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CARBON FOOTPRINT IN THE FOOD INDUSTRY. CASE STUDY – MEAT INDUSTRY

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Abstract
The food industry, but especially the meat industry, is a large consumer of energy, which often goes unnoticed and implicitly unassessed, both in terms of the amount of energy consumed and in terms of its impact on the environment and climate change. In this context, this study highlights energy consumption and greenhouse gas emissions associated with food processing and distribution to final consumers.
The main objectives of this study are to assess the carbon footprint generated by the meat industry, its impact on the environment and climate change, and ways to reduce it.
Key words: *Meat industry, greenhouse gases, carbon footprint, environmental protection.*

INTRODUCTION

Product carbon footprint (CF) is a tool to quantify greenhouse gas (GHG) emissions from a product along the entire supply chain, starting from raw material procurement, production, processing, value addition, packaging, storage, transportation, use, cooking, food waste and disposal.

CF is a quantitative expression of greenhouse gas emissions that helps manage emissions and evaluate mitigation practices. The carbon footprint of products can help identify GHG emission "tipping points" in processing and delivery activities and guide manufacturers to identify ways to save energy (Murphy-Bokern, n.d.). Food emissions comprise three main GHGs, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Carbon dioxide is released when fossil fuels are burned to generate energy. Methane is emitted from animal digestion and during the decomposition of food waste in landfills, while nitrous oxide comes from fertilizer application for growing crops. (Naresh Kumar & Chakabarti, 2019)

Methodologies for quantifying the carbon footprint of products are still evolving (Pandey et al., 2011). The comparison between different non-CO_2 GHGs is made by converting their effect into the common unit of 'equivalent' carbon dioxide (CO_2-eq) based on their global warming potential, relative to that of CO_2 (Naresh Kumar & Chakabarti, 2019).

Methodologies and standards for GHG accounting are given by IPCC2006 guidelines, World Resources Institute (WRI) GHG protocol, ISO 14064 (parts 1 and 2), publicly available specifications-2050 (PAS 2050) of the British Standard Institution (BSI), ISO 14025, ISO 14067 (Pandey et al., 2011). GHG emissions from a food industry will include both direct and indirect emissions. The direct use of energy is for agricultural activities in the production of raw materials and during the various stages of manufacturing processes, while the indirect use of energy is during storage, transport, and use of electricity for the operation of the food industry. The Intergovernmental Panel on Climate Change (IPCC) has developed a standard methodology for quantifying GHG emissions from major economic sectors (IPCC 2000, 2006), which is used by most countries to calculate GHG emissions (Naresh Kumar & Chakabarti, 2019).

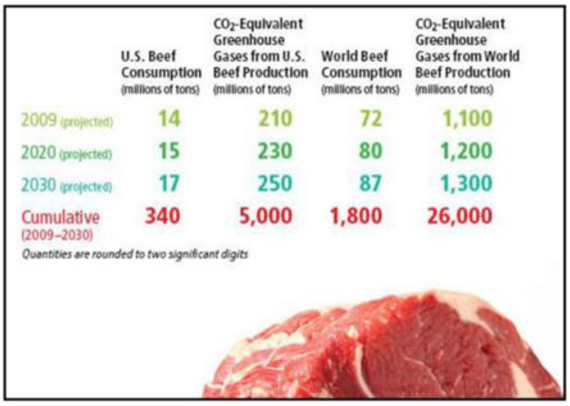
The aim of this study is to assess the carbon footprint of the food industry, focusing specifically on the meat industry, and identify several ways to reduce its carbon footprint and impact on the environment.

This study aims to highlight the impact that meat production and consumption have on climate change and the environment, highlighting the associated problems and challenges as well as possible solutions. The study brings to the fore the key concepts related to the food industry in relation to the carbon footprint, its quantification on the entire process of meat production and processing, from animal husbandry to its processing and distribution, following a thorough analysis of the specialized bibliography.

Key concepts

According to a report by the Worldwatch Institute (WI), global meat production and consumption continue to grow. Meat production has tripled in the last four decades and increased by 20% in the last 10 years alone, with massive increases expected in the coming years (Fig. 1) (Petrovic et al., 2015).

Industrial countries consume increasing amounts of meat, almost double those in developing countries.



	U.S. Beef Consumption (millions of tons)	CO_2-Equivalent Greenhouse Gases from U.S. Beef Production (millions of tons)	World Beef Consumption (millions of tons)	CO_2-Equivalent Greenhouse Gases from World Beef Production (millions of tons)
2009 (projected)	14	210	72	1,100
2020 (projected)	15	230	80	1,200
2030 (projected)	17	250	87	1,300
Cumulative (2009–2030)	340	5,000	1,800	26,000

Quantities are rounded to two significant digits

Figure 1. Approximation of beef production for the years 2009-2030 Source: (Petrovic et al., 2015)

Livestock breeding, and implicitly the manufacturing industry, has a negative impact on the environment, an impact that can be reduced by a series of measures that emerge from specialized literature.

Thus, in terms of production, greenhouse gas emissions can be reduced by improving animal productivity, proper manure management and its responsible application, reducing enteric methane production through growing and feeding. (de Boer et al. 2011)

From a consumption perspective, changing your diet can have a significant impact on reducing greenhouse gas emissions. Switching to a vegetarian diet or plant-based alternatives can significantly reduce greenhouse gas emissions (Hallström et al., 2015).

Reducing meat losses and food waste is an important strategy for reducing greenhouse gas emissions, as food waste contributes to both direct and indirect emissions. Greenhouse gas emissions related to meat waste were reported to be estimated at 186 Mt CO_2 -eq in Europe, or almost 16% of emissions of the entire food supply chain (Scherhaufer et al., 2018).

Carbon footprint in the meat industry

From specialized studies it is noted that beef and lamb stand out by an extremely high carbon footprint, especially due to methane emissions (CH_4) produced during enteric fermentation of ruminants. Dairy products, especially cheese, follow in the ranking in terms of carbon footprint. Meat from monogastric animals, such as pigs and poultry, has lower emissions than ruminant meat, but still higher than most plant-based foods. This is due to the significant amount of feed required in meat production and emissions associated with manure management (Röös, 2013).

The meat industry has a significant impact on the carbon footprint, due to high demand for resources such as land, water and energy, and significant greenhouse gas emissions. According to the Food and Agriculture Organization of the United Nations (FAO), the livestock sector contributes 14.5% to global greenhouse gas emissions, most of which come from meat and poultry production. Emissions from the meat industry are mainly related to methane and nitrous oxide released by animals and agricultural processes (Philippe & Nicks, 2015). Eliminating packaging materials used for meat products also contributes to their carbon footprint. Many packaging materials used for meat products are made of plastic, which is not biodegradable and therefore can take hundreds of years to decompose in landfills (Karwacka et al., 2020).

The food industry has a significant impact on greenhouse gas emissions due to the processes of production, transport and disposal of packaging and waste. It has been found that the carbon footprint varies significantly depending on the type of food and production processes.

The meat industry has a particularly significant impact on the carbon footprint of the food industry. The processes involved in animal husbandry, manure management and animal slaughter contribute significantly to greenhouse gas emissions. Animal husbandry requires significant amounts of resources and emits a significant amount of methane.

MATERIALS AND METHODS

The research was carried out exclusively starting from the specialized bibliography currently existing on the carbon footprint of the food industry, especially the meat industry. This approach involved collecting, selecting, and interpreting information available in existing written sources in various international databases.

Thus, following the research of many articles relevant to this topic, a research scheme was made regarding the analysis and interpretation of the specialized literature, present in Table 1.

Search engine	Search keys				Number of results relevant to the article
	Food industry	Meat industry	Carbon footprint	Pork	
Google Scholar	19	20	35	12	8
Science Direct	23	18	27	10	9
Scopus	26	22	35	14	11
Springer link	6	3	5	3	3

Table 1. Research diagram regarding the analysis and interpretation of literature

Table 1 highlights the main search engines such as Google Scholar, Science Direct, Scopus and Springer link. They served as support for the study that was the basis for the elaboration of this article, mainly due to the varied database regarding the academic and scientific literature they have.

RESULTS AND DISCUSSIONS

Studies on the carbon footprint of the food industry, with a particular focus on the meat industry, are particularly important in the context of concerns about climate change and sustainable development. This research is based on the analysis of specialized bibliography in the field of carbon footprint, with a case study focused on the meat industry.

When it comes to making greenhouse gas emissions more efficient in pork processing, the entire technological flow must be considered, starting from the management of animals on farms to the consumption of finished products by humans.

Thus, using data from literature, this route will be highlighted by pointing out the following steps:

Figure 2. The route of meat from farm to fork

Pig breeding technologies

Intensive European pig farming systems are highly dependent on concentrated off-farm feed. From a comparison of three scenarios for pig production in France, (Basset-Mens & van der Werf, 2005) concluded that feed production (including the cultivation system, processing and transport of feed) accounted for approximately 54–73% of total greenhouse gas emissions per kg of live pig. Similar values have been reported in other studies (Carlsson-Kanyama, 1998; Eriksson et al., 2005).

de Boer et al. describe various strategies to reduce GHG emissions from the production of individual forage crops, such as improving crop yields through plant breeding, improving the efficiency of fertilizer absorption by crops, and improving crop rotation. (by Boer et al., 2011)

For example (Cederberg et al., 2005) showed that wheat yields could increase by more than 15% when grown after legumes or rapeseed as opposed to monoculture; while in four crop rotations, including legumes, of cereals studied by (Nemecek et al., 2008), the use of mineral fertilizers per kg of dry matter was 6 to 20% lower compared to the same crop rotations without legumes.

Several studies have investigated the potential benefits of replacing imported feed ingredients – especially soybean products with long transport distances and land-use change – with locally produced protein crops and by-products from food and bioenergy production (Hörtenhuber et al., 2011; Lehuger et al., 2009; van der Werf et al., 2005)or adding synthetic amino acids (SAAs) as a supplement to a low-protein diet. (Eriksson et al., 2005) However, no consistent conclusions could be drawn about diet formulation from these studies, mainly due to differences in methodological choices between studies, e.g., on the inclusion of emissions from land-use change and alternative diets considered.

Manure management

The most common manure management system, which is used in 80% of integrated farms, is its storage in open manure tanks without natural crust cover, while flame biodigester is used in almost all other farms (20%)(Higarashi et al., 2013; Kunz et al., n.d.). In both scenarios, manure is then applied to the field as organic fertilizer. Looking at the situation in Brazil, biodigester use is increasing, mainly due to potential reductions in greenhouse gas (GHG) emissions by converting methane

(CH_4) emissions into carbon dioxide in combustion processes or into heat or electricity (Cherubini et al., 2015).

Some studies (Amon et al. 2006; Vallejo et al. 2006) have shown that using an anaerobic digestion system such as the biodigester also reduces nitrous oxide emissions (N_2O) during the application of manure compared to the application of raw manure. However, the biodigester does not provide solutions to other manure disposal problems, such as removing nitrogen and phosphorus or reducing manure. In this regard, an alternative to open manure and biodigester tanks is the handling of manure in solid form by composting.

Pig slaughter technology

After transportation from the farm to the slaughterhouse, pigs undergo the processes of bleeding, scalding, depilation and grooming, removal of the head, evisceration, splitting of the carcass and inspection. (Meul et al., 2012)

According to a study, the slaughter phase shows that 97% of its impact is caused by the supply of meat, while the rest is largely caused by utilities (transport from farms, electricity, natural gas burned for flames, etc.). Other inputs such as gas, diesel, water and waste treatment are negligible in this study. (Six et al., 2017)

According to the same article, pigs delivered by the farm have an impact between 3.1 and 3.4 kg CO_2 -eq per kilogram. This difference is mainly caused by the difference in the supply of feed applied by producing farms.

In the slaughter process, in addition to the main steps to obtain pig carcasses or half-carcasses, certain by-products result. Of these, some can be used to obtain other products in the meat processing plant, some can be used as natural casings and some of them represent residues that cannot be used in any way. These by-products must also be transported and incinerated, energy-consuming steps that also have a certain carbon footprint. In most literature studies, these values of the carbon footprint left by by-products are intentionally omitted because they are not of great interest, not having a significant value that can influence the result very much.

CONCLUSIONS

The concept of carbon footprint evolved with increasing concerns about climate change in the 1960s, thus becoming a topic of major interest in scientific literature. The Kyoto Protocol defined carbon footprint as an essential metric to measure the impact of products on greenhouse gas emissions. The food industry, with a particular focus on the meat industry, has a significant impact on the carbon footprint due to the processes of production, transport, and disposal of waste. This industry accounts for a significant share of global greenhouse gas emissions. The carbon footprint varies significantly depending on the type of food and production processes involved. Meat, especially beef (18.21 kg CO_2-eq/kg product) and lamb (22.96 kg CO_2-eq/kg product), have an extremely high carbon footprint due to methane emissions generated during ruminant fermentation.

According to research, there are several key strategies to reduce the carbon footprint in the meat industry. These include improving livestock efficiency management, responsibly managing manure, switching to diets with less meat or plant-based alternatives, and reducing meat losses and food waste.

Meat consumption, especially in developed countries, accounts for a significant part of the meat industry's carbon footprint. Changing your diet to include less meat can have a significant impact in reducing greenhouse gas emissions.

This study is based on a review of existing literature to understand and highlight the impact of carbon footprint in the meat industry.

Continuous research and awareness of these issues is essential to contribute to efforts to combat climate change and promote sustainability in the food industry.

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