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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.

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1. INTRODUCTION

Although digital printing has been widely developed to fulfill the need for printouts, however, the offset printing technique remains to exist due to the quality and number of prints. The reason is; that printed reading texts such as books are still needed by the public, especially for pupils in rural third countries. The packaging industry is also close to printed text which uses the offset technique to vary the product. The offset technique concept leads to the best quality of the printout, however, the public perception is split into several printing techniques. The reason is, that the complicated process of the offset technique needs more complex skills rather than other techniques (Bhoomkar et al., 2007). To form the printed image as a result of the offset printing, ink sticks to the printing plate which is attached to the printing cylinder, and then ink is transferred to a rubber pad (blanket). From the blanket, ink is delivered to the paper through the rotational motion of the plate, blanket, and paper pads, as seen in Figure 1. The ink from the ink roller is bonded on the oleophilic area of the plate (namely the image area) while the water is attached to the hydrophilic area of the plate (namely the non-image area). The

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term water is also called fountain solution or wetting water or wetting agent, which plays an important role to maintain stable image quality (Jašúrek et al., 2011; Wu et al., 2018). The transfer process to form the printed image is determined by the chemical properties of the surface of the plate, ink, and fountain solution. The offset ink is not soluble in water so the area of the printing plate containing the image is not expected to contain water (hydrophobic). On the other hand, on the non-image area of the printing plate there should be no ink (oleophobic) and only wetting water is allowed to cover the surface of the area. If the presence of ink accidentally crosses into the non-image area and vice versa water is found in the image area of the printing plate, then the print quality is certainly not following customer demands. Therefore, the use of a fountain solution is important to maintain the properties of the plate and ink in maintaining the stability of the ink and water positions in the image and non-image areas of the offset printing plate, respectively (Tåg et al., 2009; Prica et al., 2015).

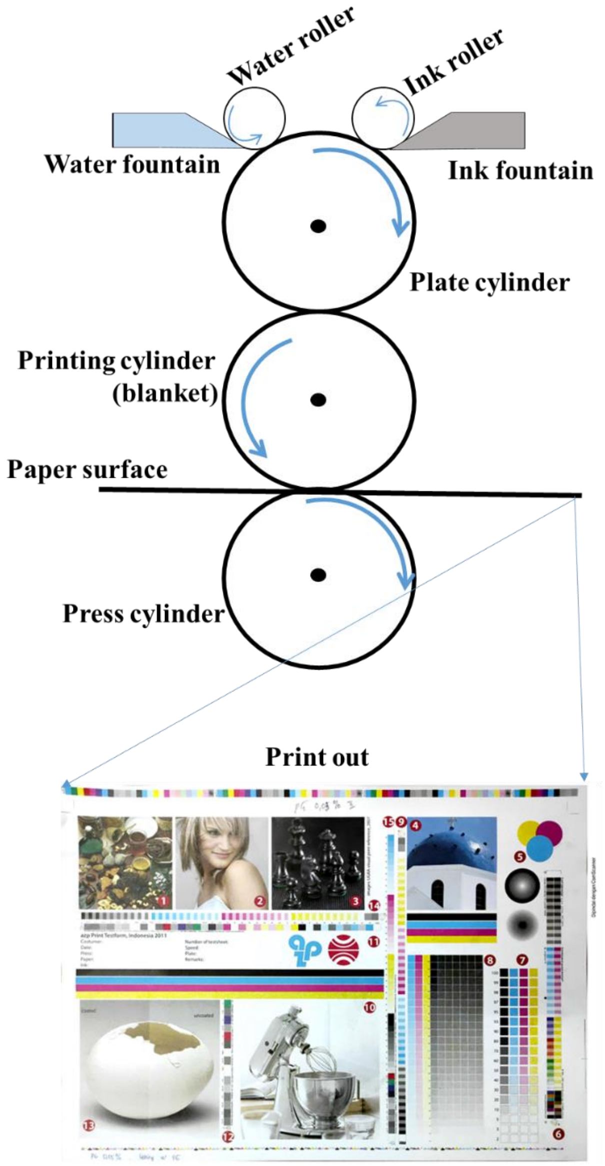


Figure 1. Schematic of the printing unit and the printout

One of the components in the fountain solution sold in the market is isopropyl alcohol (IPA). Commonly IPA plays a key role in offset printing, lowering the surface tension of the dampening solution it guarantees better wetting and adhesion on the plate surface and ensures the stability of the ink-water balance (Rossitza, 2015). Some of the advantages of this IPA are its ability to be antifungal, microorganism, and printing plate cooling as well as lowering the surface tension of water (Aydemir & Yenidoğan, 2019). The surface tension lowering property of the water is the most important property associated with the offset printing process. The risk of excessive water on the non-image area of the printing plate is at risk of causing water transfer to the image area that should only be used for ink. The ink-water mixing that occurred in the image area caused blurry printouts. Therefore, the use of wetting water in the non-image area must be kept to a minimum while ensuring that the non-image area is completely covered by water. However, a tiny layer of water on the non-image area has also a high risk to be dried quickly which leads to the ink stuck on the non-image area. Therefore, Arabic gum is considered to be added to the wetting solution since the nature of Arabic gum can hold water molecules on the surface of the image area so that a thin layer of water can be maintained in the presence of Arabic gum (Longchun Li & Ahn, 2017).

The presence of IPA in the wetting solution improves the quality of wetting by decreasing the contact angle between the water droplets and the surface of the plate due to decreasing attractive force among water molecules through hydrogen bonds. The hydrogen bonds between the water molecules in the solution are interrupted by the water-IPA-water bonds which are weaker than the water-water bonds (Ridout & Probert, 2014). Thus the use of IPA will reduce the use of wetting water while maintaining the function of the non-image area while reducing the risk of water transfer from the non-image area to the image area which interferes with print quality (Södergård et al., 1996; Chen et al., 2015; Varepo et al., 2017). However, there is always a risk of tiny water existing in the image area although IPA is optimally used. A small amount of water reaches 6 ppm on the image area of the plate producing a blurry print out which becomes a common problem in offset (Michel et al., 2001). Therefore, removing the trace water level leads to a stronger color of print out which needs the high skill of the operator to produce the best quality. For taking out the trace water from the image area of the plate, it needs a compound to attract water molecules at a minimum trace amount level. Since propylene glycol (PG) dissolves water well, we use it as a water-removing agent to improve quality offset printing. PG is a colorless and odorless solvent commonly found in packaged food products, cosmetics, and pharmaceuticals. The chemical formula of PG is $C_3H_6(OH)_2$ and belongs to the alcohol group. Whereas IPA only has one OH group in its carbon chain. Since PG can attract the trace water on the image area of the plate, the quality of the offset print will be improved. Therefore we investigated using PG to remove trace water on the image area of the plate (Jammalamadaka & Raissi, 2010; Jacob et al., 2018).

Additionally, concerning the use of IPA, there are some drawbacks of IPA used. IPA evaporates completely into the pressroom and may cause health complaints for printers such as headaches, dizziness, and eye irritation. IPA is highly flammable and contributes to the change of ozone formation, which is known as summer smog and, leads to the issues of environmental problems. Therefore, finding an alternative to IPA as a wetting agent is important by considering lowering risks for the health and safety of the environment. The use of PG is proposed in this research to overcome the issue of IPA drawbacks. The use of PG is safer compared to IPA where the boiling and flash points of PG are 187^0 C and 107^0 C, respectively, while the boiling and flash points of IPA are 11.7^0 C and 82.5^0 C, respectively (Davidy, 2019). PG is safe and commonly used in the cosmetic industry (Motoyoshi et al., 1984). PG also has never been used for offset printing before.

2. METHOD

2.1 Materials and Tools

The Propylene glycol (PG) used in this experiment was obtained from The DOW Chemical Company. The text and the picture were printed using made in Japan Oliver Sakura 472 offset printing machine. The print characterization was measured using Spectro-densitometer (Techon Advance, Made in Germany). The pH was determined using Toledo, made in the US, pH meter, and conductivity was measured using Toledo, conductivity-meter, made by the US.

2.2 Characterization Procedure

Design of the drawings and plates are prepared in the laboratory of the pre-press unit as a printing reference. To ensure the quality process, we conducted a printing test for 1000 sheets of paper using the standard of customer satisfaction in our production. The wetting solution is then dumped out to be replaced with a propylene glycol (PG) solution of 0.05%, 0.1%, and 1%. Each concentration of PG was used to print 1000 copies of the prints. However, we then did not consider the PG 1.0% solution since the prints showed the ink printed on both the image and non-image area. Before and after the printing process, the wetting solution was tested for pH value and conductivity. The 10 sheets of best prints visually are taken for measurement after the printing proses with PG concentrations of 0, 0.05%, and 0.1%. The density and dot gain tests using Techon Advance Spectro-densitometer were carried out for the prints. The procedure is presented in the flow chart as seen in Figure 2.

In this study, the data collection is carried out by conditioning the printing machine according to the best result, based on our customer satisfaction. The water inlet and outlet of the machine Oliver Sakurai 472 ED is set to 40% with a print roller pressure of 10.66 pa. The machine's printing speed is theoretically 4000 to 12000 sheets/hour, but we use it at 5000 sheets/hour. The machine standards then become a reference for adjusting the machine settings to get the best print quality for this research. For printing materials, we use HVS 80 g/m^2 paper with a paper thickness of 0.09 mm.

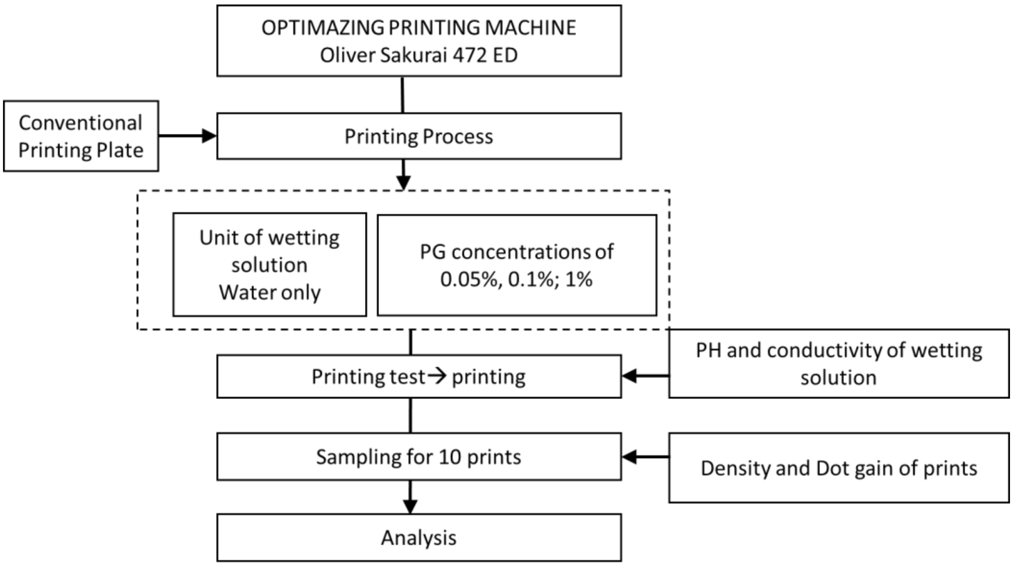


Figure 2. Taking data procedure

Since the printing number is less than 5000 sheets, we prepared a printed design on a conventional printing plate made from a thin layer of Aluminium based. The surface of the plate which is an emulsion will be heated in a non-image area so that it is easily removed using chemical reactions to leave an image area as a printing reference. The plate is processed through a computer to conventional plate (Ct-Cp) technology.

3. RESULTS AND DISCUSSION

In our study, we started the printing process from preparing the printing plate which attached it on the printing cylinder and adding PG in water fountain solution. In the printing process, the plate then wetted by water fountain and came to inking unit (we used ink from DIC Graphic) to transfer ink to blanket and then printed it out on the paper as seen in Figure 1.

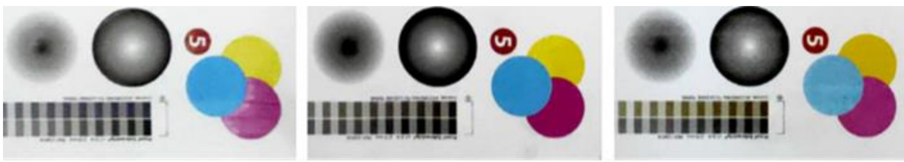
For the print out, we used HVS paper to represent an uncoated surface for printing material. The uncoated paper leads to strong absorption of the ink which causes a limited spreading radius of ink on the surface (Lin et al., 2020). It tends to lowering the sharpness of the image of the uncoated paper compared to coated paper (Nguyen et al., 2021). However, the current use of HVS paper facilitates the dominant printed books in Indonesia which relates to the price. Therefore, the study is directed to optimize and efficiently the use of HVS paper and opening to find the alternative which is becoming the main considering to use of HVS paper in our study.

Based on the study objectives, we compared the prints using water alone as the wetting agent versus the PG solution. The water we use as a wetting agent has a conductivity of 58 μS and a pH of 6.8. The process data on the use of wetting solutions are shown 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 general, the acidity of the wetting solution used in offset printing is 4.5 to 5.5 to maintain optimal performance of the wetting benefits on printing plates (Moreira et al., 2018), which is a function of Arabic gum. However, in this study we did not take into account the pH range, considering that we did not use gum Arabic because we only proved the role of PG on print quality compared to the use of solutions without the addition of adjuvants. Based on table 1, the pH of the wetting solution which consisted of water only was 6.5 after being circulated for 15 minutes. The conductivity of water before circulation shows the number 58 μS but after circulating in the machine and dissolving the particles that are installed in the machine, the conductivity of the solution becomes 248 μS. The increase in conductivity did not increase the pH significantly. The level of wetting solution conductivity is not standardized clearly. It depends on the best practice with based on the machine and human skill by considering the printing cost. In the case of our area in Indonesia, the conductivity level reaching 1000 μS is common in the printing process which remains to show good results. The general clue used by the operator to dump out the wetting solution is when the conductivity value measured is twice the beginning value of the new wetting solution made. The excessive conductivity leads to worsening the printing process which causes scumming, toning, or tinting. Vice versa, the less conductivity the better the printing process since it affects to the environment's health (Lianfang et al., 2016). Since the conductivity in our study is below 500 μS, it means the changed value of conductivity has no effect to the result of our experiment. Refer to the result on table 1, at the addition of PG up to 0.1%, there was an increase in the pH and conductivity parameters which were not too far away, meaning that there was no decrease in the quality of the wetting solution due to the increase in PG concentration up to 0.1%.



PG 0% PG 0.05% v/v PG 0.1% v/v

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

3.1 The Printout Quality based on Visual Characterization

The addition of PG to a wetting solution of 0.05% v/v was able to increase color brightness significantly compared to water only as a wetting solution, as seen in Figure 3. The 0.05% PG concentration results in the best quality image, if compared to PG 0% and 0.1%. It means that at PG 0.00%, there is tiny water on the surface of the image area plate. If the water still exists in the image area, it leads to lowering the concentration of pigment in the ink which causes the blurry printed image.

However, when the concentration of PG in the wetting solution reached 0.1%, the water on the non-image area surface of the plate is also de-attached which makes the non-image area dried. If the non-image area is dry, the ink attached to the image area is moved to the non-image area causing a blurry printed image (Leach, 2012).

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

At each data collection with different PG concentrations, we carried out conditioned the printing process by running the machine for 15 minutes to ensure the circulation of the wetting solution was normal. We took the best prints visually and then measured the print density as seen in table 2. The print density number expresses the absorbed light which is then converted to indicate the surface covered by ink. Based on table 2, the addition of PG to the wetting solution was able to increase the print density on all ink colors of the paper's surface. The yellow color (Y) had the highest density increase, followed by black (K) with the lowest in cyan (C).

Table 2. 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

There was a volume increase of ink on the surface of the plate that was wetted with PG solution compared to wetting without PG, which means the ability of the ink to stick to the image area of the plate also increased, which was supported by the dot gain data as seen in Table 3. The dot gains were observed at 80% and 40% rasters. The number of 80% represented the observations at the shadow level where the images and the background could be distinguished. The number of 40% showed lighter middle tones. In other words, the observations of raster change were carried out on bright tones which were confirmed by tone observations on the darker ones. Due to the addition of PG into the wetting solution, the highest change in the area (dot gain) occurred in yellow (Y) and followed by black (K). The dot gain of magenta (M) change tend to increase even though it was not very significant. In Cyan (C), there tends to insignificant decrease in the raster area. Overall, the data density and dot gain confirmed the effect of adding PG to the wetting solution and affected the quality of the yellow (Y) and black (K) colors. Therefore, adding PG into the wetting solution leads to a better quality of the printed image by increasing the gain of the raster. In this case, we use the printing machine standard where the 40% and 80% raster must be 56% and 91% at the printed raster image. This standard was taken based on ISO 12647 desk 2 using Oliver Sakurai 472 ED Printing offset 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

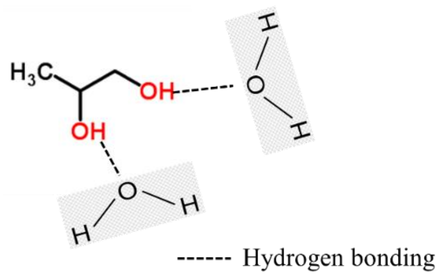


Figure 4. Interaction of PG and water molecules.

3.3 Mechanism of PG's Effect

The chemical formula of PG is C3H6(OH)2 with two –OH groups capable of binding water molecules through hydrogen bonds which causes PG to dissolve well into water and vice versa as shown in Figure 4. When the wetting of the plate occurs, the image area is hydrophobic and the water molecules can not stick to it. However, during the inking process, the area of the image will completely bind the ink. In practice, there is still a small amount of water on the surface of the image area which affects the quality of the ink. The function of PG is to prevent the occurrence of trace water on the surface of the image area and dissolve it when there is contact between the wetting roller and the surface of the plate.

During the process of the surface wetting with a 0% PG solution, when water touches the image area on the surface of the printing plate, few water molecules remain in that area according to the nature of water which can interact weakly with almost all materials including metals (Nugraha et al., 2020). The nature of a water molecule has two lone pairs electrons and can donate these electron pairs to other atoms that have vacant orbitals or which have a positive dipole charge. With the presence of 0.05% PG in the solution, the weak binding between trace water molecules and the image area of the plate can be overcome by PG through hydrogen bonding between PG and water molecules. By suppressing the number of molecular traces on the hydrophobic/oleophilic image area of the printing plate surface, increasing the volume of ink that forms in the image area. However, when the PG concentration increases to 0.1%, the water that should be attached to the non-image area of the plate surface is also attracted by PG and then dissolves again as a wetting solution. With this condition when the ink roller touches the surface of the plate, the ink not only sticks to the image area but also affects the non-image area which visually results in ink printed on the non-image area.

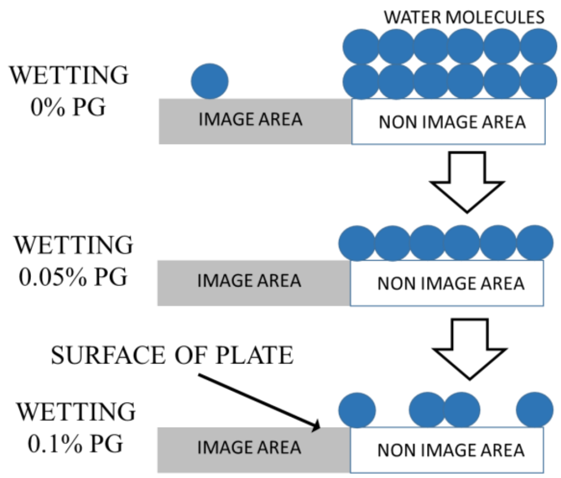


Figure 5. Schematic of the mechanism of PG performance as an auxiliary material for wetting solutions in the offset printing process

The reaction scheme that occurs is seen in Figure 5. The most optimal PG content for wetting agent solution is 0.05%. The 0.1% PG content indicates that the water-PG interaction is stronger than the interaction of water and the non-image area on the printing plate which causes the ink to participate in the non-image surface area. Although the wetting solution with 0.05% PG shows the best quality, the process durability in this condition still needs to be improved considering the very thin water layer on the surface of the non-image area which causes water to evaporate easily and leaves the non-image area to be occupied by ink when the plate is platen by ink roller. In the normal printing process, a thin film of water on the surface of the image area was carried out by gum Arabic which was not intentionally excavated in this study. However, we are currently working to explore the role of gum Arabic which is used concurrently with PG as an adjunct in offset printing wetting solutions.

4. CONCLUSION

Based on the visual, density, and dot gain data, it is proven that the addition of PG to the wetting solution of the offset printing technique has a significant effect on the yellow and black colors but has no significant effect on the cyan and magenta inks. The optimal content of PG is 0.05% v/v for a wetting solution which can increase the visual brightness and density of printed ink compared to the print quality which uses water only for wetting solutions. Mechanistically, PG prevents the occurrence of trace water molecules in the image area of the printing plate which leads to better quality, since the existence of water trace decrease the amount of ink in the image area. Therefore, adding the PG 0.05% into the wetting solution leads to a better quality printout using an offset printing machine.

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