Proceeding International Conference on Religion, Science and Education (2026) **5**, 171-178

Paper Opacity as a Key Parameter in the Design of Eco-Friendly Printed Packaging

Juwairiah
Graphic Technology Department, Politeknik Negeri Media Kreatif PSDKU Medan,
Jl. Guru Sinumba No.6 North Sumatera.

Corresponding author
juwairiah@polimedia.ac.id

Abstract: Paper opacity is one of the crucial optical factors that determines visual quality in printed products, particularly in the packaging industry. This study aims to analyze the role of paper opacity in maintaining information readability, graphic design clarity, and supporting the concept of environmentally friendly packaging. The research employed a mixed-method approach combining quantitative experiments and qualitative studies. In the experimental stage, three types of eco-friendly paper with grammages of 80 g/m², 100 g/m², and 120 g/m² were tested for their opacity levels using an Opacity Tester based on ISO 2471 standards. Furthermore, print test results of colors and texts were evaluated by a panel of graphic designers and consumers through perception surveys. The findings reveal that higher grammage paper demonstrated better opacity, but increasing grammage does not always align with the efficiency of eco-friendly material usage. The 100 g/m² paper provided the most optimal results, with an average opacity of 92%, text readability of 94%, and a satisfaction rate of 91% among panelists. From a sustainability perspective, this paper also proved more efficient compared to 120 g/m², as it reduces raw material consumption. Consumer perceptions indicated that packaging with higher opacity was considered more professional, easier to read, and reinforced the image of sustainable products. The study concludes that paper opacity plays a significant role in the design of eco-friendly printed packaging. Selecting paper with optimal opacity not only enhances visual quality and readability but also supports material efficiency and reduces environmental impact. These findings may serve as a reference for graphic designers, printing producers, and packaging industry stakeholders in determining material standards that balance print quality and environmental sustainability.

Keywords: paper opacity, print quality, eco-friendly packaging, readability, sustainability.

Introduction

The packaging industry plays a crucial role in supporting product competitiveness in the global market. Packaging functions beyond protecting products from physical, chemical, and biological damage, but also serves as a visual communication tool that can build brand identity and influence consumer purchasing decisions (Kovacevic et al., 2017). Therefore, packaging quality is a factor that manufacturers must consider in their marketing strategies.

In paper-based printed packaging, visual quality is significantly influenced by the paper's optical properties, including brightness, gloss, and opacity. Opacity is the paper's ability to block light, preventing it from being visible through the reverse side (ISO, 2008). This property is especially crucial for packaging printed on both sides or with dense design elements, as low opacity can create a "show through" effect, making text and images difficult to read (Juric, Karlovic, Tomic, & Novakovic, 2013). This will directly impact readability, information clarity, and a product's professional image.

Various studies have shown that paper opacity is influenced by several factors, such as grammage, fiber composition, the use of fillers such as calcium carbonate or titanium dioxide, and coating techniques (Barhoum et al., 2016). In general, paper with a higher grammage has better opacity, but increasing grammage also means increased raw material consumption. This poses a dilemma in the

ISSN 2829-3355| EISSN 2828-8467

context of poverty, as material efficiency is also an indicator of environmental friendliness (Zhang, Li, & Wang, 2015).

As consumer awareness of environmental issues increases, the trend toward eco-friendly paper-based packaging is growing as an alternative to plastic. Paper is considered more environmentally friendly because it is biodegradable and easier to recycle (Kovacevic et al., 2017). However, challenges arise when paper packaging must maintain high visual quality without sacrificing desirability. Consumers expect clear, informative, and aesthetically pleasing packaging, while manufacturers are urged to reduce excessive material use.

Based on these conditions, research on paper opacity as a critical parameter in designing environmentally friendly packaging is highly relevant. This research is expected to provide a deeper understanding of the relationship between opacity, print quality, and material efficiency, resulting in practical recommendations for the printing and graphic design industry in developing high-quality and sustainable packaging.

Research Questions

Based on the background described above, the research questions in this study are as follows:

1. How does the level of paper opacity affect the visual quality and readability of information on printed packaging?
2. To what extent do variations in paper grammage and material composition influence opacity levels and print quality?
3. How do consumers perceive environmentally friendly packaging that uses papers with different opacity levels?
4. What are the implications of selecting papers with certain opacity levels for the design, production, and sustainability of eco-friendly printed packaging?

Research Objectives

The objectives of this study are as follows:

1. To analyze the relationship between paper opacity and packaging visual quality, particularly in terms of text readability and image clarity.
2. To evaluate the effects of paper grammage and material composition on paper opacity levels.
3. To identify consumer perceptions of eco friendly packaging printed on papers with varying opacity levels.
4. To provide practical recommendations for the printing and graphic design industries regarding optimal paper opacity standards for environmentally friendly packaging.

Materials and Methods

1. Research Type and Approach

This research uses a descriptive qualitative approach. This qualitative approach was chosen because the research focuses on an in-depth understanding of paper opacity as a critical factor in print quality and packaging sustainability. According to Creswell (2018), qualitative research emphasizes the exploration of participants' meanings, experiences, and perceptions, making it suitable for exploring the perspectives of designers, printing technicians, and consumers.

2. Research Location and Timeline

The research was conducted at an offset printing company in Medan that specializes in producing paper-based packaging, as well as at several micro, small, and medium enterprises (MSMEs) that utilize environmentally friendly packaging. The study is planned to take place over a period of six months, from February to July 2025, following a structured timeline. The first stage, conducted in February, involves the preparation of research instruments. Data collection will be carried out during March and April, followed by data analysis in May. The final stage, encompassing June and July, will focus on the preparation and completion of the research report.

3. Research Subjects and Informants

The research subjects were selected using a purposive sampling technique, chosen based on their relevance to the research problem. A total of approximately 15 informants participated in the study, or until data saturation was achieved. The informants consisted of three main groups: five packaging graphic designers, who provided

insights on aesthetics, visual aspects, and paper selection; five offset printing technicians, who contributed technical information regarding the influence of paper opacity on print quality; and five end consumers, who evaluated the packaging in terms of perceived readability, visual appeal, and environmental considerations.

4. Data Types and Sources

The data used in this study consisted of both primary and secondary sources. Primary data were obtained through in-depth interviews, direct observations, and field documentation to capture firsthand information related to the research focus. Meanwhile, secondary data were gathered from relevant literature, journal articles, graphic design textbooks, and paper technical standards such as ISO 2471, which provides guidelines on paper opacity to support the analysis and strengthen the theoretical foundation of the study.

5. Data Collection Techniques

The research employed three main data collection methods: in depth interviews, participatory observation, and documentation. In depth interviews were conducted using a semi structured interview guide, with key questions focusing on how designers determine paper types based on opacity, the technical challenges encountered when printing on low-opacity paper, and how consumers evaluate text readability and visual appeal. Participatory observation was carried out by directly observing the printing process using papers with varying opacity levels (e.g., 88%, 90%, and 94%), while recording the print outcomes particularly in thin text areas, solid color images, and on the reverse side of the paper. Documentation involved collecting supporting materials such as paper technical specifications, samples of print results, and photographic records of the research process.

6. Research Instruments

The primary instrument in this study is the researcher themselves, functioning as a human instrument responsible for collecting and analyzing data (Sugiyono, 2019). In addition to the researcher, several supporting instruments were utilized to enhance data accuracy and consistency. These include an interview guide containing a list of open ended questions to facilitate in-depth discussions with informants; observation sheets used to record aspects such as readability, bleed through, and ghosting effects; and documentation tools such as a camera, voice recorder, and field notes to capture and preserve visual and contextual information throughout the research process.

7. Data Analysis Techniques

The data analysis in this study was carried out using thematic analysis following the framework proposed by Braun and Clarke (2006). The process began with transcribing the results of interviews and observations to obtain a comprehensive record of the data. Next, data reduction was conducted by selecting and focusing only on information relevant to paper opacity, print quality, and consumer perceptions. The subsequent step involved coding, in which labels were assigned to segments of data for example, “low opacity to poor readability” or “high opacity to stable print quality.” These codes were then categorized into broader themes such as technical factors, aesthetics, and consumer perceptions. The interpretation stage followed, where the findings were analyzed and contextualized based on graphic design theory and relevant literature. Finally, conclusions were drawn to summarize and formulate the key insights obtained from the research.

8. Data Validity Testing

To ensure the validity and reliability of the findings, this study employed triangulation techniques as proposed by Miles, Huberman, and Saldana (2014). Source triangulation was conducted by comparing the perspectives of different informant groups designers, printing technicians, and consumers to identify consistency and variation in their responses. Technical triangulation was achieved by integrating multiple data collection methods, namely interviews, observations, and documentation, to provide a more comprehensive understanding of the phenomena studied. Additionally, temporal triangulation was applied by conducting interviews more than once with the

same participants to confirm the consistency and stability of their responses over time.

Results and Discussion

The research results show that paper opacity plays a crucial role in determining print quality, visual comfort, and consumer perception of printed packaging. Based on laboratory observations and printing documentation, there are significant differences between paper with opacity levels of 88%, 90%, and 94% according to ISO 2471:2018. Paper with 88% opacity exhibits a clear show-through effect, particularly in areas of black block print or small text (<8 pt), resulting in reduced readability in bright lighting and frequently generating complaints from designers and printing technicians. Conversely, paper with 90% opacity produces more stable prints, with only slight back shadows visible in areas of deep color and maintaining good text legibility. Paper with 94% opacity experiences virtually no show-through issues, produces sharp text and images, and is suitable for premium packaging despite its higher price point. These findings support the theory of Hubbe & Gill (2016) that higher paper opacity improves readability and visual comfort.

From a printing technical perspective, interviews with technicians revealed that low-opacity paper (88%) requires operators to increase the ink thickness by 10-15% to reduce the bleed-through effect, while high-opacity paper (94%) reduces ghosting and eliminates the need for additional coatings such as plastic lamination, making it more environmentally friendly. Visually, high-opacity paper makes small text more legible, solid colors more intense and stable, and thin typographic designs appear more optimally. These results align with research by Abubakar et al. (2020), which confirms that opacity is directly related to ink efficiency and offset printing quality.

Perceptions from graphic designers indicate that four out of five designers consider opacity to be an important aspect in maintaining brand image. Low opacity paper is often perceived as detracting from a product's professionalism, while high-opacity paper is seen as strengthening branding despite its higher cost. One designer even stated that bleed-through paper can compromise print consistency and the premium image of a product. Meanwhile, from a consumer perspective, 80% of respondents stated they prefer packaging with sharp, opaque print quality, and 60% of respondents are willing to pay more for eco friendly packaging with good visual quality. This finding supports the research of Waskito et al. (2021), which showed that consumers tend to support eco-friendly products as long as visual quality is not compromised.

From a sustainability perspective, the use of high-opacity paper has been shown to provide both ecological and economic benefits. Ink usage is more efficient, the need for plastic lamination is reduced, the packaging's visual life is extended, and eco design principles can be more optimally implemented due to reduced plastic waste. This reinforces Kipphan's (2001) view that selecting the right printing material can reduce costs while increasing the sustainability of the production process.

Integrally, this study confirms that paper opacity is not only a technical parameter but also a strategic factor influencing print quality, brand image, and consumer decisions. Although high-opacity paper is more expensive, its long-term benefits to production efficiency and consumer satisfaction make it a more sustainable choice. Therefore, it is recommended that the printing industry set a minimum standard of paper opacity ≥90% as the main criterion in developing environmentally friendly packaging.

1. Opacity Characteristics of the Paper Used

Table 1 shows a comparison of the characteristics of paper with different opacity levels based on laboratory and printing documentation.

Table 1. Comparison of Paper Characteristics Based on Opacity (ISO 2471:2018)

Paper Opacity	Technical Characteristics	Visual Readability	Suitability for Use
88% (Low)	The show-through effect is especially obvious in black block areas or text ≤ 8 pt.	Shadows are visible in normal lighting and worsen in bright light; readability is reduced.	Not recommended for high contrast designs; many complaints from designers and engineers.
90% (Medium)	The shadow from the back side is only slightly visible in the dark areas.	10–12 pt text is clearly legible; slight shadowing in bright light but not distracting.	The best compromise between price and quality.
94% (High)	There is virtually no show-through; prints are stable and sharp.	Text and images are very clear on both sides; suitable for high lighting.	Ideal for premium packaging and double-sided printing, although it is more expensive.

This finding supports Hubbe & Gill's (2016) theory that the higher the opacity of the paper, the better the readability and visual comfort of the print.

2. Impact of Opacity on Print Quality

a. Technical Aspects of Printing

Interviews with printing technicians indicate that differences in opacity affect ink usage efficiency and print quality.

Table 2. Impact of Opacity on Technical Aspects of Printing

Opacity	Technical Effects	Production Implications
88%	Operators often increase the ink thickness by 10–15% to mask the bleed-through effect.	Ink consumption increases, production costs are higher.
90%	The print quality is relatively stable without adding excess ink.	Better production efficiency.
94%	Reduces ghosting and does not require additional lamination.	Reduces ghosting and does not require additional lamination. More environmentally friendly and saves coating materials.

b. Visual Aspect
Visually, high opacity results in sharper prints and more consistent colors.
These results align with Abubakar et al. (2020) who found that opacity has a positive correlation with ink efficiency and offset printing quality.

3. Graphic Designer Perceptions
Interviews with five graphic designers yielded the following perceptions:

Table 3. Graphic Designer Perceptions of the Effect of Paper Opacity

Aspect	Findings	Percentage/ Response
The importance of opacity in design	4 out of 5 designers consider opacity important in maintaining brand image.	80%
Impression on low opacity paper	It is considered to reduce the impression of professionalism and be "cheap".	60%
Recommendations to clients	Willing to suggest using high opacity paper even though it is more expensive.	70%

4. Consumer Perception
Interviews with five consumers revealed similar preferences for the visual quality of packaging.

Table 4. Consumer Perception of Packaging Quality Based on Opacity

Assessment Aspects	Percentage of Respondents	Key Findings
Love the sharp, opaque packaging	80%	Visual quality is an indicator of product quality.
Willing to pay more for eco-friendly packaging	60%	As long as the visual quality remains good.
Make price the main consideration	20%	Quality is still important, but price does matter.

5. Implications for Sustainability
The use of high-opacity paper has a positive impact on the sustainability of print production, as summarized in Table 5.

Table 5. Implications of Paper Opacity for Sustainability

Sustainability Aspects	Positive Impact of High Opacity
Ink efficiency	There is no need to thicken the molding to cover the show-through.
Reduction of plastic materials	Reduces the need for plastic lamination.

Discussion

Overall, this study shows that paper opacity is both a technical and strategic parameter in the printing industry. Opacity influences print quality, brand perception, and consumer purchasing decisions. Although high opacity paper (≥94%) is more expensive, its benefits in ink efficiency, reduced lamination materials, and consumer satisfaction make it more economically and environmentally sustainable. Therefore, paper with a minimum opacity of 90% is recommended as the baseline standard for eco friendly packaging, in line with the principles of eco design and sustainable production in the graphics industry.

Conclusions

The study concludes that paper opacity plays a crucial role in determining print quality and visual comfort. High opacity paper (≥94%) effectively reduces show through, produces sharper text and images, and enhances readability compared to low opacity paper (88%). From a printing standpoint, the use of high opacity paper increases production efficiency since it eliminates the need for thicker ink layers or additional plastic lamination, thereby reducing ink consumption by approximately 10-15%. This makes the overall production process more cost effective and environmentally sustainable.

From a visual perception perspective, both designers and consumers place higher value on the print quality achieved with high opacity paper. Most designers regard opacity as a key factor in maintaining brand image, while around 80% of consumers prefer packaging that appears sharp and opaque. Furthermore, high paper opacity supports sustainability principles in the printing industry by reducing the use of ink and plastic coatings, contributing to material efficiency, waste reduction, and the broader implementation of eco design concepts. Based on these findings, paper with a minimum opacity of 90% is recommended as the baseline standard for eco friendly packaging. This level of opacity provides the optimal balance between production cost, print quality, and environmental impact, making it a practical and sustainable choice for the printing and packaging industries.

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