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Reduction of Material Waste in Production of Sparkling Wine Bottle Capsules

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Abstract

The sparkling wine industry faces increasing pressure to enhance the sustainability of its packaging processes, particularly regarding the use of polylaminate capsules, which are complex, multi-material components with limited recyclability. Current manufacturing practices typically result in significant material waste, with polylaminate losses reaching up to 17% and aluminium foil waste exceeding 40%. This study introduces and evaluates a novel method to optimize material use by repurposing the residual polylaminate offcuts from capsule production to fabricate the capsule's top disc, replacing the conventional aluminium foil. A detailed analysis of geometric feasibility was conducted, followed by the development of technical solutions to enable seamless integration into existing production lines. The new process was patented and tested, demonstrating the potential to fully eliminate aluminium foil usage for the top disc and reduce overall polylaminate waste by 17.65%. These results highlight meaningful environmental and economic benefits, offering manufacturers an effective pathway to reduce raw material consumption, streamline production, and lower waste management costs. The proposed method supports broader industry goals of improving sustainability and efficiency and provides a basis for further technological innovation in capsule manufacturing.

Introduction

Industry Scale and the Waste Issue

According to the OIV Focus 2020 report, global sparkling wine production reached 20 million hectolitres (mhl) in 2018 (International Organisation of Vine and Wine 2020). Given that one hectolitre equals 100 litres, and considering a standard sparkling wine bottle contains 0.75 litres, this equates to approximately 2.67 billion bottles produced worldwide in that year with major contributions from regions such as Champagne, Prosecco, and Cava-producing areas. Each of these bottles requires a polylaminate capsule creating a considerable production volume of these packaging components.

The manufacturing process for polylaminate capsules generates sizeable material waste. Current industry estimates suggest that between 15–19% of raw materials are lost during standard production processes, translating to millions of kilograms of complex materials entering waste streams annually (Technologia JSC 2023). This waste represents not only a significant economic loss for manufacturers but also poses environmental challenges due to the difficulty in recycling these multi-material components.

The potential impact of waste reduction in this sector is substantial. Beyond the environmental benefits of reduced landfill contributions and lower resource extraction requirements, manufacturers stand to gain considerable economic advantages through decreased raw material costs, reduced waste management expenses, and improved production efficiency.

As sustainability becomes increasingly central to consumer purchasing decisions and regulatory frameworks, addressing material waste in sparkling wine packaging represents an opportunity for meaningful environmental progress while simultaneously improving industrial efficiency and economic outcomes. This paper examines specific technical interventions in the polylaminate capsule production process that can help achieve these complementary goals.

State of the Art

Early examples of wine bottle capsule producing technology is described in patents from

(Konstantin 1980; Sauget 1985; Larrous 2012). These

Today two main materials are used to produce sparkling wine bottle capsules:

- *Polylaminate*: a multilayer composite material consisting of *Al-PE-Al (aluminium-polyethylene-aluminium)*, which is used to make the conical part of the capsule.
- 40–80 µm thick aluminium foil coated with thermal varnish on one side, which is used to make the disc covering the conical part of the capsule. (Technologia JSC 2023)

We began by investigating the contemporary machines used for the production of sparkling wine bottle capsules. Our review revealed that leading manufacturers, primarily from Germany, (Emmendiger Maschinenbau GmbH 2020; Blema Kircheis GmbH 2023), with emerging manufacturers from China (Kete Group 2023), rely on essentially the same technological framework.

The capsules are produced on these specialized machines which cut polylaminate, roll it in conical shape and adhere the varnished aluminium foil top disc on, which is separately cut out of separate roll of material. As a consequence, these systems consistently generate similar amounts of material waste. The principle of these machines and the process of manufacturing capsules is described in Fig. 1.

The Polylaminate is depicted in green, while varnished aluminium foil is depicted in blue.

The production process is as follows: The polylaminate is pulled from the roll (Fig. 1, a) and goes through several stations for processing (applying rip stripe, decorative varnish) and is cut in work piece (Fig. 1, b) for rolling in conical shape. The cut off piece (Fig. 1, c) goes to waste.

At another position previously varnished aluminium foil (Fig. 1, d) is cut into discs and is applied to the workpiece with thermal adhesive. Here

During this process, the amount of the material going to waste equates to:

17% of polylaminate – 340 kg per 1 million capsules

40% of aluminium foil for the top disc – 40 kg per 1 million capsules

On a global scale (assuming 3 billion bottles/year), the industry annually generates:

- 1,020 tons of polylaminate waste
- 120 tons of aluminium foil waste

Methods

Within our study, we investigated whether polylaminate waste (Fig. 2, c) from the conical part of the capsule could be repurposed to produce the top disk (Fig. 2, e) of the capsule.

In order to analyse the Geometry of the material cutoffs, different geometries of the capsule was modeled in Autodesk Autocad. Within this program the geometry boundaries were determined which allowed extraction of the top disc (Fig. 2, e) from the waste polylaminate (Fig. 2, c).

To calculate the material usage. The dimensions of materials was derived from commonly used geometries in this field.

For polylaminate 165 mm wide polylaminate foil with 9-30-9 *AL-PE-Al* was; for every capsule

21459 mm^2 material was 17820 mm^2 is used for the capsule and the rest 3232 mm^2 goes to waste.

Aluminium foil was 32mm wide foil with 26 mm circular cutoff for the top disc. For every disc

960 mm^2 material is, 615 mm^2 is used for top disc and the rest 345 mm^2 goes to waste. As the materials have continuos thickness, material waste to usage ratio was calculated using areas of corresponding pieces.

The challenge of using the top disc from the waste polylaminate was transporting the top disc (e) from the position of the cutting to the position of application on the capsule top. After thorough technical development, a method was devised to transport the cutout top discs from the cutting position to the application position using a pneumatic system. This innovative approach was recognized as a novel invention by the National Intellectual Property Center of Georgia - Sakpatenti and was granted patent P20247640B.

Results

Geometric analysis confirmed that the dimensions of the waste polylaminate are sufficient for producing the top disc.

Based on these findings, we developed new technical solution to integrate the reuse of this material into the manufacturing process. In the revised process, during the production of a sparkling wine bottle capsule, the upper disk is cut directly from the residual zone of the primary polylaminate material.

Newly engineered mechanisms were then designed to accurately transfer the disk to its designated application position on the capsule.

The implementation of our new approach produced several notable improvements:

- **Material Savings: Elimination of Varnished Aluminium Foil**

The total amount of material needed for production of a capsule is reduced by 4,24%. The Aluminium foil used for the top disk is completely eliminated, resulting in a 100% saving of this material. The top disc is now cut directly from the polylaminate and no longer requires preliminary varnishing and coloring of the aluminium foil and reduces the manpower, equipment and material previously dedicated to this task. This elimination leads to reduction in the overall production costs.

- **Waste Reduction:**

The amount of polylaminate waste is reduced from 16,16% to 13,42%, Total amount of waste for capsule production is therefore decreased by 24,18% (Through elimination of varnished aluminium foil).

- **Technical Feasibility:**

The solution can be implemented either as retrofit mechanism to existing machines or integrated into the design of new machinery.

Discussion

Overall, the results demonstrate that the novel approach not only improves resource efficiency but also contributes to significant economic and environmental benefits, aligning with contemporary goals of sustainable production in the packaging industry.

Declarations

Author Contributions:

conceptualization, methodology, data curation, validation, formal analysis, writing - original draft preparation, M.T.;

review, visualization and editing, G.T.

All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflicts of interest.

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Figures

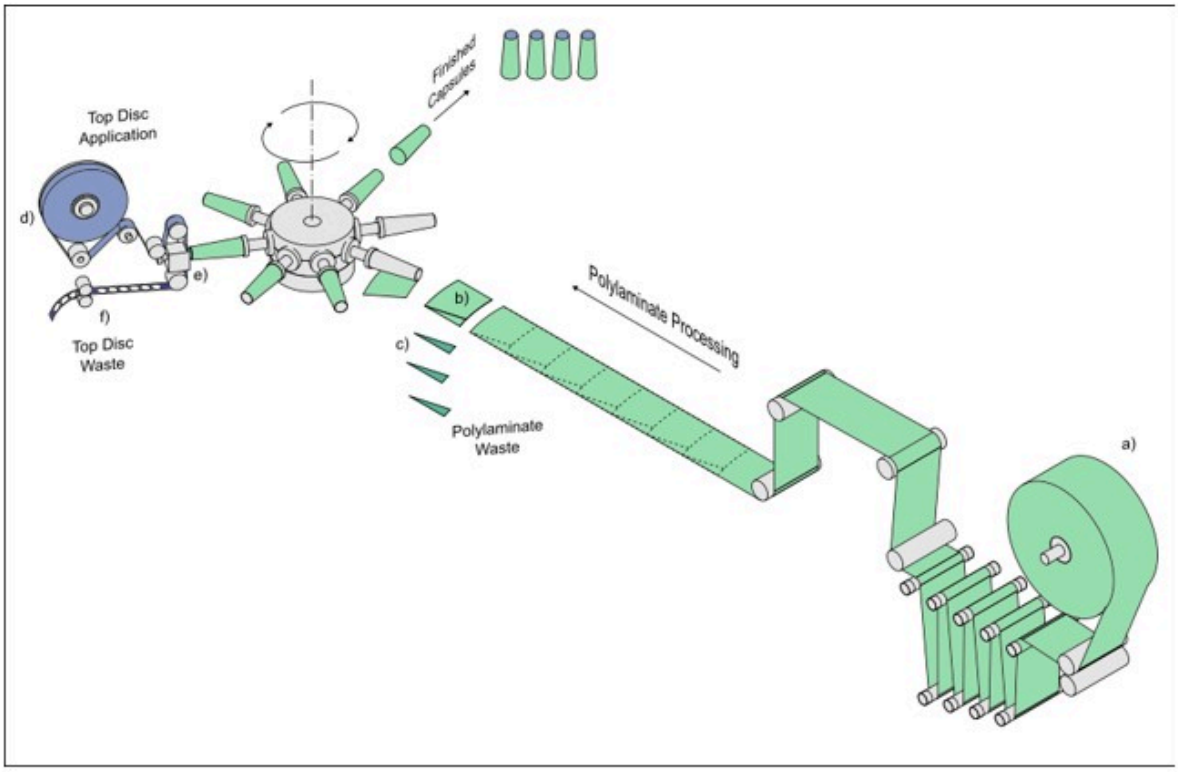


Figure 1

Production Process of Sparkling Wine Capsules, light green – Polylaminate foil, dark green – Polylaminate waste, light blue – Aluminium foil, dark blue – Aluminium foil waste

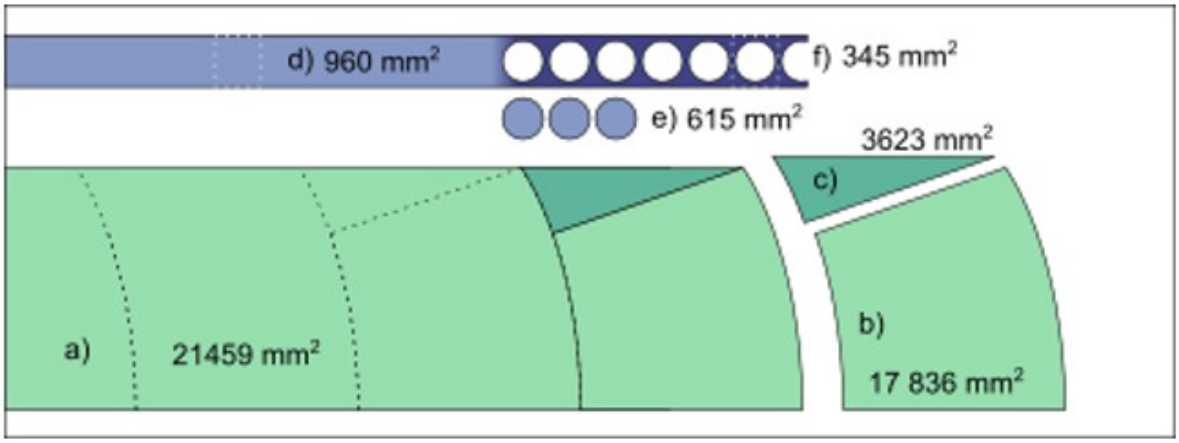


Figure 2

Material and Waste of Polylaminate (green) and Aluminium Foil (Blue)

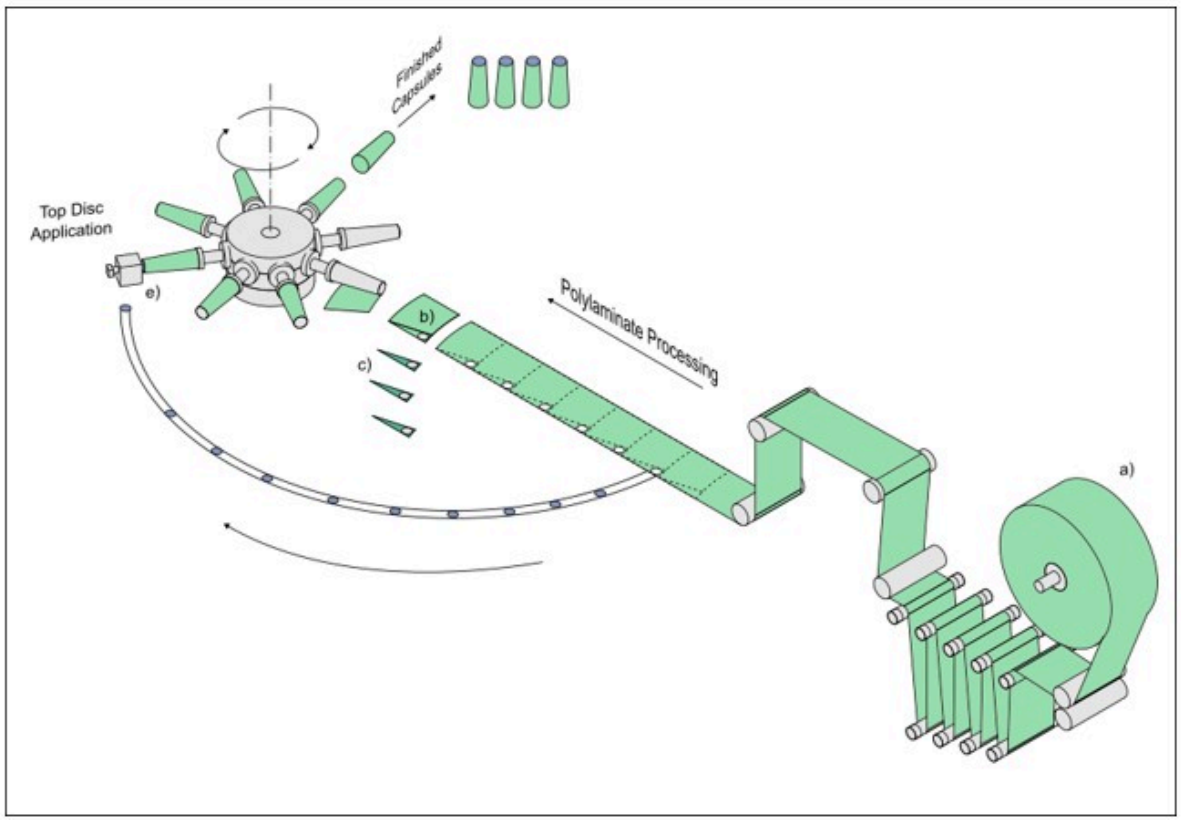


Figure 3

Modified Principle: top disc is cut out at position 1 and transported to the positon 2 for application.

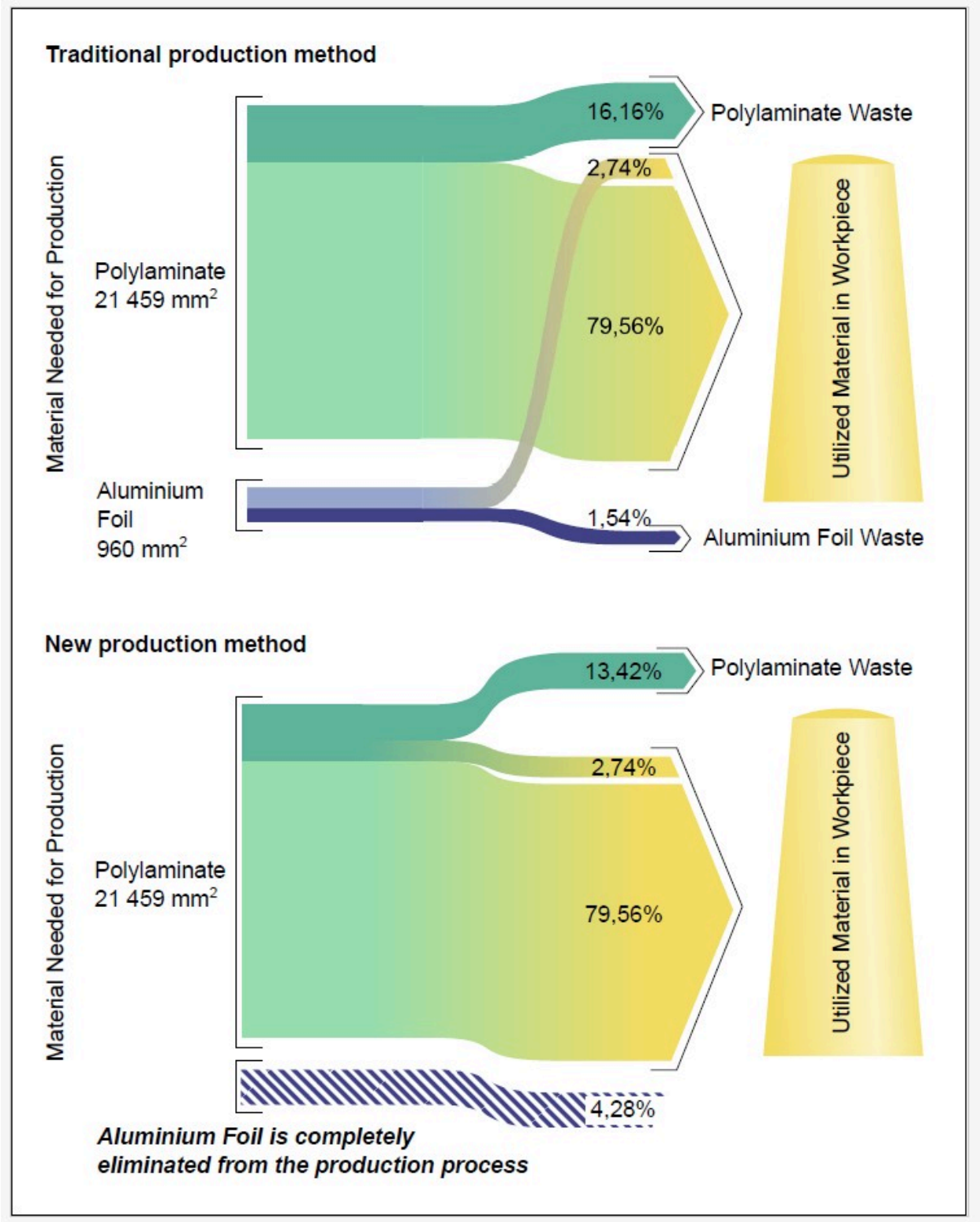


Figure 4

Material flow of traditional production process and our new production method

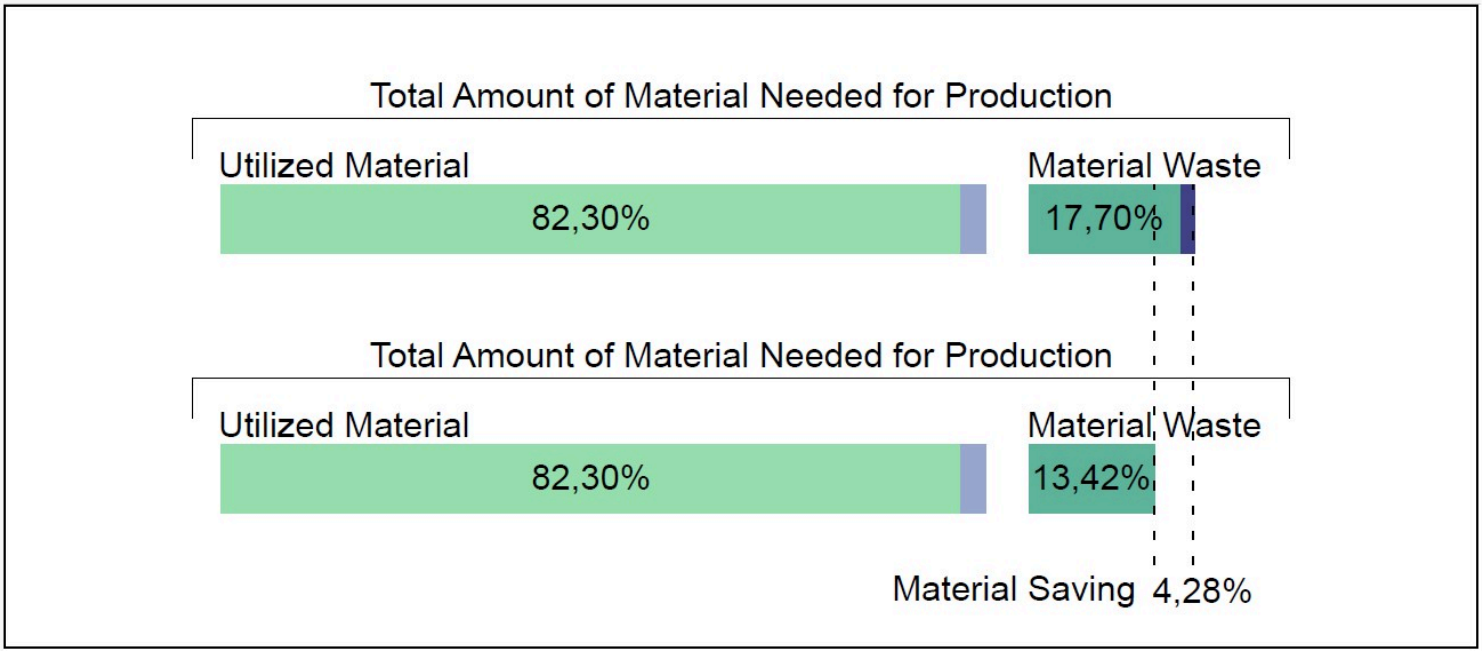


Figure 5

Ratio of utilized and waste material