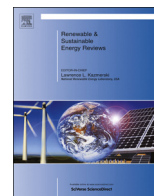




ELSEVIER

Contents lists available at ScienceDirect

## Renewable and Sustainable Energy Reviews

journal homepage: [www.elsevier.com/locate/rser](http://www.elsevier.com/locate/rser)

## Key points on the energy sustainable development of the food industry – Case study of the Portuguese sausages industry



J. Nunes<sup>a</sup>, Pedro D. Silva<sup>b</sup>, L.P. Andrade<sup>a</sup>, Pedro D. Gaspar<sup>b,\*</sup>

<sup>a</sup> Politechnic Institute of Castelo Branco, Av. Pedro Álvares Cabral n°12, 6000 Castelo Branco, Portugal

<sup>b</sup> University of Beira Interior, Electromechanical Engineering Department, Calçada do Lameiro, 6200-001 Covilhã, Portugal

## ARTICLE INFO

## Article history:

Received 10 February 2015

Received in revised form

3 August 2015

Accepted 10 December 2015

## Keywords:

Food industry

Energy consumption

Energy efficiency measures

Energy indicators

Sustainability

Sausages

Refrigeration

## ABSTRACT

Sausage is an ancient food type that is nowadays considered as a delicatessen. Sausages are categorized within the deli sector as meat sub products. It is a food product preferred by consumers due to its nutritional value and organoleptic characteristics (wide range of flavors and textures). The heating and cooling processes during sausages production are indispensable technologies to ensure both the specific organoleptic characteristics and properties conservation through time. Energy is a major cost in the operation of these facilities. This paper starts with a review of the research related to energy consumption, energy efficiency measures and energy indicators in the food industry. Additionally it describes the major cost-effective electricity savings (improved door protection, defrost optimization, control settings and repairs) that can be applied to this industry. Later a case study that characterizes the production process and the energy consumption of sausages processing industry in Portugal (20 industries) is presented. The results from this case study show that energy consumption of this type of industries is mainly of electricity (82%). The annual average specific energy consumption (SEC) of electricity is 660 kWh<sub>e</sub> per tonne of raw material. Correlations were developed that show the relationships between tons of raw material and electricity consumption, volume of cold stores and compressors nominal power. A strong relationship between SEC and the usage of cold rooms was determined. Several electricity savings, estimated in 24%, can be achieved by implementing simple practice measures in the refrigeration systems.

© 2015 Elsevier Ltd. All rights reserved.

## Contents

1. Introduction	393
2. Energy consumption in the food industry	394
3. Energy efficiency in the food industry	396
4. Energy consumption indicators	397
5. Cold storage facilities	399
6. Case study of Portuguese sausages industry	401
6.1. Productive process	402
6.2. Material and methods	402
6.3. Results analysis and discussion	403
6.3.1. Facilities	403
6.3.2. Refrigeration systems	403
6.3.3. Energy consumption	404
6.3.4. Specific indicators	405
6.3.5. Refrigeration system modeling	406
7. Best practice measures and technologies	406
8. Conclusions	408
References	409

\* Corresponding author.

E-mail addresses: [jnunes@ipcb.pt](mailto:jnunes@ipcb.pt) (J. Nunes), [dinho@ubi.pt](mailto:dinho@ubi.pt) (P.D. Silva), [luispa@ipcb.pt](mailto:luispa@ipcb.pt) (L.P. Andrade), [dinis@ubi.pt](mailto:dinis@ubi.pt) (P.D. Gaspar).

## 1. Introduction

The industrial sector is comprised by a diverse set of industries that are globally responsible for 37% of a worldwide energy consumption and 36% of carbon dioxide emissions (CO<sub>2</sub>) [1]. The main industries of this sector are manufacturing industries within which stands agrifood industries [122,123]. At European level, the food industry represents a universe of 286,000 industries with 4.2 million direct jobs and had in 2014 a turnover of 1048 billion euros [32].

In Portugal, the food industries follow the European trend, being also the largest group of manufacturing industries in the country (13.2%). In 2011 reached a business turnover of 9340 million euros [51]. Within the food industry, the largest sector corresponds to the meat industry. In 2010, this sector was represented by 1159 industries with a turnover of 1130 million euros, representing 12.3% of total volume sales volume of food industries [51]. The main products of the meat industry sector are the cured sausages. Based on the results of 2012, these industries produced 87,400 tonnes of cured sausages, representing 46.8% of all industrial production of meat products and corresponding to a turnover of 249.4 million euros [50]. In Portugal, as in many European countries, there has been an increased production of cured sausages. It was registered an increase of 10.6% in 2012 comparing with the previous year [127,52,99].

In general, industries in this sector use two types of energy: electricity and fossil fuels. The electricity is used primarily on operating the cooling systems to comply with food safety requirements due to the high degree of spoilage of meat [108,113,122]. In the particular case of cured sausages manufacture, about 25% of the total industrial energy is used for cooling and refrigeration processes, and 48% for food processing [81]. However, during the production period, the cooling systems can consume 45–90% of total electricity. In non-production periods (retention periods), they are responsible for all electricity consumption [84,97].

The energy consumption in sausages factories depends on various factors such as the type of production process, the size and structure of the product, the chemical and physical properties of raw materials, the technology used, the mechanization level of the factory and the usage of installed capacity [128,129,44,61]. In order to maintain a sausages industry competitive taking into account the rising of energy costs, it is necessary to have a good energy and environmental performance. Thus, these industries should use the best available techniques and production practices, with major emphasis for its energy efficiency [17–19,22,87].

In general, for evaluating the energy efficiency of an industrial unit is common to use a normalized scale, often defined by the ratio of energy expended during production and the result obtained from such production [97,98,129]. Thus, indicators of Specific Energy Consumption, SEC, (electrical and thermal) are obtained, that allow the evaluation of the performance of an industrial unit by comparison with indicators that belong to others units with the same category for similar activities and technologies [129].

There are some SEC values for these two types of energy in related literature, although they correspond to industrial units with different dimensions, technology level and world regions [104,18,19,35,97,129]. None of these studies deals specifically with sausage-making industries and furthermore they only use one pilot plant or fictional scenarios. Nevertheless, these indicators allow to find the best practices and procedures for the reduction of energy consumption in this type of industry. Fritzson and Berntsson [35] estimated that the energy savings in cooling meat products could achieve 10% of in modern industries and 15% in the oldest ones.

In Portugal, the industrial food sector is made up mostly by micro, small and medium industries, that having energy intakes lower than 500 tonnes of oil equivalent (toe) do not require by government diploma an evaluation of their energy performance. The energy profile and the main features that contribute to its energy performance, with special attention to refrigeration systems, were not known for this specific type of industry.

This paper provides a review of the research related to energy consumption, energy efficiency measures and energy indicators in the food industry. The review starts with the description of these topics in the general industrial sector to the specific sector of meat processing. It is provided a review of the research developed in several countries focusing on the energy consumption, energy efficiency measures and energy indicators values in the food industry. The energy savings potential is quantified in terms of procedures and technologies. To highlight the relevance of this approach, this paper also presents a study with the results of 20 sausages factory audits located in central region of Portugal to assess the characteristics of energy consumption, with particular emphasis on electrical energy. The characteristics of the infrastructures, refrigeration systems, energy consumption, energy performance and potential savings of electricity are analyzed. A set of mathematical equations that relate the main parameters that influence the performance of cooling systems, such as: raw materials, cold rooms volume, electrical energy consumption and the nominal compressors power are obtained. Using these correlations, the owner of a sausage company can evaluate how much competitive is his company in terms of energy efficiency compared with his national counterparts. Knowing this value, the owner can apply a set of practice measures with different payback times to achieve energy savings that can go up to 24%. These general recommendations, some of them very cost-effective, may help companies' competitiveness through energy sustainability measures.

Globally, the review and the case study results are used to present the key points on the energy consumption, energy efficiency measures and energy savings potential to encourage the energy sustainable development of food industry.

## 2. Energy consumption in the food industry

The energy consumption of refrigeration systems in the food industry has been growing due to increasing production of food and the requirements imposed by quality, hygiene and food safety standards [97]. The cooling systems are considered as intensive energy consumption systems due to the high degree of use in many industrial processes [131,132,75]. The specific characteristics of the food industry business within the various countries, which is composed by a large number of small sized manufacturing food industries, result on a very high electrical energy consumption [97]. In the EU, the majority (99.8%) of these industries was small and medium enterprises (SMEs) –about 20.9 million– and more than nine out of ten companies (92%) employed less than 10 workers. This scenario is more relevant in the member states of southern Europe, such as Italy, Spain and Portugal [25]. A few sub-sectors had an improvement of energy consumption resulting from increased activities and simultaneously by increased use of refrigeration systems [97]. In fact, the electrical energy consumed by refrigeration systems may reach 85% of total energy consumption [121]. In the UK, 11% of final energy is consumed by the food industry and some sectors are using more than 90% of electrical energy into the refrigeration system [107]. Many economic sectors require the use of a fast cooling technique to remove the initial thermal load of products before the cold storage. Swain et al. [107] points out that in the UK there are six categories where it is

Download English Version:

<https://daneshyari.com/en/article/8114553>

Download Persian Version:

<https://daneshyari.com/article/8114553>

[Daneshyari.com](https://daneshyari.com)