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The Study of Propylene Glycol Effect as Wetting Agent Content for Offset Printing Technique

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ABSTRACT

Although the printing offset technique offered the best printout quality among other printing techniques, however, there is a drawback of the offset technique which needs great skill to handle the process, i.e the presence of trace water molecules on the image area of the plate. The water's existence in the image area leads to the poor covering of ink which makes the blurry printout than it must be. Therefore, we used various concentrations of propylene glycol such as 0%, 0.05%, and 0.1% as wetting agents to prevent the trace water sticks to the image area of the plate. We used the HVS paper 80 g/m^2 as printing material and the machine of Oliver Sakurai 472 ED to study the role of propylene glycol. Propylene glycol has been considered based on stronger interaction with water molecules than the interaction of the image area - propylene glycol. By investigating the visual quality, density, and dot gain of the printout, we concluded that the wetting agent content of PG 0.05% (v/v) increased the visual brightness, and density of the printout, compared to the water only as the wetting solution.

1. INTRODUCTION

Despite the rapid advancements in digital printing technologies, offset printing continues to hold a significant place in the production of high-quality printouts, particularly for bulk requirements like books and packaging materials. This preference stems from the necessity for printed texts in educational settings, especially in less developed regions where digital alternatives are not as accessible, and for pupils in rural areas where traditional learning materials remain indispensable (Bhoomkar et al., 2007). The packaging industry, too, relies heavily on offset techniques to achieve a diverse range of high-quality printed products.

Offset printing, known for its exceptional print quality, utilizes a rigorous transfer process that generates unparalleled results. This process demands a high level of skill from the operators (Bhoomkar et al., 2007). The ink is transferred from a printing plate, positioned on a cylinder, to a rubber blanket, and then to the paper. This process, depicted in Figure 1, relies on the principle of ink adhering to oleophilic (image) regions of the plate. The hydrophilic (non-image) areas attract a water-based fountain solution, commonly referred to as wetting water or wetting agent, which is essential for sustaining image quality (Jašúrek et al., 2011; Wu et al., 2018).

The clarity of the printed image is highly dependent on the chemical composition of the printing plate, ink, and fountain solution. The offset ink being hydrophobic, it is crucial to avoid any water coming in contact with the image region of the plate. Similarly, the non-image area must remain oleophobic and solely covered by the wetting agent sans any ink. Failure to prevent unintentional ink and water contact on the plate may lead to printouts that are below customer expectations. The fountain solution is crucial for maintaining ink and water stability on the offset printing plate's respective areas, which guarantees that each print meets the high-quality standards of the industry (Tåg et al., 2009; Prica et al., 2015).

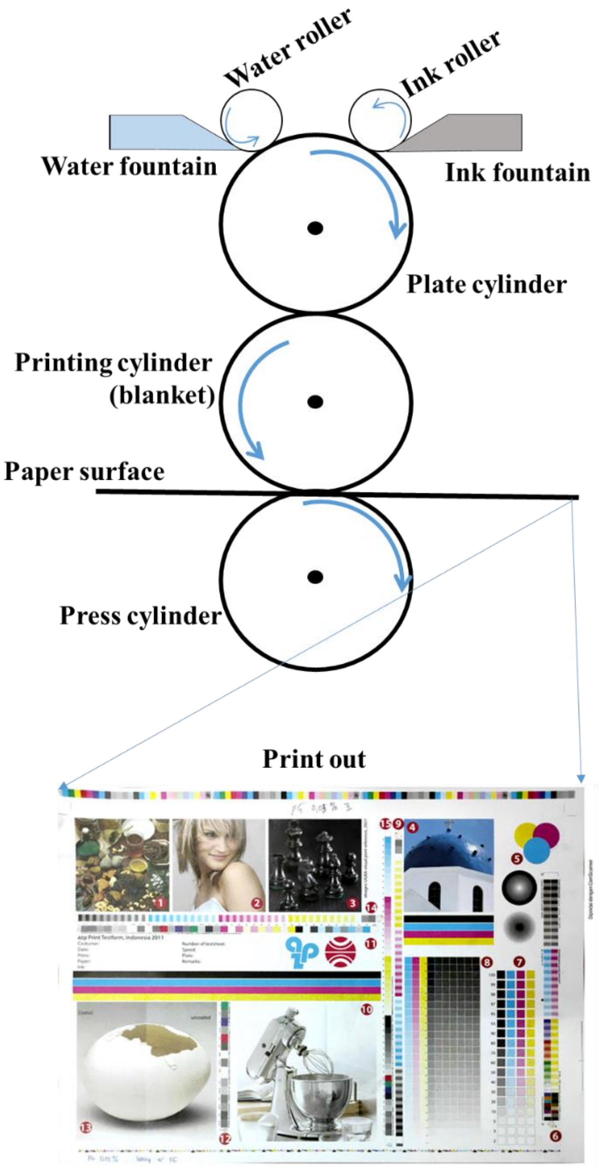

Figure 1 Schematic of the printing unit and the printout.

Isopropyl alcohol (IPA) serves as a crucial ingredient in fountain solutions used for offset printing. Its main function is to decrease surface tension, which enhances the wetting and adhesion of the solution on the printing plate surface, thereby ensuring the ink-water equilibrium is maintained (Rossitza, 2015). IPA's multifaceted benefits extend beyond reducing surface tension; they also possess antifungal properties and can cool the printing plate, further improving the printing process (Aydemir

& Yenidoğan, 2019). However, the greatest challenge in offset printing is still preventing excess water from migrating to the inked image areas, which causes blurry prints. Achieving a delicate balance is crucial in minimizing water in non-image areas while ensuring complete coverage to prevent ink adherence. To address this, fountain solution additives, such as Arabic gum, are integrated to stabilize the water film by binding water molecules on the surface, thus preventing rapid drying (Longchun Li & Ahn, 2017).

The addition of IPA in the fountain solution results in a decreased contact angle of water droplets on the plate. This is due to the weaker water-IPA-water bonds disrupting the hydrogen bonds in water molecules (Ridout & Probert, 2014). The effectiveness of IPA lies in reducing the need for wetting water and limiting the risk of water coming into image areas, which is critical in preserving print quality (Södergård et al., 1996; Chen et al., 2015; Varepo et al., 2017). However, the use of IPA at its optimal level does not entirely eliminate water traces in image areas. As little as 6 parts per million of water can adversely affect the print clarity (Michel et al., 2001). Consequently, researchers sought an agent that can attract and hold water at trace levels resulting in the investigation of propylene glycol (PG), a compound known for its water-dissolving efficacy. With the presence of dual hydroxyl groups, PG is postulated to improve the quality of offset printing by efficiently decreasing water marks in the image area (Jammalamadaka & Raissi, 2010; Jacob et al., 2018).

The disadvantages of spraying IPA cannot be ignored due to its complete evaporation in press areas, which can potentially lead to health problems for printers and contribute to environmental issues such as ozone production and summer smog (Davidy, 2019). Therefore, this study recommends using PG as a safer and more ecologically friendly alternative. PG's high boiling point and flash point, at 187°C and 107°C respectively, demonstrate its superiority over IPA for safety and stability in industrial settings (Davidy, 2019; Motoyoshi et al., 1984). Remarkably, PG's recent application in offset printing demonstrates its novel potential in addition to its established use in the food, cosmetic, and pharmaceutical industries.

2. METHOD

2.1 Materials and Tools

The Propylene glycol (PG) utilized in this experimentation was acquired from The DOW Chemical Company. The text and image were printed utilizing the Japanese-made Oliver Sakura 472 offset printing machine. The print characterization was determined using the Spectro-densitometer (Techon Advance, Made in Germany). The pH was measured by the US-produced Toledo pH meter, and conductivity was determined using the US-made Toledo conductivity meter.

2.2 Characterization Procedure

The drawings and plates for printing are designed in the pre-press laboratory as a reference. To guarantee quality, we performed a printing test on 1000 sheets of paper according to our customer satisfaction standard. Afterwards, the wetting solution was replaced with a 0.05%, 0.1%, and 1% propylene glycol (PG) solution. Each concentration of PG was utilized to produce 1000 copies of the prints. However, we ruled out the PG 1.0% solution as the ink printed on both the image and non-image area, indicating unsatisfactory results. To ensure accuracy, we conducted pH value and conductivity tests on the wetting solution before and after the printing process. Further, we selected the 10 highest quality prints for evaluation, printing with PG concentrations of 0%, 0.05% and 0.1%. The prints underwent density and dot gain tests using Techon Advance Spectro-densitometer. Please refer to Figure 2 for the outlined procedure.

The data collection in this study conditions the printing machine to achieve optimal results based on customer satisfaction. The water inlet and outlet of the Oliver Sakurai 472 ED machine are set to 40%, with a print roller pressure of 10.66 Pa. Although the machine's printing speed is theoretically between 4000 and 12000 sheets/hour, we employ it at 5000 sheets/hour. The machine standards serve as a guide for calibrating the machine settings to achieve optimal print quality for this study. HVS 80 g/m^2 paper with a thickness of 0.09 mm is utilized for printing materials.

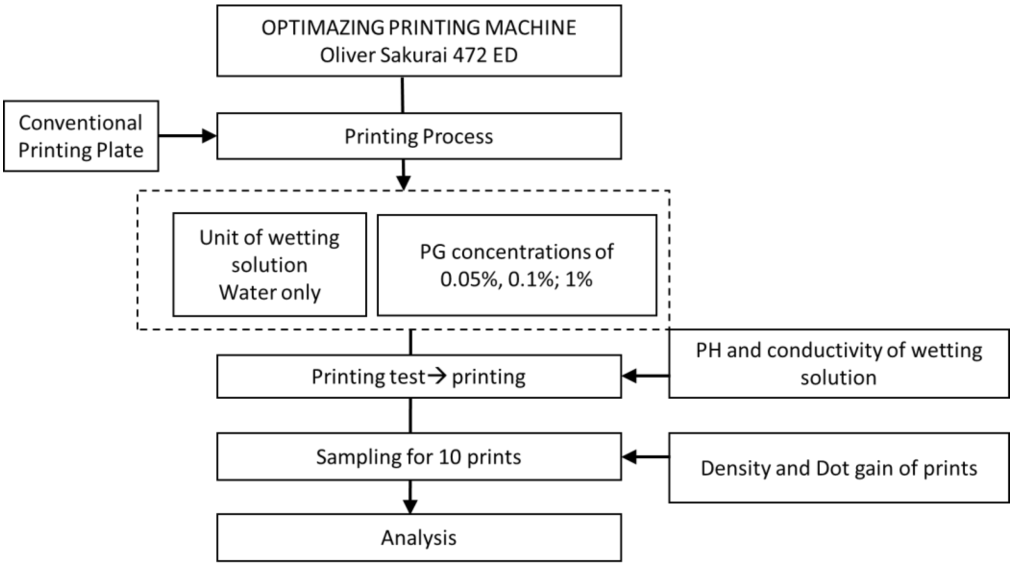

Figure 2 Taking data procedure.

Since the print run is less than 5000 sheets, a conventional printing plate containing a thin layer of Aluminum was utilized to print the design. The plate's emulsion surface is then heated in non-image areas, making them easier to remove through chemical reactions, leaving behind only the image area for reference. The plate is processed via standard computer to conventional plate (Ct-Cp) technology.

3. RESULTS AND DISCUSSION

In our study, the printing process commenced with the preparation of the printing plate, which was attached to the printing cylinder. PG was added to the water fountain solution. The plate was wetted by the water fountain and then moved to the inking unit where we utilized ink from DIC Graphic to transfer ink to the blanket.

Finally, the image was printed on HVS paper, an uncoated surface for printing material, as depicted in Figure 1. Uncoated paper absorbs ink strongly, limiting its spread on the surface and decreasing image sharpness compared to coated paper (Lin et al., 2020; Nguyen et al., 2021). Nevertheless, the widespread use of HVS paper assists in maintaining printed books' dominance in Indonesia due to its affordability. Therefore, this study aims to optimize and efficiently utilize the HVS paper while exploring alternative options as the primary material.

In accordance with the study objectives, prints using only water as a wetting agent were compared to prints using a PG solution. The water utilized as a wetting agent possesses a conductivity level of 58 µS and a pH value of 6.8. Details of the wetting solution usage can be found in Table 1.

Table 1 The printing process used.

Wetting agent	0% PG	0.05%PG	0.1% PG
pH	6.5	6.6	7.5
Conductivity	248	256	303

In offset printing, the wetting solution is typically maintained at a pH of 4.5 to 5.5 for optimal performance of the wetting benefits on printing plates, as noted by Moreira et al. (2018). This is attributed to Arabic gum. However, our study did not consider the pH range since we did not include gum Arabic. Instead, we focused on the role of PG in improving print quality compared to solutions without adjuvants.

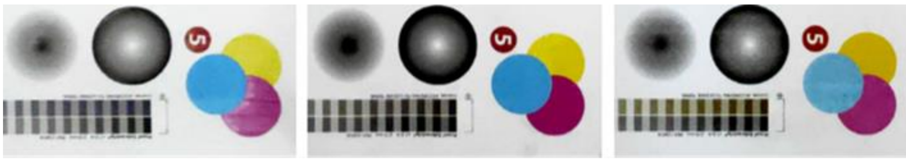

Figure 3 The view of the visual quality of prints using wetting agents of PG0%, 0.05%, and 0.1%.

According to Table 1, after being circulated for 15 minutes, the pH of the wetting solution comprising solely water was 6.5. Prior to circulating, the conductivity of water measured 58 µS, but after circulating in the machine and dissolving machine-installed particles, the solution's conductivity increased to 248 µS. Notably, the increase in conductivity did not have a significant effect on the pH. It is clear that the wetting solution's conductivity level is not sufficiently standardized. It depends on best practices based on machine and human skills, considering printing costs. In the case of our area in Indonesia, a conductivity level of 1000 µS is typical during the printing process and often results in good outcomes. The operator typically replaces the wetting solution once its conductivity value is twice that of the newly prepared solution. Excessive conductivity deteriorates the printing process, resulting in scumming, toning, or tinting. Conversely, lower conductivity improves the printing process and positively impacts environmental health (Lianfang et al., 2016). As our study's conductivity value is below 500 µS, changes in conductivity would have no effect on our experimental results. Referring to Table 1, when PG was added up to 0.1%, both pH and conductivity parameters increased by a small amount. This indicates that the quality of the wetting solution did not decrease due to the increased PG concentration up to 0.1%.

3.1 The Printout Quality based on Visual Characterization

The addition of PG to a wetting solution of 0.05% volume-to-volume (*v/v*) was found to significantly increase color brightness compared to using water alone as the wetting solution, as shown in Figure 3. The 0.05% concentration of propylene glycol produced the highest quality image when compared to PG 0% and 0.1%. This suggests that at PG 0.00%, only a minute amount of water is present on the surface of the image area plate. If water remains in the image area, it results in a decrease in the concentration of pigment in the ink, causing a blurry printed image. However, when the PG concentration in the wetting solution reaches 0.1%, the water on the plate's non-image area surface detaches, causing it to dry out. As a result, the ink from the image area is transferred to the non-image area, creating a blurred image (Leach, 2012).

Table 2 The density of prints with PG 0%, 0.05% and 0.1% as wetting agent.

Color	**Optical Density**		
	0%PG	**0.05%PG**	**0.1%PG**
C	0.90	0.94	0.94
M	0.76	1.02	0.96
Y	0.38	0.68	1.13
K	1.08	1.34	1.38

3.2 The Printout Quality is based on Optical Density and Dot Gain

For each data collection with varying PG concentrations, we conditioned the printing process by running the machine for 15 minutes to ensure normal circulation of the wetting solution. We then visually selected the best prints and measured their print density, as shown in Table 2. The print density number indicates the absorbed light, which is then converted to represent the ink-covered surface.

According to Table 2, the addition of PG to the wetting solution increased print density on all colors of the paper's surface. Yellow (Y) experienced the highest density increase, while cyan (C) had the lowest increase, with black (K) falling in between.

The volume of ink on the PG solution-wetted plate surface increased in comparison to the non-PG wetted surface. This indicates an increased ability of the ink to adhere to the image area of the plate. The dot gain data, found in Table 3, supports this idea through observations made at 80% and 40% raster. The 80% figure pertains to shadow levels where the images and backgrounds can be distinguished. The 40% measurement displayed lighter middle tones. Specifically, observations of raster change were made on bright tones and confirmed through tone observations on darker tones. The addition of PG to the wetting solution resulted in the greatest change in the area (dot gain) in yellow (Y), followed by black (K). While the dot gain of magenta (M) tended to increase, it was not significant. In cyan (C), a minor decrease in the raster area was observed. Overall, the data density and dot gain support the impact of PG addition to the wetting solution on the quality of the yellow (Y) and black (K) colors. As a result, incorporating PG into the wetting solution enhances the printed image quality by boosting the raster gain. We observe the printing machine's standard, where the 40% and 80% raster should exhibit 56% and 91%, respectively, in the printed raster image. This standard conforms to ISO 12647 desk 2 and was printed using the Oliver Sakurai 472 ED offset printing machine.

Table 3 Dot gain of prints with PG 0%, 0.05%, and 0.1% as a wetting agent

Color	Dot Gain					
	Raster Area 40%			Raster Area 80%		
	0%PG	0.05%PG	0.1%PG	0%PG	0.05%PG	0.1%PG
C	0.47	0.44	0.43	0.84	0.81	0.81
M	0.62	0.50	0.47	0.95	0.93	1.08
Y	0.41	0.52	0.68	0.68	0.84	0.96
K	0.43	0.60	0.58	0.77	0.91	0.9

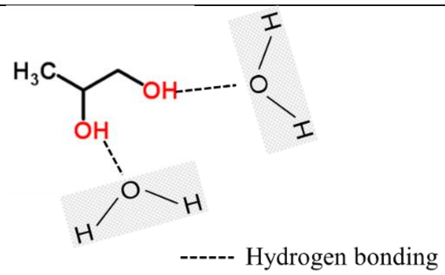

Figure 4 Interaction of PG and water molecules.

3.3 Mechanism of PG's Effect

The chemical formula for PG is $C_3H_6(OH)_2$, possessing two –OH groups that can bind water molecules through hydrogen bonds facilitating its dissolution in water and vice versa, as displayed in Figure 4. In the wetting process of the plate, the image area is hydrophobic, prohibiting water molecules from adhering. Nonetheless, during the inking process, the image area binds ink completely. In practice, there may still be some water present on the image area surface, which can negatively impact ink quality. The role of PG is to prevent any trace water from forming on the surface and dissolve it upon contact with the plate's wetting roller.

During the process of wetting the surface with a 0% PG solution, when water comes into contact with the image area on the printing plate's surface, only a few water molecules persist in that area due to water's nature of weak interaction with almost all materials, including metals (Nugraha et al., 2020). A water molecule possesses two lone electron pairs and donates these pairs to other atoms with vacant orbitals or a positive dipole charge. The addition of 0.05% PG to the solution can overcome weak binding between trace water molecules and the image area of the plate by forming hydrogen bonds between PG and water molecules. This technique suppresses the number of molecular traces on the hydrophobic/oleophilic image area of the printing plate surface, thereby increasing the volume of ink that forms in the image area. However, at a PG concentration of 0.1%, water attaches to the non-image area of the plate surface and is subsequently dissolved by PG, forming a wetting solution. When the ink roller touches the surface of the plate under these conditions, the ink not only adheres to the image area but also affects the non-image area, resulting in visual ink printing on the non-image area.

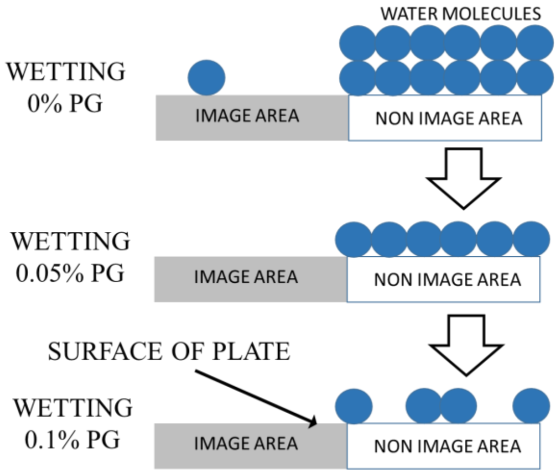

Figure 5 Schematic of the mechanism of PG performance as an auxiliary material for wetting solutions in the offset printing process.

The reaction scheme is shown in the Figure 5. The wetting agent solution's ideal PG content is 0.05%. Meanwhile, at 0.1% PG content, water-PG interaction surpasses that of water and the non-image area on the printing plate, leading to the ink's participation in the non-image surface area. Although the wetting solution containing 0.05% PG demonstrates superior quality, further improvements to the process's durability are necessary. This is due to the presence of a very thin layer of water on the non-image area's surface, which evaporates quickly and causes ink to occupy this area when the plate is inked using a roller. In the conventional printing process, gum Arabic unintentionally carried out a thin film of water onto the image surface without exploration in this study. Nevertheless, we are presently researching the function of gum Arabic as an adjunct in wetting solutions for offset printing, combined with PG..

4. CONCLUSION

Our study on the impact of propylene glycol (PG) as a wetting agent in offset printing has provided informative outcomes. These results indicate the potential of PG as an effective tool for enhancing print quality. The collected data confirms that adding PG to the wetting solution considerably amplifies the richness and concentration of yellow and black inks, while the cyan and magenta inks remain unaffected. These findings align with the initial discussion on the continued importance of offset printing for producing high-quality prints, especially in the context of educational literature and packaging. The wetting solution's optimal concentration of PG was established as 0.05% *v*/*v*, significantly outperforming conventional water-based solutions. By minimizing the presence of water molecules on the image area of the printing plate, PG significantly improved the ink density in the image areas, resulting in elevated print quality. This achievement is especially significant considering the introduction's emphasis on the crucial role of fountain solutions in preserving the integrity of offset printing. The incorporation of 0.05% PG into the wetting solution successfully aligns with the objective of enhancing print quality while addressing environmental and health concerns related to isopropyl alcohol (IPA) previously discussed in the introduction. This study effectively achieves its goal of improving print quality, in addition to advancing a more sustainable and secure practice for the offset printing industry. The shift from IPA to PG in offset printing could potentially signify a noteworthy change, reflecting our dedication to innovation and eco-consciousness.

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