., Hoang, H. M., Flick, D.: Experimental investigation and modelling in the food cold chain: Thermal and quality evolution. Trends in Food Science & Technology 29(2), 87-97 (2013).
3. IEA: 2012 Key World Energy Statistics. International Energy Agency (IEA), (2012).
4. Harding, A.H., Wareham, N.J., Bingham, S.A., Khaw, K., Luben, R., Welch, A., Forouhi, N.G.: Plasma vitamin C level, fruit and vegetable consumption, and the risk of new-onset type 2 diabetes mellitus: the European prospective investigation of cancer--Norfolk prospective study. Archives of Internal Medicine 168(14), 1493-1499 (2008).
5. World Cancer Research Fund (WCRF) Panel: Food, Nutrition, Physical Activity, and the Prevention of Cancer: A Global Perspective. World Cancer Research Fund: Washington, DC (2007).
6. Mirmiran, P., Noori, N., Zavareh, M.B., Azizi, F.: Fruit and vegetable consumption and risk factors for cardiovascular disease. Metabolism 58(4), 460-468 (2009).
7. Hung, H.C., Joshipura, K.J., Jiang, R., Hu, F.B., Hunter, D., Smith-Warner, S.A., Colditz, G.A., Rosner, B., Spiegelman, D., Willett, W.C.: Fruit and vegetable intake and risk of major chronic disease. Journal of the National Cancer Institute 96(21), 1577-1584 (2004).
8. Rissanen, T.H., Voutilainen, S., Virtanen, J.K., Venho, B., Vanharanta, M., Mursu, J., Salonen, J.T.: Low intake of fruits, berries and vegetables is associated with excess mortality in men: the Kuopio Ischaemic Heart Disease Risk Factor (KIHD) Study. Journal of Nutrition 133(1), 199-204 (2003).
9. World Health Organization: WHO European Action Plan for Food and Nutrition 2007-2012. WHO: Copenhagen, Denmark (2008).
10. European Food Safety Authority: Concise Database summary statistics - Total population (2008). `http://www.efsa.europa.eu/en/datexfoodcdb/datexfooddb.htm`
11. Gogou, E., Katsaros, G., Derens, E., Li, L., Alvarez, G., Taoukis, P.: Development and applications of the European Cold Chain Database as a tool for cold chain management. In: 2nd IIR International Conference on Sustainability and the Cold Chain (ICCC 2013), pp. 2-4. Paris, France, April (2013).
12. Food Refrigeration Innovations for Safety, consumers Benefit, Environmental impact and Energy optimisation along the cold chain in Europe.
13. Stahl, V., Alvarez, G., Derens, E., Hoang, H. M., Lintz, A., Hezard, B., El Jabri, M., Lepage, J. F. Ndoye, F. T., Thuault, D., Gwanpua, S. G., Verboven, P., Geeraerd, A.: An essential part of the frisbee software tool: Identification and validation of models quantifying the impact of the cold chain on the RTE pork products. In: 2nd IIR International Conference on Sustainability and the Cold Chain (ICCC 2013), pp. 2-4. Paris, France, April (2013).
14. Foster, A., Zilio, C., Corradi, M., Reinholdt, L., Evans, J.: Freely available cold store energy models. In: 2nd IIR International Conference on Sustainability and the Cold Chain (ICCC 2013), pp. 2-4. Paris, France, April (2013).
15. ICE-E Improving cold storage equipment in Europe, 2013.
16. Evans, J. A., Hammond, E. C., Gigiel, A. J., Foster, A. M., Reinholdt, L., Fikiin, K., Zilio, C.: Assessment of methods to reduce energy consumption of food cold stores. Applied Thermal Engineering 62(2), 697–705 (2014).
17. Evans, J.A., Foster, A. M., Huet, J.-M., Reinholdt, L., Fikkin, K., Zilio, C., Houska, M., Landfeld, A., Bond, C., Scheurs, M., T.W.M. van Sambeeck: Specific energy consumption values for various refrigerated cold stores. Energy and Buildings 74, 141-151 (2014).
18. Eden, M., Colmer, C.: Improved Cold Chain Management: efficiency and food safety through international project results. Food Safety and Tecnhology 24(1), 30-32 (2010).

19. Welcome to the Chill-on Project, http://www.chill-on.com/.
20. Colmer, C., Kuck, M., Lohmann, M., Bunke, M.: Novel Technologies to improve safety and transparency of the chilled food supply chain. *Innovation in the nordic marine sector*, May (2009).
21. Butler, D.: Fridges could save power for a rainy day. Nature (2007).
22. Saint Trofee – Refrigeration Tools, http://www.nightwind.eu/night-wind.html
23. IAPMEI, PME em números, http://www1.ionline.pt/conteudo/37754-populacao-activa-portuguesa-e-das-que-tem-menos-habilitacoes-literarias-
24. Ionline, http://www1.ionline.pt/conteudo/37754-populacao-activa-portuguesa-e-das-que-tem-menos-habilitacoes-literarias-
25. Nunes, J,: Energetic efficiency evaluation in refrigeration systems of agrifood industries in the Beira Interior region. PhD Thesis, University of Beira Interior, Covilhã, Portugal (2014).
26. Nunes, J., Silva, P.D., Andrade, L.P., Gaspar, P.D.: Characterization of specific energy consumption of electricity of Portuguese sausages industry. Energy and Sustainability 2014 - WIT Transactions on Ecology and the Environment, vol. 186 (2014).
27. Nunes, J., Silva, P.D., Andrade, L.P.: Energetic efficiency evaluation in refrigeration systems of meat industries. In: 23rd International Congress of Refrigeration - ICR 2011, August 21 - 26, Prague, Czech Republic (2011).
28. Nunes, J., Silva, P.D., Andrade, L.P., Gaspar, P.D., Domingues, L.C.: Energetic evaluation of refrigeration systems of horticultural industries in Portugal. In: 3rd IIR International Conference on Sustainability and Cold Chain (ICCC 2014), London, United Kingdom, June 23-25 (2014).
29. Matworks: MATLAB Creating Graphical User Interfaces. The Mathworks, Inc., USA (2013).
30. Evans, J.A., Hammond, E.C., Gigiel, A.J., Reinholdt, L., Fikiin, K., Zilio, C.: Improving the energy performance of cold stores. In: 2nd IIR International Conference on Sustainability and the Cold Chain (ICCC 2013), Paris, France, 2-4 April (2013).
31. Santos, R., Nunes, J., Silva, P.D., Gaspar, P.D., Andrade, L.P.: Ferramenta computacional de análise e simulação do desempenho de unidades de conservação de carne através de frio industrial. In: VI Congreso Ibérico y IV Congreso Iberoamericano de Ciencias y Técnicas del Frío (CYTEF-2012), Madrid, Spain, February (2012).
32. Santos, R., Nunes, J., Silva, P.D., Gaspar, P.D., Andrade, L.P.: Computational tool for the analysis and simulation of cold room performance in perishable products industry. In: 2nd IIR International Conference on Sustainability and the Cold Chain (ICCC 2013), Paris, France, April 2-4 (2013).
33. Neves, D., Gaspar, P.D., Silva, P.D., Andrade, L.P., Nunes, J.: Computational tool for the energy efficiency assessment of cheese industries - Case study of inner region of Portugal. In: V Congreso Iberoamericano de Ciencias y Técnicas del Frío (CYTEF 2014), Tarragona, Spain, June 18 - 20 (2014).