Improving Energy Usage in Food Processing Technologies

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Abstract

Problem solving and innovation capabilities are instinctive on engineers. The combination of these skills with continual improvement disciplines has been demonstrated to accelerate technological advancement processes, including improving equipment for energy usage. The purpose of this presentation is to review the potential application of CI techniques to improve energy usage in food technologies, particularly food processing equipment. A review of the problem solving and innovation techniques will be followed by technical and numerical examples of improvements in energy usage and ideas about how the innovation process could be speeded.

Keywords: energy, food processing, technology

Résumé

La résolution de problème et les capacités d'innovation sont des compétences innées chez l'ingénieur. Il est démontré que la combinaison de ces compétences et des disciplines d'amélioration continue (CI) accélérait les processus de développement technologique, incluant notamment le perfectionnement des équipements en matière d'utilisation d'énergie. Le but de cette présentation consiste à examiner l'application possible des techniques de CI à une meilleure utilisation de l'énergie dans le domaine des technologies de l'alimentation, plus particulièrement les équipements de transformation des aliments. Une revue des techniques de résolution de problèmes et d'innovation sera suivie d'exemples numériques et techniques d'amélioration de l'utilisation de l'énergie dans le cas de technologies de l'alimentation innovatrices, ainsi que des idées sur l'accélération possible du processus d'innovation.

Mots clés : énergie, transformation des aliments, technologie

1. Introduction

Visionaries have said that engineers make improvements in a cycle of problem recognition, formulation and solution, and as we advance to the future these improvements include providing solutions for a sustainable future [1]. Reducing energy use is considered an essential component of an eco-efficient strategy, and a driver of innovation and competitiveness. Energy usage is considered a critical performance indicator in Corporate Social Responsibility reports, and estimating the relative energy consumption per amount of product manufactured can be used as key performance indicator to benchmark energy use across manufacturing plants and companies, as well as to direct improvement efforts when implementing energy management systems. In addition to this, it has been observed that following an eco-efficient strategy may be limited because the savings obtained from waste minimization at some level of efficiency are subject to the law of diminishing returns, and therefore it must be complemented with other strategies like optimization [2].

The objective of this mini-review was to complement the current understanding on energy use by novel food technologies by evaluating the application of continual improvement techniques to improve food processing technologies.

2. Continual Improvement, Energy and Food Processing Operations

Food processing operations are closely related to chemical engineering operations and involve the transfer of momentum, mass, heat or a combination of them [3]. For commercial purposes, food processing technologies are grouped based on their function (i.e. heating, cooling, clarifying, concentrating, pasteurizing). With the advances on discoveries on their fundamental mechanisms of operation the development of commercial applications is continually growing together with the interest in classifying them based on their use for environmentally and energy friendly food processing [4, 5].

Analysing improvements in energy efficiency cannot be separated from improvements in productivity because that is the ultimate goal of utilizing the energy resource and interesting discoveries can be made only by improving the latest. Figure 1 illustrates that implementing continual improvement projects, at the company or plant level is one of the easiest ways to realize gains because there is a potential to decrease the storage capacity and create more products utilizing the same amount of energy, or alternatively create the same amount of products utilizing less energy [6].

It is generally suggested that analysing the entire Life Cycle of a product is the best approach to identify and prioritize the areas of improvement. One challenge that this approach presents is to allocate the use of common resources (like lighting, air conditioning and cleaning) to the various lines of products that the different players of the supply chain may have [7]. While this can be facilitated utilizing accounting techniques the other challenge to overcome is to is to coordinate obtaining information from all the different players in the supply chain.

At the plant level, a minimization (waste reduction) effort can be complemented with an optimization strategy. In continual improvement language this can be interpreted as a lean and six sigma or Theory of Constraints project. Six Sigma projects generally include design of experiments (DoE) for optimization which has been considered the heart of engineering [8]. The DoE toolbox includes tools like factorial design, response surface, and robust design and is complemented with regression theory. Several efforts have been made to utilize these tools to solve food engineering problems [9], especially in situations where multi-parametric analysis is required to find optimum conditions for treatment [10, 11].

In addition to statistical tools, engineering design requires problem solving skills, because of this Design for Six Sigma projects are complemented with problem solving tools like the Theory of Problem Solving (TIPS) or TRIZ which accelerates the improvement process by facilitating system analysis and search for solutions based on what already has been invented [12].

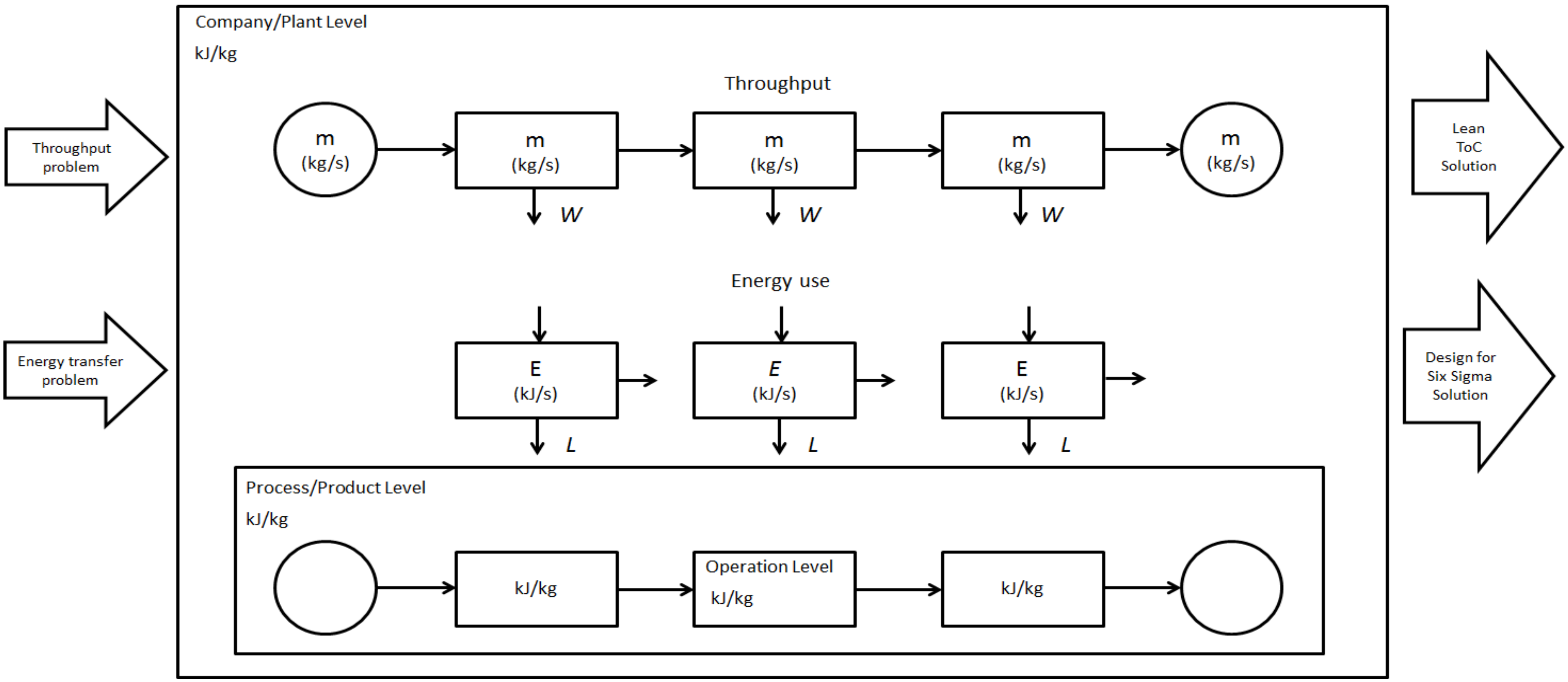

Figure 1 Illustration of the areas and levels of energy improvement. ToC: Theory of Constraints, M: mass flow rate, E: energy, W: Waste, L: Losses.

A recent review on the energy use by novel microbial decontamination technologies followed up the idea of utilizing specific energy (energy use per unit mass) as an indicator of microbial inactivation intensity, and has concluded that this indicator can be used to analyse energy usage at various levels (from energy utilized to power consumption) and can be used to estimate efficiencies in energy usage [13, 14]. Parallel to this, a study of the sustainability performance indicators reported by the food and beverages sector (based on the guidelines of the Global Reporting Initiative), observed that some of the largest food and beverage manufacturing companies are reporting their global energy use as relative to productivity (i.e. Gigajoules per tonne or joules per litre) because this allows for a fair comparison of their energy consumption [14].

3. Examples of energy savings in Food Processing Operations

In the implementation of continual improvement projects system thinking is a very useful tool to establish the context in which the improvements are made. On engineering this is a growing field as system engineers continue to discover the applications of their knowledge.

A common example of energy waste is the energy losses that occur in an oven. Because the heat energy is applied to the entire cavity filling efficiency affects energy use per unit product (Figure 2). Given that is not feasible to increase the amount of product manufactured (throughput), a solution for this problem could be to create fillers for the empty spaces to reuse the heat and potentially recover the energy wasted. Parallel to this, energy use could be improved by understanding the alternatives that can be utilized to increase temperature, prevent heat losses and reusing the heat loss during cooling.

Some other examples of how solutions for energy improvements can be viewed utilizing a systems perspective and problem solving techniques (like TIPS) to improve energy usage is separating a big cooler into containers to maintain cold temperatures, recycling heat in tubular or plate heat exchangers, or applying lower pressures in membrane filtration systems (Figure 3). The use of these solutions has been demonstrated in scientific and industrial contexts but the beauty of using a TIPS perspective is that facilitates benchmarking and use in other contexts.

It is important to understand that a complete perspective about the context where the solution is applied is necessary to discover the best solution for energy improvements. One of the sensitive areas of improvements is food pasteurization because it requires decreasing energy usage while achieving the same food safety objective [15]. In a particular study on the application of High Pressure Processing (HPP) it was observed that the inactivation of *E. coli* in skim milk could be achieved by pre-heating the sample from 20°C to 50°C (118.4 J/g) previous to one cycle of 550 MPa (524 J/g), or by treating the product with two pressure cycles of 550 MPa (1,048 J/g). In this case the previous action leads to a more energy efficient process compared to partial actions. Taking a complete process perspective, skim milk is generally subjected to mild temperatures (50°C) for cream separation and homogenization, therefore an integration of the HPP treatment in the process line is more feasible. If an absolute cold treatment is desired, all the previous processes should be adjusted to cold temperatures, and the evaluation of the energy requirements of the new process should be considered.

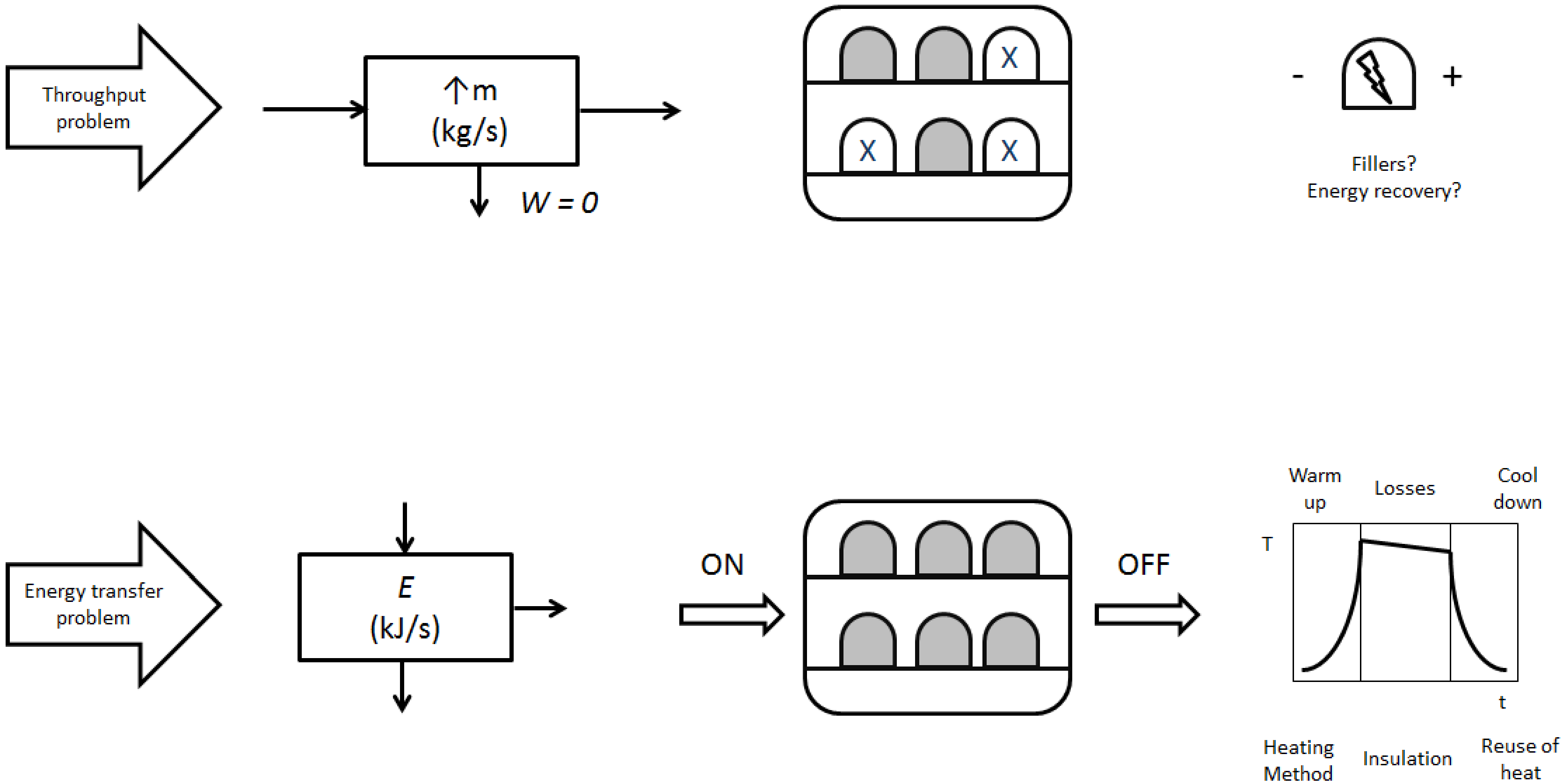

Figure 2 Examples of alternatives for improving energy usage in a food oven

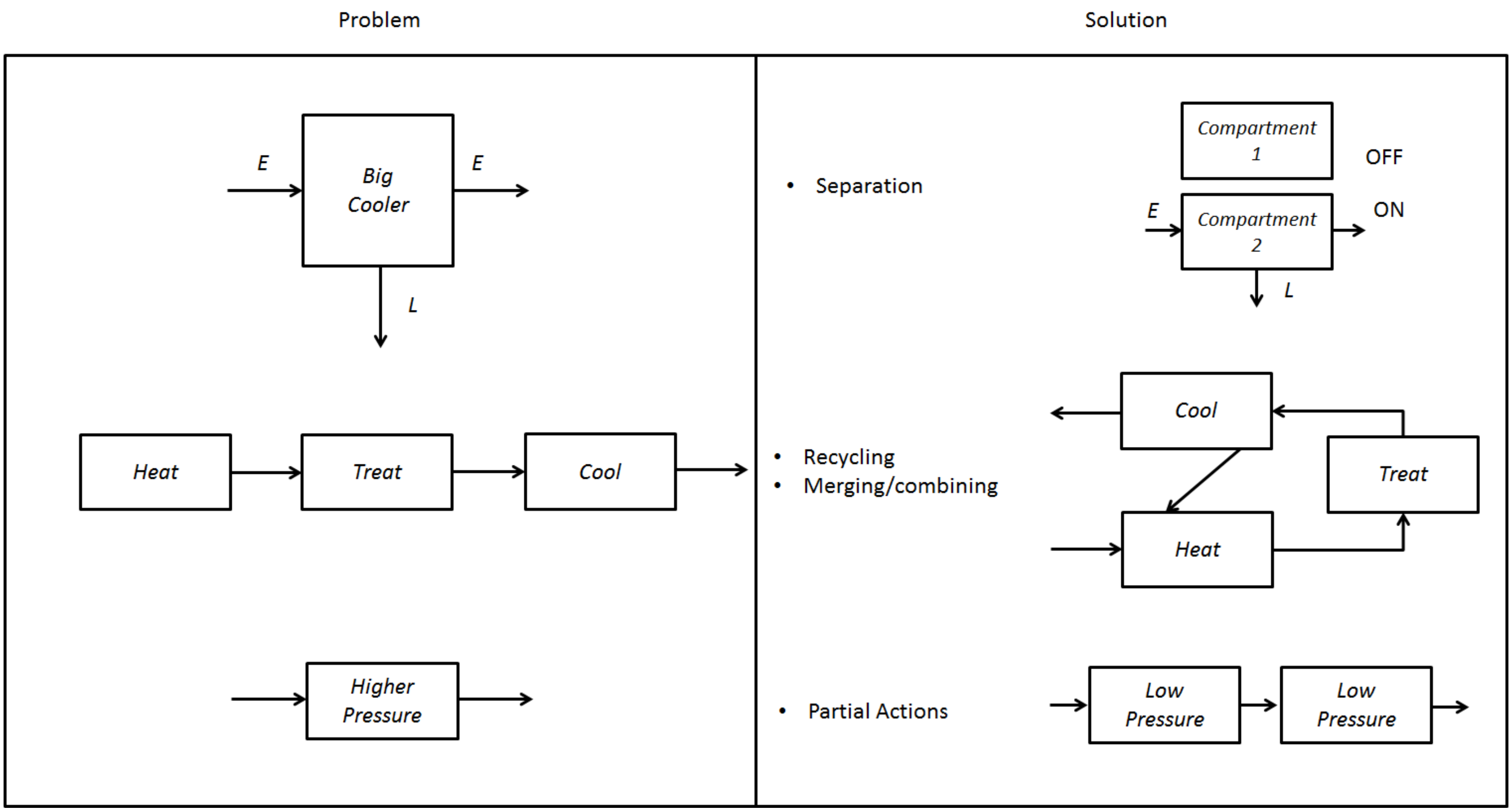

Figure 3. Examples of inventive problem solving

Ultraviolet light treatment systems are benefited by the use of optics and mechanical vibration. Energy calculations based in number of lamps, and their output power, suggest that a system that utilizes a spiral tube to circulate the fluid has the potential to consume up to 200 times less energy that regular treatment chambers, and it could be lowered by pulsing the light. Because not all the energy applied is utilized there UV treatment chambers have more room for improvement.

7. Conclusion

In resume, continual improvement techniques are benefited from advances on engineering and as the profession advances new areas of application like systems and sustainable engineering advance. Food processing technologies have the potential for improving their energy usage if the existing fundamental knowledge is strategically applied.

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10. Biography

Oscar Rodriguez Gonzalez is a consultant at Rodriguez-Gonzalez Services. He obtained his PhD in Food Science at the University of Guelph, his MSc in Biological and Agricultural Engineering at Texas A&M University, and his BSc in the Escuela Agricola Panamericana (Zamorano). He is also a Professional Agrologist, HACCP and Lean Six Sigma Black Belt certified, continuously researching topics in Food Safety Engineering, Continual Improvement and Sustainability and contributing to various professional groups.