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THE ENVIRONMENTAL IMPACT OF SUSTAINABLE FOOTWEAR

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Abstract: *Circular economy is a model of production and consumption involving the minimization of waste. When a product reaches the end of its life cycle, the materials from which it is made are kept in the economy as much as possible by recycling. They can be used in production again and again, creating even more added value. Global footwear production reached 24.3 billion pairs in 2019. Footwear consumption in Europe accounts for approximately 15% of total production, with approximately 4.4 pairs of shoes per person. The generation of waste is a consequence of the increase in the production and consumption of footwear, and the landfill is still the main destination of such waste. In this study, the carbon footprint generated by sustainable footwear materials and manufacturing processes is analyzed. All the materials used to make the eco-engineered footwear are organic, chemicals-free and animal-free, achieving an organic, vegan and recycled product. The proposed process for making the shoe is based on the STROBEL system. Carbon footprint was analyzed with LCA software GaBi ts (Professional). Life-cycle assessment was performed on materials and processes for several shoe models. The carbon footprint has dropped to a value of 2.23 Kg CO_2eq. If we consider that the average value for a classic shoe is 13.5 Kg CO_2eq, the reduction is 83.5%. These values depend on the type and quantities of materials and whether this footwear is repaired/recycled.*

Keywords: *carbon footprint; Life-cycle assessment; recycling; footwear.*

1. INTRODUCTION

Circular economy is a production and consumption model that involves sharing, renting, reusing, repairing, renovating and recycling existing materials and products for as long as possible. Thus, the product lifecycle is extended.

In practice, it involves minimizing waste. When a product reaches the end of its lifecycle, the materials from which it is made are kept in the economy as much as possible by recycling. They can be used in production again and again, creating even more added value. [1].

Footwear items are comprised of an average of five different materials assembled together with glue/stitches making disassembly difficult. Once disassembled and sorted, these materials must be processed (shredded, melted, purified, etc.) so that they can be integrated into new applications.

Only a small amount of materials (e.g apparel, shoes, packaging) are recycled and reused. Most of waste textiles, shoes and plastics are landfilled or incinerated, with a high environmental impact.

Recycling and reuse of waste materials can provide an important enhancement of resource utilization efficiency and effectiveness of companies. More effective and efficient utilization of these resources will ensure minimization of environmental impact and economic acquisitions which will enhance competitive capacity.

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Footwear worldwide production reached 24.3 billion pairs in 2019 [2]. Footwear consumption in Europe represents about 15% of the total production, with about 4.4 pairs of shoes per person. Waste generation is a consequence of footwear production and consumption increase, and the landfill is still the main destination of such waste.

In recent years, consumer awareness of sustainability issues has been growing rapidly. Moreover, European and international governments issue long-term programs to establish a strategic vision with the aim of drastically reducing the impacts caused by human activities on the environment [3]. Therefore, the concept of environmental sustainability is currently a key aspect to consider [4].

A study by Quantis, a leading environmental sustainability consultancy working with leading organizations around the world to drive sustainable transformation, estimates that the footwear sector is responsible for 700 million tonnes of CO_2 eq, or 1.4% of global greenhouse gas emissions, and that much of this attribution is due to the extraction of raw materials [5].

Circular economy proposes a transition from the current economic model to a more sustainable one, where waste is designed and resources will be reused and recycled as long as possible. In this transition, Life Cycle Analysis (LCA) is an important tool to help decision-making [6].

In this study, the carbon footprint generated by the materials and manufacturing processes of 11 models of sustainable footwear is analyzed.

2. MATERIALS AND METHODS

All the materials used to make the shoes analyzed were organic, without chemicals and without animals, obtaining a 100% organic, vegan and recycled product. The footwear manufacturing method is an innovative element that will make it easier to repair, reuse and recycle shoes. Disassembly is one of the main problems preventing the reuse and recycling of footwear.

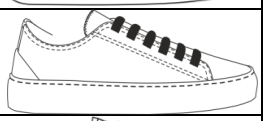
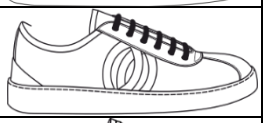
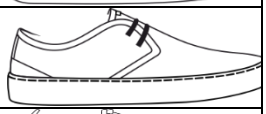
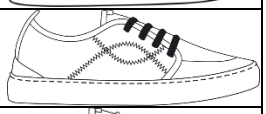
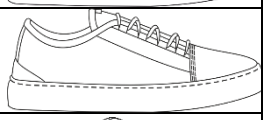
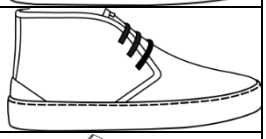
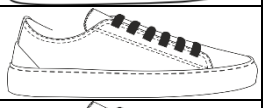
The technological process of making the shoe is based on the durable STROBEL system, which consists in attaching a non-woven textile material (the insole) to the upper assembly through a seam. After that, attaching the upper part to the sole is done by sewing, with minimal use of glue, anyway water-based. Thus, we obtain a shoe that is easily disassembled after the end of its life, allowing the feasible recycling of the product (Figure 1).

Figure 1. Circular economy system

Footwear soles are materials that allow 100% recycling by mechanical grinding (Table 1). The upper assembly is made of textile materials, each fabric used being recycled in percentages from 40 to 100% and 100% recyclable (Table 1). Six of the fabrics used are woven at INCDTP. Figure 2 shows three footwear models made using fabrics woven at INCDTP.

Figure 2. Footwear made using fabrics woven at INCDTP

Table 1. Footwear materials and models

Footwear materials and models	
M1 UPPER PART: FABRIC 50% R-pet and 50% recycled cotton OUTSOLE: 80% natural rubber and 20% synthetic rubber vulcanized	
M2 UPPER PART: FABRIC 50% pet and 50% recycled cotton OUTSOLE: 30% preconsumer recycled and 70% synthetic TR rubber injected	
M3 UPPER PART: FABRIC 50% recycled cotton, 47% R-pet and 3% other fibers OUTSOLE: 100% bio eco TPU injected	
M4 UPPER PART: FABRIC 50% pet and 50% recycled cotton OUTSOLE: 100% bio eco TPU injected	
M5 UPPER PART: FABRIC 50% pet and 50% recycled cotton OUTSOLE: 50% natural rubber and 50% synthetic vulcanized rubber	
M6 UPPER PART: FABRIC 50% pet and 50% recycled cotton OUTSOLE: 50% natural rubber and 50% synthetic vulcanized rubber	
M7 UPPER PART: FABRIC 100% recycled cotton OUTSOLE: 25% recycled EVA and 75% synthetic conventional EVA	
M8 UPPER PART: FABRIC 50% recycled cotton and 50% pet OUTSOLE: 100% bio eco TPU injected	
M9 UPPER PART: FABRIC 50% pet and 50% recycled cotton OUTSOLE: 100% bio eco TPU injected	
M10 UPPER PART: FABRIC 100% linen OUTSOLE: 50% natural rubber and 50% synthetic vulcanized rubber	
M11 UPPER PART: FABRIC 50% linen and 50% R-EARTH OUTSOLE: 50% natural rubber and 50% synthetic vulcanized rubber	

In order to perform LCA GaBi ts (Professional) software and ecoinvent database were used, that incorporate emission factors associated to processes and materials, as well as data provided by the producer and collected in the Life Cycle Inventory.

The GaBi software (Figure 3) is extremely advanced and has a lot of data and features to work with. For the vegan organic shoe, a new project and a Plan were created.

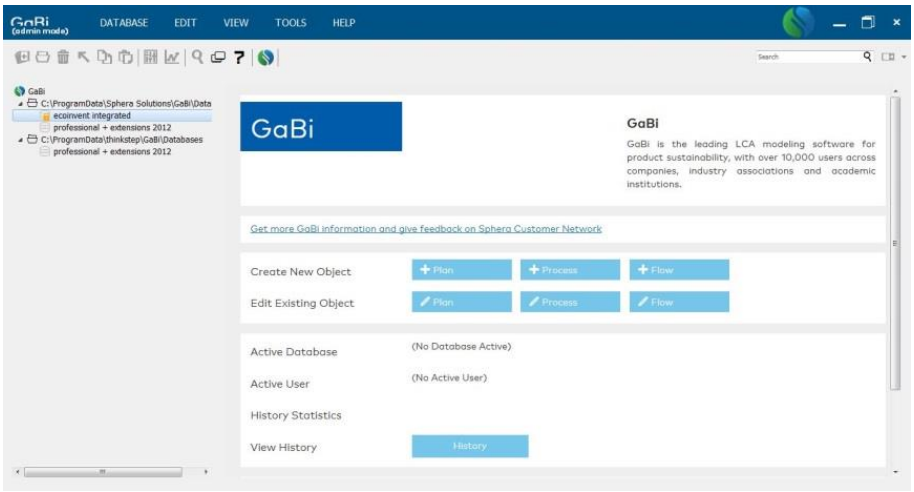


Figure 3. GaBi software interface

The functional unit is a very important element in the study of carbon footprint and water footprint, all inventory data (inputs and outputs of the system) are related to it. In addition, the results obtained must be reported by functional unit. For this study, the functional unit is a pair of shoes, size no. 42 (European size), created in the LIFE REWEART project [7].

Figure 4 shows the flow diagram of a studied system (M4).

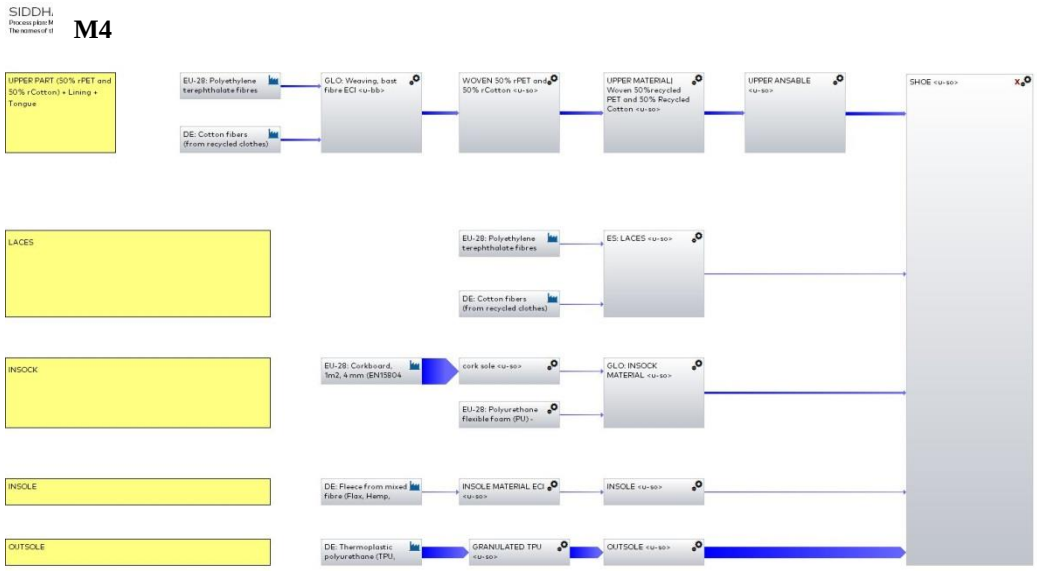


Figure 4. Flow diagram of the system under study

The LCA study was performed for all 11 footwear models.

3. RESULTS AND DISCUSSION

Figure 5 presents values obtained for the carbon footprint for each analysed model.

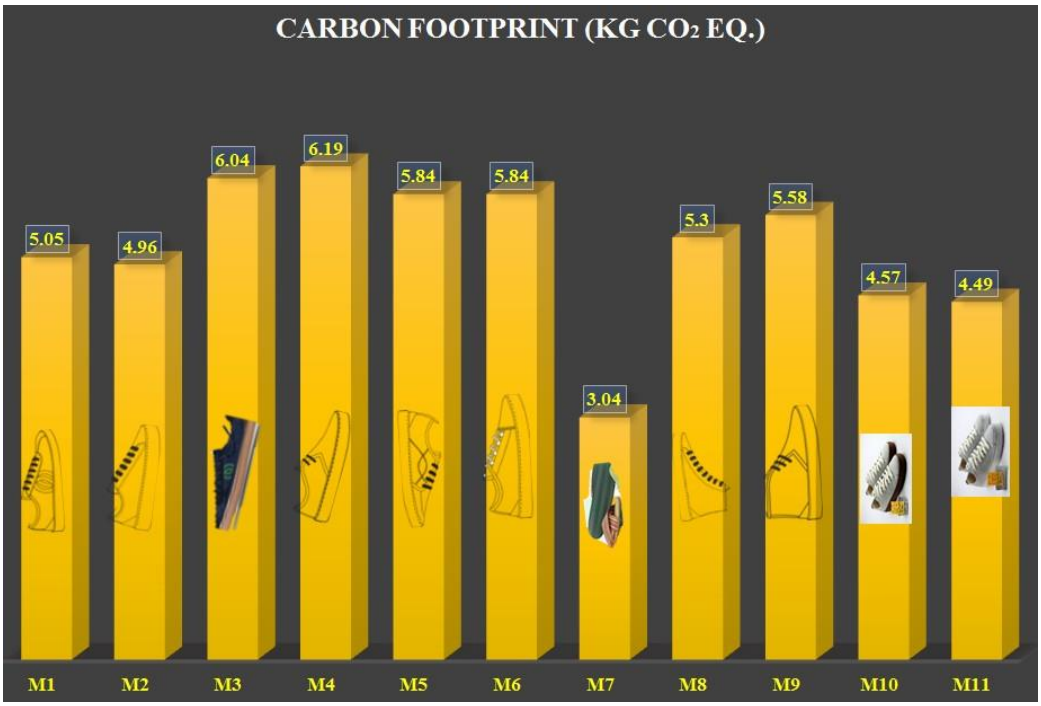


Figure 5. Values obtained for carbon footprint

Values of carbon footprint for the models made fall between 3.04 Kg CO_2eq/pair in the case of sandals (M7) and 6.25Kg CO_2eq /pair in the case of sports shoes with TPU sole (M4), with an average of 5.5 Kg CO_2e_q/pair. Typical values of carbon footprint for classic footwear made of various materials (leather, polymers, etc.) varies from 10 to 14 Kg CO_2eq/pair. The water footprint has also been reduced to almost zero, as all recycling procedures are based on mechanical processes leading to near zero water consumption. As per energy consumption, typical values for casual/man shoes contribute from 3 to 6 % of the total carbon footprint (5.05 kWh/pair). In the case of our models the contribution is 0.5 kWh/pair.

The analysis of the results indicates a low environmental impact for all the models studied, mainly due to the selection of sustainable materials and the efficient production process in which renewable energy sources are used. The circular economy system used to manufacture the product, taking into account its end of life, helps to reduce the environmental impact of the model without transferring the impact to other stages of the life cycle. The type and sustainable source of the materials that make up the footwear have a major influence. The shoe sole has the biggest impact, so reusing/recycling it greatly reduces your carbon footprint. In addition to the type, the source of the materials has an important influence.

Recycling and reuse of waste can provide an important improvement in resource efficiency. More effective and efficient use of these resources will ensure that the impact on the environment is minimized.

4. CONCLUSIONS

Footwear is made of materials that are recycled or easily recyclable, so that it can be disassembled and recycled. The upper part will be returned for insock, manufacturing or further manufacturing of yarns. The outsoles can be milled and recycled into new outsoles.

The carbon footprint was reduced to a value of 2.23 Kg CO_2eq. If we consider as average for a casual shoe a value of 13.5 Kg CO_2eq, the reduction is 83.5 %. We consider below 2 Kg CO_2eq/pair is almost impossible to reach, even if we run the process with

photovoltaic energy, as recycling of materials needs resources (mainly energy for melting, milling, shredding and transport).

The circular economy system manages to recover the product at the end of its useful life for recycling/reuse, thus avoiding its disposal at the landfill. Moreover, by recovering its components and reusing the sole, it is possible to obtain the same model again with reused and recycled products, thus avoiding the extraction of raw materials.

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