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Reducing Carbon Footprint of PET Films for Food Packaging Products Through Minimizing Solvent Consumptions

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Abstract

Since solvents are used during the printing process of polyethylene terephthalate film, there are substantial environmental risks associated with this process. Solvents significantly increase the manufacturing process's carbon footprint. This abstract explains a comprehensive strategy to reduce solvent emissions in the production of PET films, in response to the industry's urgent demand for sustainable practices. The energy used in each unit to compute and convert carbon emissions into direct emissions is known as the "solvent usage" calculation; the electric carbon emission factor was used to calculate indirect emissions. Emission factor per day: 12 kg; direct solvent usage per day: 52.08 kg. It is not appropriate to use the Carbon Footprint as a means of making comparisons between various sectors, as various approaches and system limitations could be used. Solvents consumed during printing of PET films calculated because VOC compounds effects environment with high emission factor. Each colour's volatile organic compounds were computed and converted to direct carbon emissions. The overall amount of greenhouse gases, mostly carbon dioxide and other pollutants, is referred to as a carbon footprint. The electric carbon emission factor and the unit usage of 2400 kg/kw on the press were used to determine the indirect carbon emissions. Carbon footprint calculations will help industries towards more sustainable and ecofriendly environment and green earth.

Keywords: PET film, Sustainability, carbon emission, VOCs, Carbon footprint.

Introduction

Packaging that minimizes its environmental impact while fulfilling essential responsibilities for product protection and delivery is referred to as sustainable packaging. This includes materials and methods that are designed, produced, and used. It seeks to lessen waste, preserve resources, and minimize the environmental impact of packaging and is a crucial part of ecologically conscious company practices. A popular and adaptable plastic material, polyethylene terephthalate film is renowned for its remarkable strength, clarity, and barrier qualities. PET film is commonly used in various applications, from packaging to industrial processes. This information brief provides an overview of PET film, its properties, applications, and environmental considerations. The solvent-based ink is a type of printing ink that uses volatile organic solvents as a carrier for pigments and other additives. This ink is commonly employed in the gravure printing process, a high-speed and high-quality printing method. In this overview, we'll delve into the key characteristics, components, applications, and considerations associated with solvent-based inks in gravure printing. An organization's carbon footprint is a measure of how much greenhouse gas it produces overall, which is how the organization affects the environment. Global warming and climate change are accelerated by the carbon emissions produced by several activities. A person, group, activity, occasion, or product's whole direct and indirect greenhouse gas emissions is called their carbon footprint. The precise proportion of carbon footprint attributed to gravure printing can vary based on multiple factors such as the production scale, the efficiency of operations, the type of materials used, and the energy sources employed by a printing facility. While exact figures can fluctuate, gravure printing, known for its high-quality and high-speed production, tends to have a comparatively higher carbon footprint than some other printing methods due to its energy-intensive nature and the use of solvent-based inks. According to conventional estimates, a sizable amount of the total emissions in the printing industry may be attributed to the carbon footprint of gravure printing. However, the precise percentage may differ between different studies or assessments based on the methodologies used and the specific practices of individual printing operations. Efforts to reduce this footprint involve adopting energy-efficient technologies, utilizing sustainable materials, optimizing production processes, and implementing environmentally friendly practices to lessen the impact on the environment order to maximize the likelihood of preventing a 2℃ increase in global temperatures, it is necessary for the average annual carbon footprint to decrease to less than 2 tons by 2050. It takes time to reduce carbon footprint from 16 tons to 2 tons. Solid emissions in gravure printing encompass the release of particulate matter and volatile organic compounds into the air during the printing process. These emissions arise from ink dust, solvent evaporation, and potential particulate matter from the printing substrate. To mitigate this environmental impact and address health concerns, printing facilities implement various strategies such as emission control systems, the use of low-VOC inks, adherence to good manufacturing practices, recycling initiatives, and strict compliance with regulatory standards. Minimizing solid emissions not only supports environmental sustainability but also ensures a safer and healthier working environment for employees, aligning with broader industry goals of reducing environmental impact and promoting sustainability.

Literature Review

A sustainable thing is, in essence, something that can be maintained over time. This suggests that an unsustainable society will ultimately come to an end and that it cannot exist indefinitely. A sustainable society might therefore last for several millennia at the very least. An assertion can only be considered an axiom if it can be verified by scientific methods of testing. A basic set of axioms is required to define sustainability collectively. Simultaneously, the axioms should be adequate, with no obvious gaps. It is best to phrase the axioms in a way that is understandable to laypeople. The majority of corporate sustainability initiatives seem to view social sustainability as a public relations gimmick, conducted as acts of charity [1-2].

Sustainable enterprise development refers to the adoption of business strategies and practices that meet the needs of the organization and its stakeholders now while preserving, enhancing, and developing the natural and human resources that will be needed tomorrow. Such sophisticated assessment instruments are still required in order to provide guidance for the future as well as to analyse the progress made toward sustainability. Because sustainability evaluation approaches do not provide advise on how an enterprise might become more sustainable, this study focuses on helping enterprises achieve better sustainability. The evaluation provided by assessment does not include solutions. Integrating several tools into the sustainability assessment paradigm is the aim of this study. Certain sustainability assessment criteria are challenging to evaluate in qualitative data should be included because quantitative units are used. A system for evaluating sustainability has been established that takes into account both the quantitative and qualitative components of sustainability. Not every printing company has the ability to employ renewable energy. Following the implementation of environmental management systems, businesses now give their suppliers more consideration. A deal between Supplier and Enterprise B allows for the production of electricity using some renewable resources. Other businesses don't have any renewable energy equipment or agreements with suppliers of renewable energy. Utilizing rainwater is one way to meet the soft water requirements of the printing industry. Typically, softened water is used by printing companies. Rainwater does not need to be softened; nonetheless, it is best to filter away any particles before using. [3-4]

Unwanted and discarded stuff is defined as solid waste. Wastes are the root cause of environmental issues and global warming. Wastes are divided into a number of categories, including solid trash, construction waste, medical waste, and commercial garbage. In response to the promotion of sustainable development, the previous waste management system changed into a new one. This involves moving from a single selection support on the waste's location to many conceptions of waste arrangement, or the 3R concept. The three pillars of the 3R philosophy are reducing waste, recycling, and reusing resources. Reducing is the process of selecting and applying elements to lower the generated waste value. Reusing waste as a resource is known as recycling. Utilizing waste that is still in a usable state is known as recycling. [5-6]

Materials that have favourable qualities for various applications, including packaging, automotive, and biomedical uses, are known as biodegradable plastics. In a test setup, films were placed between the bottom and top sections of a cell, and screws were used to secure the pressure. The film was placed between the rubber O-ring and the cell bottom to improve the sealing capacity. The material to be tested was then added to the lower section of the cell, and a tiny hole was sealed with a screw and a rubber O-ring. The weight loss of the solvent through the film was tracked and recorded over time after the cell was configured as intended. Aluminium-film-covered cells were also used as control samples to determine the amount of solvent lost throughout the process. [7-8]

Antimicrobials are used in food packaging to guard against dangerous germs. For heat-stable antimicrobials, this can be accomplished by directly incorporating antimicrobial compounds into polymers using thermal techniques like compression moulding or film extrusion. An alternative that is more suited for heat-sensitive antimicrobials is the nonthermal application of antimicrobial coatings to polymer surfaces. This paper offers quantitative evaluations of different antimicrobial-coated films and covers the migratory profile, benefits, and disadvantages of these films for food applications. The difficulties of bringing these movies' production up to an industrial scale are discussed in the conclusion. [9-10]

Building construction generates 40% of trash annually in the EU and requires 40% of primary energy and resources. By promoting energy efficiency and the use of renewable energy, which can progress scientific and technological advancements, carbon taxes can aid in the reduction of greenhouse gas emissions. They are also easy to administer and well-known to stakeholders.

In This study shows that customers frequently fail to recognize the benefits of plastic packaging for sustainability, even in spite of the large volumes of packaging waste. Packing improves transportability and storage while reducing contamination and extending the shelf life of important commodities. Custom packaging solutions are able to satisfy a wide range of needs by mixing different materials. While certain multilayer packaging, such as liquid packaging boards can be recycled, there isn't yet an industry solution for polymer-polymer multilayer materials. [11-12]

High print quality while using the least amount of ink is the goal of printers. The area covered by a kilogram of ink is known as ink mileage, and the term "ink requirement" refers to the amount of ink required per unit of paper area to achieve a particular print density. Because solvent-based gravure ink has a roughly 30% solids content, weight-based measures are not accurate. It is inconvenient and imprecise to measure ink mileage the old-fashioned way—by weighing ink before and after printing. Rather, we employed a technique in which ink is doped with a quantifiable tracer that was not initially contained in the ink or paper. [13-14]

In many industries where solvents are used for cleaning, degreasing, chemical reactions, separation, dilution, or as transporters, this literature discusses solvent emissions. High toxicity and the ability to produce secondary air particles or ozone are just two of the detrimental environmental characteristics of organic solvents. They are easily released into the environment due to their volatility. The goals of green chemistry are to employ solvent-free procedures, utilize less solvents, or use greener solvents. Solvents' effects on the environment must be evaluated using meticulous techniques that take into account a number of factors. These assessments are easier to understand when reduced to a single dimension and unit. [15-16-17]

Because of its light weight, portability, chemical stability, and strong protection, plastic—which is derived from synthetic resin monomers plus additional stabilizers, plasticizers, antioxidants, colorants, insecticides, and preservatives—is frequently used in food packaging. Plastic food packing, however, is dangerous for your health and safety. Contamination can result from the dissolution and migration of hazardous monomers, oligomers, additives, and organic chemicals employed in manufacture into food. [18-19-20]

While indices like the GDP and Human Development Index assess social and economic aspects, indicators like Water Footprint, Carbon Footprint, and Ecological Footprint measure particular resources and environmental factors. These indexes contrast products, activities, or processes according to energy and emission consumption. Financial stability is a prerequisite for industrial sustainability, which seeks to increase productivity by taking into account the environmental effects of energy and resource use. Sustainability originally centred on economic forecasting of resource availability and market demand. [21-22]

Research Objectives

The objectives of the research for the paper are described as follows:

1. To identify the parameters effecting solvent emission for PET films
2. To calculate the solvent consumption and solvent emissions with varying parameters such as ink viscosity, press speed and cell geometry for PET during printing.
3. To calculate carbon footprint on PET substrate.
4. To reduce carbon footprint during printing for PET films of food packaging

Research Methodology

This project aims to reduce the carbon footprint associated with PET printing by minimizing solvent emissions. In our experimentation endeavours, we opted for the film 50-micron PET roll, boasting dimensions of 500x500mm. This roll, crucial to our process, is of the laminated variety, enhancing its durability and suitability for our purposes. In the printing phase, our choice of ink was the esteemed from company. We employed cyan, magenta, yellow, and black solvent-based inks. Notably, these inks feature a Nitrocellulose (NC) base, a pivotal component renowned for its efficacy in dispersing and grinding ink pigments to achieve vibrant and consistent coloration. Several factors can influence the carbon emissions of a manufacturing process, including cell angles, viscosity, machine speed, solid content, and LPI/CM. These elements can significantly affect the total amount of CO_2 emissions and are essential in establishing how sustainable the production process is. Additionally, the use of a GSM tester can help in monitoring and optimizing these factors to reduce carbon emissions and improve the environmental performance of the manufacturing process. Then we have existing and variable parameters, in existing parameter contain values viscosity 19 seconds, speed 40 m/min, Lines per inch/cm= 80, cell angles K-40 C-34 M-60 Y-45 (Cell angles in degrees). For variable parameters viscosity= 17/21 seconds, speed 35/45 m/min, Lines per inch/cm= 60/100, cell angles K-40 C-34 M-60 Y-45. At first ink trays are filled with CMYK colours. The viscosity of each ink is measured using a Ford cup, a device utilized for measuring the viscosity of liquids. The initial viscosity measurement is recorded at approximately 23 seconds. Following this, an additional litre of solvent is added to all ink units, and viscosity measurements are taken again, resulting in a reduced viscosity of 18 seconds. Subsequently, machine parameters are adjusted, and the printing process commences. Throughout the printing process, 3 litres of solvent are intermittently added, with a total solvent usage, including cleaning, amounting to 4.315 litre. Carbon footprint calculations will be conducted utilizing both direct and indirect methods. In the direct method, the emissions resulting from solvent usage during printing will be quantified. The formula for calculating direct emissions is as follows:

Direct emissions = Total solvent consumption × solvent carbon emissions factor.

$=52.08 \times 12 = 624.96$kg

Indirect emissions originating from electricity consumption, encompassing various mechanical equipment, computers, and lighting systems, will also be accounted for. The formula for determining indirect emissions is: Indirect emissions = Power consumption × electrical carbon emissions factor.

$=100$kw$\times 24 = 2400$kg/kw

Total carbon footprint =Direct + indirect

$= 624.96 + 2400$

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=3024.96 kg

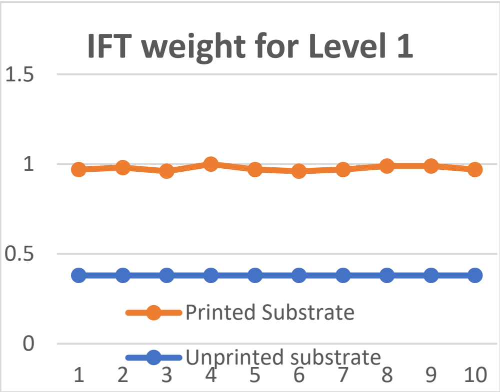
To analyse print quality, the GSM (grams per square meter) testing method will be employed. This testing procedure involves cutting unprinted PET samples into square shapes measuring 10x10 cm, and subsequently weighing them using a digital paper GSM tester. Additionally, printer samples measuring 10x10 cm from each parameter (60, 80, 100 LPI) will be cut, weighed, and their readings recorded. These readings will then be analysed to ascertain if the values obtained for level 1 and 2 parameters align with existing standards. The results will be presented graphically to provide a visual representation of the impact of parameter adjustments on both print quality and carbon footprint reduction.

Printing parameters set during trials:

- Viscosity = 15-20 seconds
- Pressure = 2 kg/cm^2 (± 0.2)
- Film thickness = 50 micron
- Machine speed = 30-50 m/min
- Drying temp = 35-45 degrees Celsius
- Impression hardness = 65 Shore A

Data Collection and Analysis

Graph 1.1 IFT of 80 LPI



Graph 1.2 IFT weight for Level 1

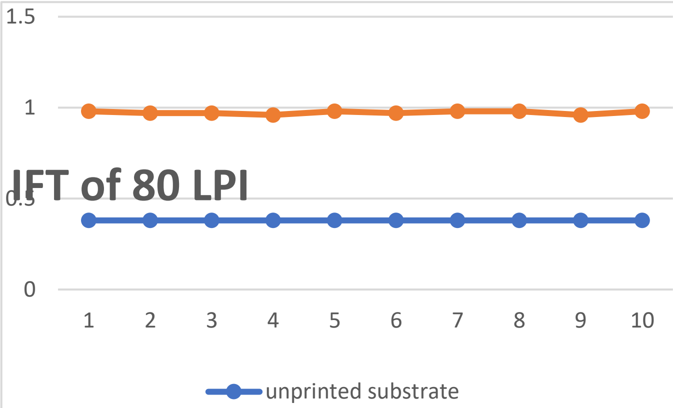


Table 1.1 IFT Test of Existing

Sample	Unprinted substrate	Printed Substrate
80 LPI		
1	**0.38**	**0.6**
2	**0.38**	**0.59**
3	**0.38**	**0.59**
4	**0.38**	**0.58**
5	**0.38**	**0.6**
6	**0.38**	**0.59**
7	**0.38**	**0.6**
8	**0.38**	**0.6**
9	**0.38**	**0.58**

10	**0.38**	**0.6**

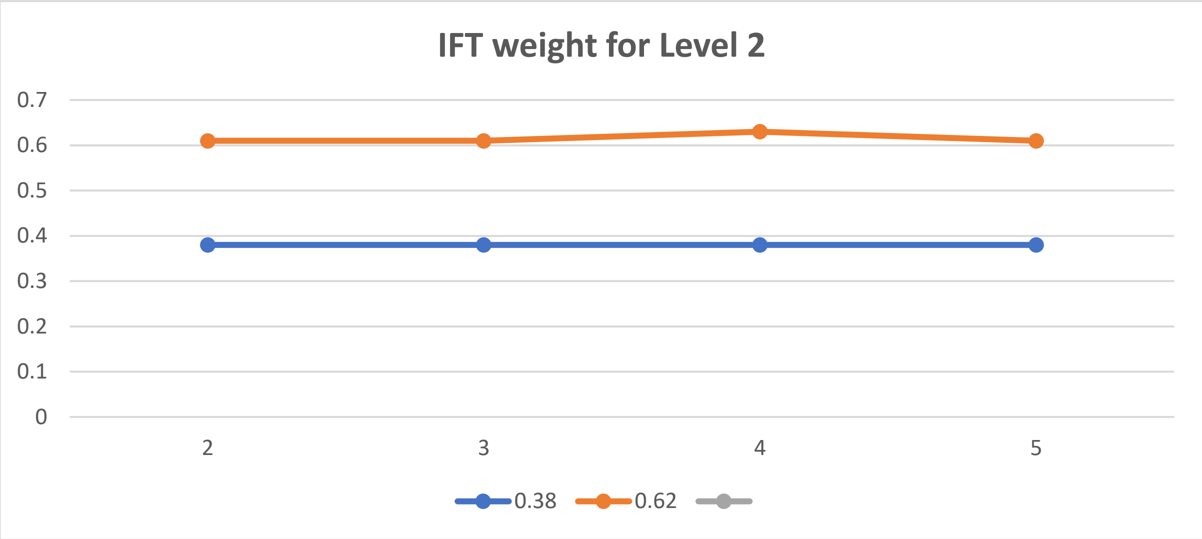
Table 1.2 IFT Test for Level 1

Sample	**Unprinted substrate**	**Printed Substrate**
Level 1 60 LPI		
1	**0.38**	**0.59**
2	**0.38**	**0.60**
3	**0.38**	**0.58**
4	**0.38**	**0.62**
5	**0.38**	**0.59**
6	**0.38**	**0.58**
7	**0.38**	**0.59**
8	**0.38**	**0.61**
9	**0.38**	**0.61**
10	**0.38**	**0.59**

Table no. 1.3 IFT test for level 2

Sample	**Unprinted substrate**	**Printed Substrate**
Level 2 **100 LPI**		
1	**0.38**	**0.62**
2	**0.38**	**0.61**
3	**0.38**	**0.61**
4	**0.38**	**0.63**
5	**0.38**	**0.61**
6	**0.38**	**0.63**
7	**0.38**	**0.60**
8	**0.38**	**0.63**
9	**0.38**	**0.63**
10	**0.38**	**0.60**

Graph 4.1.5 IFT weight for Level 2



Calculation: Carbon footprint = 100 LPI = IFT x 24 hours +Indirect

= 2.13 x 48 x 15.6 + 2400kw

=1594.944 x 24 + 2400kw

=40678.658 kg

Carbon footprint = 80 LPI = IFT x hours +Indirect

= 2.18 x 48 x 15.6 + 2400kw

=1632.384 x 24 + 2400kw

=41577.216 kg

Carbon footprint = 60 LPI = IFT x hours

= 2.37 x 48 x 15.6 + 2400kw

=1774.656 x 24 + 2400kw

=44991.74 kg

Carbon footprint= 80 LPI - 100 LPI

= 41577.216 kg - 40678.658 kg

=898.56 kg

Carbon footprint= 80 LPI - 60 LPI

= 44991.74 kg - 41577.216 kg

= 3414.528 kg

4.2.1 Results and Conclusion

In conclusion, minimizing solvent emissions in the production of PET film is crucial for reducing the carbon footprint of the manufacturing process. By carefully controlling factors such as cell angles, viscosity, machine speed, solid content, and LPI/CM, manufacturers can optimize their processes to minimize solvent emissions and overall CO2 emissions. Utilizing tools like a GSM tester can further aid in monitoring and optimizing these factors to improve environmental performance. Implementing these strategies can lead to a more sustainable production process, lower carbon emissions, and a reduced impact on the environment.

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