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Carbon Footprint Analysis of Processing Tomato Cultivation in Greece

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RESEARCH ARTICLE

Abstract

Agriculture contributes to global warming through the emissions of greenhouse gasses (GHGs). As one of the most important horticultural crops, tomato (*Lycopersicon esculentum* Mill.) is of great economic importance. Approximately 80% of the tomatoes grown around the world are processed into sauces, juices, ketchup, canned tomatoes, and soups. The goal of the present study was to assess the carbon footprint of commercially grown processing tomatoes in Greece. The emissions were calculated by using the Cool Farm Tool software. For data collection, a questionnaire was distributed to processing tomato producers. The questionnaires were completed by 40 producers from the main processing tomato-growing regions of Greece. The estimated total carbon footprint value of tomato cultivation for a mean area of 7.16 ha (producing 94.8 tn of tomatoes per ha) was 1,369,700 kg CO_2-eq. Specifically, the estimated carbon footprint values per hectare and kg of fruit were 191,298.88 and 0.20 kg CO_2-eq, respectively. In addition, the current study revealed that the highest CO_2-eq emissions per tonne of fruit were observed in energy use (fuel consumption) for field operations, corresponding to 40.49% of the total emissions per tonne of product.

Keywords: carbon footprint, greenhouse gas emissions, processed tomato

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is arguably one of the most imprtant vegetables, second only to potato (Padmanabhan et al., 2016). It originates from South America (Baranski et al., 2016) and nowadays it is cultivated all around the globe (Padmanabhan et al., 2016), with China, India, the United States, Turkey, and Egypt being the major tomato producers. Tomato is either consumed as a raw vegetable, or are processed into sauces, tomato paste, canned tomatoes, juices, and catsup (Padmanabhan et al., 2016). These products correspont to approximately 80% of the global tomato production (Bilalis et al., 2018). In the EU alone, processsed tomato production exceded 10,000,000 tonnes in 2021 (European Commission, 2022). Despite its economic significance, the cultivation of processed tomatoes often has a notworthy environmental impact (Payen and Basset-Mens, 2013). Overall, agriculture is estimate to produce nearly the 1/3 of the global greenhouse gassess (GHGs) emissions (World Bank, 2023). In particular, the extensive use of chemical inputs such as chemichal fertilizers and pesticides, the use of machinery, and the management of residues have been proposed to emit significant amounts of GHGs in the atmospere (Lynch et al., 2021). In Greece, tomato requires significant amouts of chemical inputs, thus it is believed to have a significant environmental footprint. However, the available literature lacks a presice estimation of this footprint, and particularly the carbon footprint of the crop. The goal of the present study was to assess the carbon footprint (based on the sources of the GHGs) of commercially grown processing tomatoes in Greece.

MATERIALS AND METHODS

The greenhouse emissions were calculated using Cool Farm Tool software, which was developed by Cool Farm Alliance (Grantham, Lincolnshire, UK) as a calculating tool to estimate greenhouse gas emissions and carbon footprint based on yield and marketable yields in a field, crop area, fertilizer application (type and rate), pesticide application number, and energy use (use of electricity and fuel). In general, the Cool Farm Tool covers nearly all crops worldwide, with the exception of crops grown in non-soil media (e.g. greenhouses or hydroponic systems).

For data collection, a questionnaire divided into five categories/groups (cultivation details, soil characteristics, inputs, fuel, and water use) was distributed to processing tomato producers.

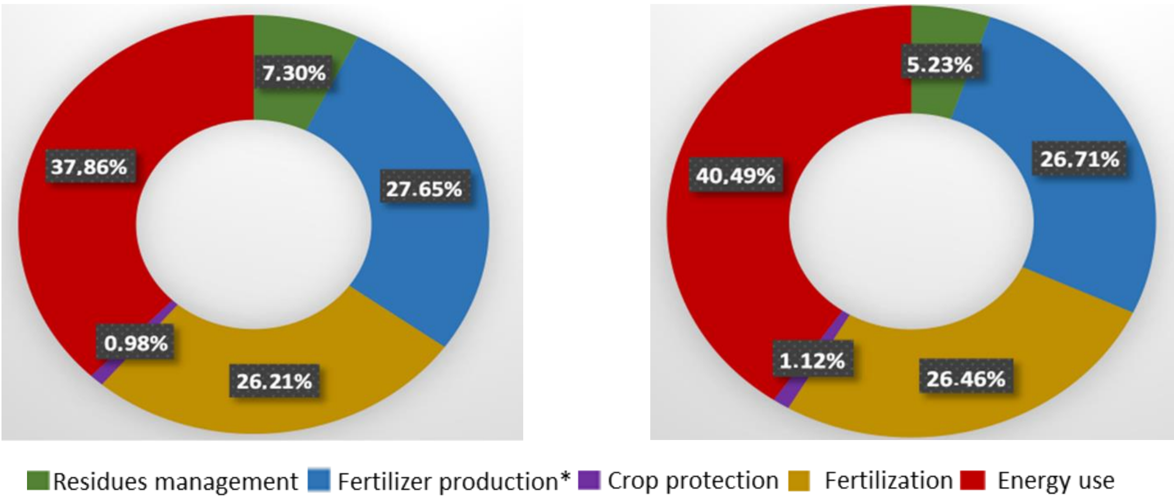
- Group 1 contained information regarding the cultivation area and amount of final product. The data on waste management was also provided to Group 1. A unanimous decision was reached by the producers regarding the management of the residues. It was either distributed on the plot, or it was integrated or used as a cover with the crop residues.
- Group 2 recorded soil characteristics such as soil texture (clay, silty, sandy, etc.), soil organic matter. The soil moisture was described as "dry", and the soil drainage as "good". In addition, the pH of the soil was also determined.
- Group 3 included fertilization methods and plant protection applications. In particular, the type of fertilizer used, its application dose, and the evaluation of the measure (fertilizer units or products) were selected. For the purposes of describing the application of plant protection, a category was chosen which describes both the time and method of application (seed treatment, soil treatment, or post-emergence) as well as the number of applications (doses) for each operation individually (weed control, leafing, etc.).
- Group 4 recorded direct energy use, i.e., the energy source was selected and the amount of energy (liters) used for the crop was entered. The consumption of each task was recorded separately (plowing, cultivator, harrowing, sowing, fertilizing, plant protection, irrigation, supervision visits, and harvesting).
- Group 5 recorded water use, i.e. how many times irrigation was conducted, by what method and the source of the water. Drilling was the source of water for all producers. Pumping depth was set at 160 m, and horizontal distance at 200 m. The values are averages derived from different regions. As a final step, the energy source (oil, electric power, or gravity) used to irrigate the tomato was determined.

The questionnaires were completed by 40 producers from the main processing tomato-growing regions of Greece. Excessive values were excluded from the results in order to calculate the mean value and minimize error. Finally, in the present study, the greenhouse gases (GHG: CO_2, CH_4, and N_2O) were expressed as kilograms of CO_2 equivalent (kg CO_2-eq).

RESULTS AND DISCUSSIONS

The estimated total carbon footprint value of tomato cultivation for a mean area of 7.16 ha (producing 94.8 tn of tomatoes per ha) was 1,369,700 kg CO_2eq-. The estimated carbon footprint values per hectare and tonne of product were 191,298.88 and 200 kg CO_2eq-, respectively. Based on the findings of the current study, the highest CO_2eq- emissions per tonne of product were reported in energy use (fuel consumption) for field operations with a value of 40.49% CO_2eq-, followed by fertilizer production (26.71%), the application of fertilizers and soil amendments (26.46%), residues management (5.23%), and the use of pesticides (1.12%). Similar findings were reported in the emissions per ha (Figure 1).

More than 75% of the emissions (both per ha and per kg of product) derive from the use of machinery and chemical fertilizers. The excessive use of machinery is closely correlated to the tillage and fertilization regimes. Conventional tillage intensifies the present problem through frequent ploughing and ploughing, leading to the release of gases into the atmosphere (Alskaf, 2021). In recent years, more and more farmers are adopting reduced tillage or even no-tillage worldwide (Smith., 2007). Interestingly, conservation tillage has reported increases in yields in several crops (Bilalis et al., 2010). Regarding fertilization, the mitigation of GHGs emissions due to the volatilization of NH3 can be achieved through the utilization of slow-release fertilizers (Byrne et al., 2020). These fertilizers contain inhibitors (urease and nitrification) and release nitrogen (N) gradually to the soil. This way, losses are reduced as the release of the nutrient is prolonged. In studies conducted, the use of fertilizers containing inhibitors gave higher yields in cotton (Karydogianni, et al., 2020) and sweet potato (Kakabouki, et al., 2020) crops. Moreover, the adoption of organic farming is an option that could reduce greenhouse gas emissions. The use of organic fertilizers leads to soil improvement and induction of microbial activity (Liu et al., 2015). These help to reduce leaching of nutrients from the soil, resulting in reduced losses.



(a) Distribution of CO_2eq- emissions per hectare (%)

(b) Distribution of CO_2eq- emissions per tonne of product (%)

Figure 1. Distribution of CO_2eq emissions per: (a) ha; (b) kg of product. The different emission sources (residue management, fertilizer production, crop protection, fertilization, energy use) are depicted with different colors. Fertilizers' production was calculated with valid preset values by the Cool Farm Tool.

CONCLUSIONS

Efforts should be made to improve the environmental impact of processing tomato cultivation by minimizing GHGs emissions and mitigating the climate change effect by adopting integrated management strategies. In particular, the use of machinery and the application of synthetic mineral fertilizers should be minimized. Alternatives that would contribute to this cause include optimization of tillage and fertilization, expansion of organic farming, and promotion of renewable energy sources.

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Conflicts of Interest

The authors declare that they do not have any conflict of interest.

REFERENCES

1. Alskaf K, Mooney SJ, Sparkes DL, Wilson P, Sjögersten S. Short-term impacts of different tillage practices and plant residue retention on soil physical properties and greenhouse gas emissions. Soil tillage res. 2021; 206:104803. https://doi.org/10.1016/j.still.2020.104803
2. Baranski R, Goldman I, Nothnagel T, Scott JW. Improving color sources by plant breeding and cultivation. In: Reinhold C, Schweiggert RM, editors. Handbook on Natural Pigments in Food and Beverages. 1st ed. Cambridge: Woodhead Publishing; 2016. p. 429-72. https://doi.org/10.1016/B978-0-08-100371-8.00019-1
3. Bilalis D, Krokida M, Roussis I, Papastylianou P, Travlos I, Cheimona N, Dede A. Effects of organic and inorganic fertilization on yield and quality of processing tomato (*Lycopersicon esculentum* Mill.) Folia Hortic. 2018; 30(2):321-32. http://dx.doi.org/10.2478/fhort-2018-0027
4. Bilalis DJ, Karkanis A, Papastylianou P, Patsiali S, Athanasopoulou M, Barla G, Kakabouki I. Response of Organic Linseed ('*Linum usitatissimum*'L.) to the Combination of Tillage Systems, (Minimum, Conventional and No-

Tillage) and Fertilization Practices: Seed and Oil Yield Production. Aust J Crop Sci. 2010; 4(9):700-705.

5. Byrne MP, Tobin JT, Forrestal PJ, Danaher M, Nkwonta CG, Richards K, Cummins E, Hogan SA, O'Callaghan TF. Urease and nitrification inhibitors—As mitigation tools for greenhouse gas emissions in sustainable dairy systems: A review. Sustainability. 2020; 12(15):6018. https://doi.org/10.3390/su12156018
6. European Commission [Internet]. The tomato market in the EU: Vol. 1-Production and area statistics. 2022; https://agriculture.ec.europa.eu/system/files/2022-07/tomatoes-production_en.pdf
7. Kakabouki I, Togias T, Folina AE, Karydogianni S, Zisi C, Bilalis D. Evaluation of yield and nitrogen utilization with urease and nitrification inhibitors in sweet potato crop (*Ipomoea batatas* L.). Folia Hortic. 2020; 32(2):147-57. http://dx.doi.org/10.2478/fhort-2020-0014
8. Karydogianni S, Darawsheh MK, Kakabouki I, Zisi C, Folina AE, Roussis I, Tselia Z, Bilalis D. Effect of nitrogen fertilizations, with and without inhibitors, on cotton growth and fiber quality. Agron Res. 2020; 18(2):432–49. https://doi.org/10.15159/AR.20.148
9. Liu H, Li J, Li X, Zheng Y, Feng S, Jiang G. Mitigating greenhouse gas emissions through replacement of chemical fertilizer with organic manure in a temperate farmland. Sci Bull. 2015; 60(6):598-606. https://doi.org/10.1007/s11434-014-0679-6
10. Lynch J, Cain M, Frame D, Pierrehumbert R. Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO_2-emitting sectors. Front sustain food syst. 2021; 4:518039. https://doi.org/10.3389/fsufs.2020.518039
11. Padmanabhan P, Cheema A, Paliyath G. Solanaceous fruits including tomato, eggplant, and peppers. In: Cabellero B, Finglas P, Toldra F, editors. The Encyclopedia of Food and Health. 1st ed. Oxford: Academic Press. 2016; p. 24-32. https://doi.org/10.1016/B978-0-12-384947-2.00696-6
12. Payen S, Basset-Mens C. 2013. Environmental assessment with LCA of tomato produced in Morocco and exported to France: the importance of freshwater use impacts. Poster session presented at: Sustainable water use for securing food production in the mediterranean region under changing climate. IAV Hassan II, University of Copenhagen. 2013 Mar 10-15; Agadir, Morocco.
13. Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B, Sirotenko O, Howden M, McAllister T, Pan G, Romanenkov V, Schneider U, Towprayoon S. Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture. Agric Ecosyst Environ. 2007; 118(1):6-28. https://doi.org/10.1016/j.agee.2006.06.006
14. World Bank [Internet]. Climate Smart Agriculture; 2023. https://www.worldbank.org/en/topic/climate-smart-agriculture