Effect of ink and paperboard characteristics on flexographic print quality based on print density

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ABSTRACT: Flexography is an evolving printing technology that is suitable for printing on coated and uncoated paperboard and board, nonporous substrates including metalized and paperboard foils, and plastic films used especially in the packaging industry. This study evaluated the effect of paperboard and ink characteristics on flexographic print density in paperboard. Three commercial paperboards from different companies were prepared: brown kraft from Thailand, white kraft from Spain, and test liner from Iran. Four samples of process print inks from Iran were used in this investigation. Paperboard properties, such as roughness and water absorption, and ink characteristics, including solids content, PH and particle diameter, were measured. The inks were printed on paperboards using a roll no.15 applicator with a blade metering device, and the print densities were measured. Results showed that solids content, pH, and particle diameter of printing inks influenced print density, while the roughness and water absorption of the three types of paperboard had no significant influence on print density. Results also illustrated that two levels of ink viscosity (25–30 and 50–55 mPa·s) were insignificant to print density.

Application: Packaging board mills can optimize flexographic print quality and print density, which are important factors in terms of quality of images printed on various substrates.

Flexographic printing, with its use of environmentally friendly water-based inks, is increasing in importance, especially for point of sale packaging that requires the creation of marketing appeal for cartons and boxes. Water-based flexography is the dominant process for the printing of corrugated board and other packaging materials [1, 2]. It is an efficient and cost-effective printing method that continues to grow and improve the quality of the printed work produced. Typical products using flexography include brown corrugated boxes and flexible packaging, including retail and shopping bags, food and hygiene bags and sacks, flexible plastics, self-adhesive labels, and wallpaper.

The development of flexography over the years has been described by Moir [3]. Flexography is a rotary printing method that applies fast-drying, fluid inks from a simple inking system and prints from resilient plates of rubber or photopolymer that have the image in relief. Flexographic printing has a number of advantages:

- Reductions in cost
- Use of low-cost material (i.e., inks and substrates)
- Printing from reels
- Simpler printing process
- Environmentally friendly printing process
- Expected improvements in print quality

Today's flexographic presses produce excellent quality impressions on many different substrates. Flexography is an economical and simple printing process for decorating and packaging materials. Fast-drying, water-based inks are generally used, which allow for fast-running machine speeds. On a modern flexographic press, it is possible to come up to color in minutes, whereas on an offset press it could take hours. This reduction in waste has a significant effect in lowering overall costs. The flexography process is more versatile and simpler than lithography and, for short- to medium-run printing jobs, is more economical than gravure. In addition, the flexible printing plates are able to contact the rough surfaces of corrugated board under relatively low pressure, which is important for minimizing the strength loss of the boards. On the other hand, simplicity and flexibility have also limited the quality of flexographic printing. Often, the deformation of printing plates causes image distortion, and poor ink control has led to poor consistency of ink color. However, flexographic technology has been improved remarkably during the past decade [1,2,4], although the cost has increased due to the steps to achieve higher quality.

Print quality is an important factor in the sale of end products. Print quality is defined as the degree to which the appearance characteristics of the print fulfill those of the desired target and is the result of several interacting properties and factors [5,6]. As with images printed on paperboard, the judgment of quality of images printed on corrugated board is largely a subjective matter [7]. Although there are no commonly accepted criteria for evaluating the print quality, different observers who judge the quality of a print may each emphasize the influence of different factors, depending on individual experience and expectations [7, 8].

Many researchers have studied the effect of different factors on print quality. Zang and Aspler [9] found that the print

quality of corrugated board is mainly affected by print density, print uniformity, print gloss and image fidelity. Bulow et al. [10] found that the size of pigment particles and calendering affect print quality. Cook [11] investigated the effects of ink viscosity of water-based inks on print quality in flexographic printing and found that reduction of the ink viscosity reduced print quality.

Print density is an important factor for the quality of images printed on all substrates, including printed linerboards [12–17]. Print density is defined as the difference in optical density between a printed image and the unprinted substrate; it is a measure of this absolute contrast. A higher density value indicates a darker surface has absorbed more light. Print density can be used as an indication of the quality of ink on the substrate and the print quality.

The aim of our study was to investigate the effect of ink and paperboard characteristics on print quality by measurement of print density.

EXPERIMENTAL

Materials

Three types of packaging paperboard with basis weights varying from 116 g/m² to 132 g/m² in the machine direction (MD) were prepared: (A) brown kraft from Panjapol, Thailand; (B) white kraft from Saica, Spain; and (C) brown test liner from Chuka, Iran. Four samples of water-based process ink from SunColor Inks (Tehran, Iran) were used: blue (cyan), red (magenta), black, and yellow, with codes AC-03510, AC-03310, AC-03810, and AC-03110, respectively. Ink viscosities were adjusted by adding water to two levels (i.e., 25–30 and 50–55 mPa·s). These viscosity levels are those applied at most paperboard mills.

Test methods: Paperboard properties

Roughness

Roughness or smoothness measurements aim to describe the topography of the paperboard surface simply. The principle generally applied for this purpose measures the ability of the paperboard surface to resist an air stream flowing between the paperboard surface and a surface or an edge (measuring head) pressed against it. The test instrument used was a Parker Print Surf (PPS) from Lorentzen & Wetter (Kista, Sweden) applying the TAPPI T 555 om-10 "Roughness of paper and paperboard (Parker-surf method)." Roughness values were expressed in microns (μ).

Water absorption

In the measurement of the absorption properties of the paperboard, colored water or oil is applied to the paperboard surface. During the movement, the liquid fills the surface cavities of the paperboard and simultaneously moves partly into the paperboard structure by absorption. On the other hand, the Cobb test measures the amount of water absorbed by a known area of the sample during a certain time from an excess of water in g/m². This test is primarily used as an indicator of the degree of sizing, i.e., the water repellency of the paperboard. The Cobb test was applied for water absorption according to TAPPI T 441 om-09 "Water absorptiveness of sized (non-bibulous) paper, paperboard, and corrugated fiberboard (Cobb test)" and expressed in g/m².

Test methods: Ink properties

Solids content

The rheological behavior of slurries is a function of its solids content. The SCAN-P 39:80 was used to measure solids content. In this method, some was transferred to aluminum foil and then oven-dried at 110°C. The solids content was calculated according to difference of liquid ink with ovendry ink. Solids content values were expressed in percentage.

Particle diameter

The Simex Grindometer (Simex; Haan, Germany) is a particle diameter test instrument. This test determines the diameter of ink particles in microns.

Paperboard Type	Process Ink Color	pH value	Particle Diameter (μ)	Solids Content (%)	Roughness (μ)	Water Absorption (g/m²)	Print Density
A	Blue	8.4	5	62.1	8.9	20	2.48
	Red	8.4	1	65.6			2.10
	Black	8.3	2	71.2			2.50
	Yellow	8.8	4	77.5			2.09
B	Blue	8.4	5	62.1	6.3	22	2.43
	Red	8.4	1	65.6			2.11
	Black	8.3	2	71.2			2.53
	Yellow	8.8	4	77.5			2.09
C	Blue	8.4	5	62.1	11.3	32	2.43
	Red	8.4	1	65.6			2.07
	Black	8.3	2	71.2			2.45
	Yellow	8.8	4	77.5			2.09

I. Ink and paperboard properties and print density (ink viscosity 25–30 mPa·s)

Paperboard Type	Process Ink Color	pH value	Particle Diameter (μ)	Solids Content (%)	Roughness (μ)	Water Absorption (g/m²)	Print Density
A	Blue Red Black Yellow	8.3 8.2 8.3 8.8	5 2 5 9	59.8 49.1 70.7 75.1	8.9	20	2.47 2.09 2.52 2.11
B	Blue Red Black Yellow	8.3 8.2 8.3 8.8	5 2 5 9	59.8 49.1 70.7 75.1	6.3	22	2.48 2.09 2.53 2.07
C	Blue Red Black Yellow	8.3 8.2 8.3 8.8	5 2 5 9	59.8 49.1 70.7 75.1	11.3	32	2.47 2.07 2.49 2.06

II. Ink and paperboard properties and print density (ink viscosity 50–55 mPa·s).

pH level

The pH was measured using the Testo 230 analysis instrument (Testo; Lenzkirch, Germany). The ISO 787-9 method ("General methods of test for pigments and extenders—Part 9: Determination of pH value of an aqueous suspension") was applied.

The flexographic print trial

First, we measured paperboard properties (roughness and water absorption) and ink characteristics (solids content, pH, and particle diameter). Then, inks were transferred on prepared paperboards using a pilot scale coater fitted with a roll no.15 applicator blade metering device. Finally, print densities on the paperboard coated with process inks were measured with the Techkon Spectro-Densitometer SD 620 (Techkon; Königstein, Germay) and expressed in g/m².

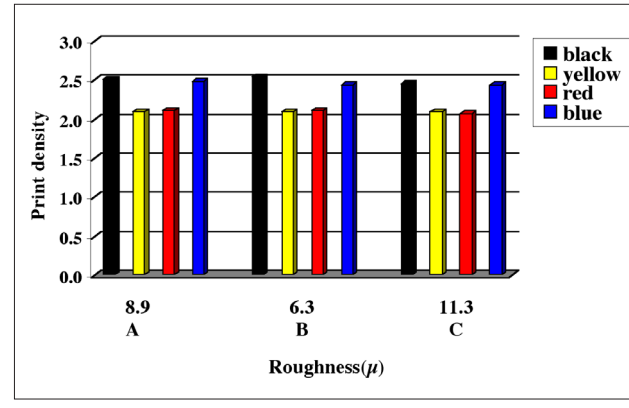
All experiments were replicated 5–10 times. Statistical analysis was done, based on a completely randomized design, to determine the effects of paperboard and ink properties on print quality. Means were analyzed and grouped using the Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

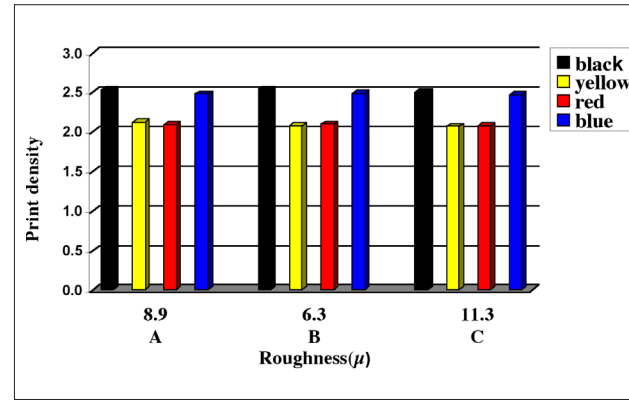
Tables I and **II** show the average results of paperboard (roughness and water absorption) and ink (solids content, pH, particle diameter) characteristics and print density.

Effect of paperboard roughness on print density

Figures 1 and **2** show the effects of paperboard PPS roughness on print density. Statistical results show that paperboard PPS roughness has no statistically significant influence on print density, although data in Tables I and II show that the roughness difference between the paperboards was statistically meaningful. Also, the change in ink viscosity had no significant effect on print density, as observed in a previous study [18].



1. The effect of paperboard roughness on print density (ink viscosity 25–30 mPa·s).



2. The effect of paperboard roughness on print density (ink viscosity 50–55 mPa·s).

It is well known that surface roughness, or smoothness, is an important property for printing paperboard and it affects ink transfer and print evenness. It takes a smooth surface to receive a uniform film of ink from the printing plate [19,20]. Studies by others have shown that flexographic image fidelity can be significantly affected by water absorption and surface roughness. In some cases, the high smoothness is unsuitable

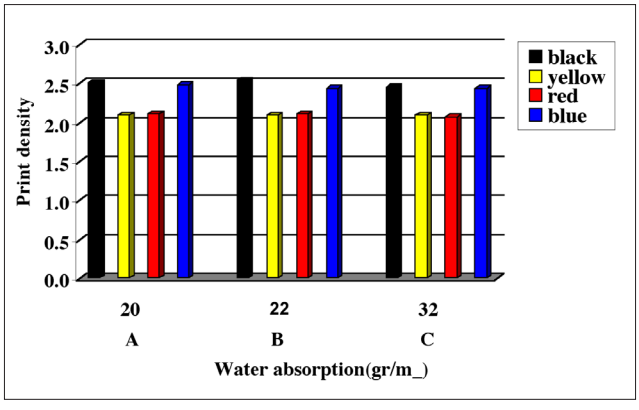
because it is accompanied by slipperiness [21]. Usually, printability is used as the ultimate criterion for determining the surface roughness of paperboard products. However, surface roughness ranges for high-quality flexographic prints on combined boards have not been established [9].

Jensen [16] found that, under constant printing conditions, the optical density of a solid print decreased with increasing PPS roughness numbers, measured at a pressure of 10 Kg/m^2. Similarly, for uncoated boards, Ginman and Tiainen [12] found that the PPS 10 roughness was a fairly good predictor for the unevenness of printed halftone areas.

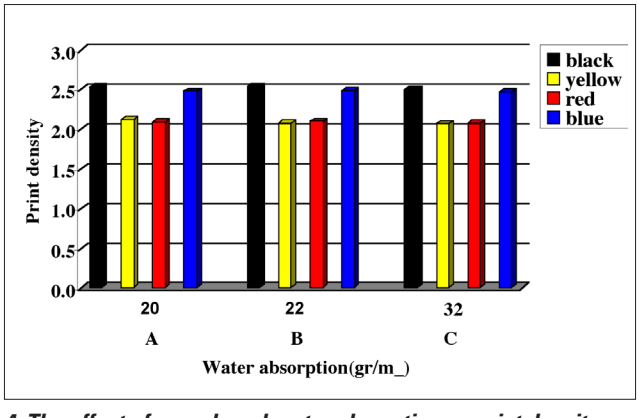
The highest print density at two viscosities occurred with black and blue inks (Figs. 1 and 2), because they produced the highest light absorption and solid prints in printed surfaces and, therefore, produced the best print quality.

Effect of paperboard water absorption on print density

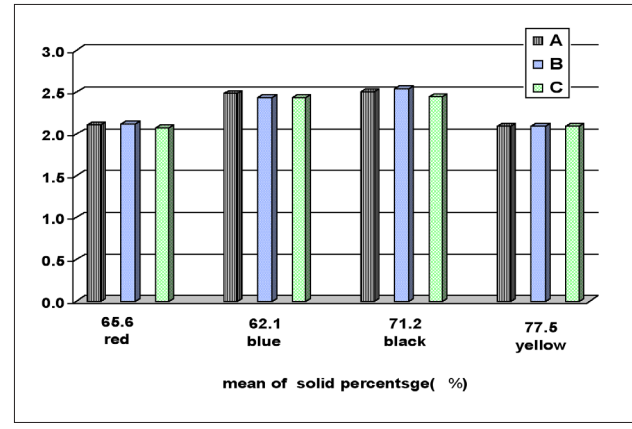
Figures 3 and **4** show the effect of paperboard water absorption on print density. The results for water absorption were proportional to paperboard smoothness (inverse to PPS roughness). Statistical results showed that paperboard water absorption had no statistically significant effect on print density, due to nonuniform ink distribution on the paperboard



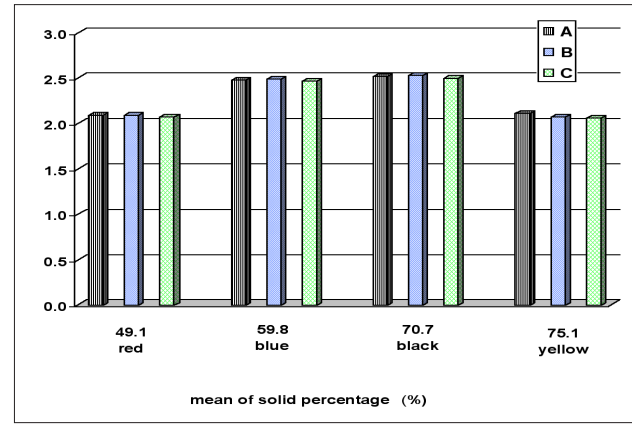
3. The effect of paperboard water absorption on print density (ink viscosity 25–30 mPa·s).



4. The effect of paperboard water absorption on print density (ink viscosity 50–55 mPa·s).



5. The effect of ink solids content on print density (ink viscosity 25–30 mPa·s).



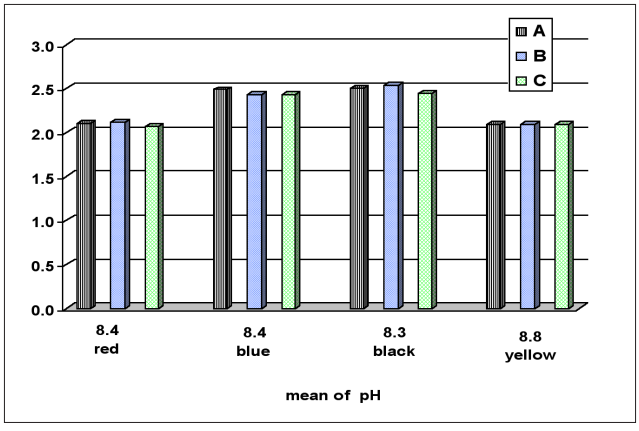
6. The effect of ink solids content on print density (ink viscosity 50–55 mPa·s).

surface resulting from differences in ink pigment particles. Zang and Aspler [9] found that the paperboard water absorption influence on the quality of prints with combined boards has not been consistent. Steadman and coworkers [22] also found that the Cobb test provides little or no useful information about flexographic printability, although it offers a good indication of the degree of sizing.

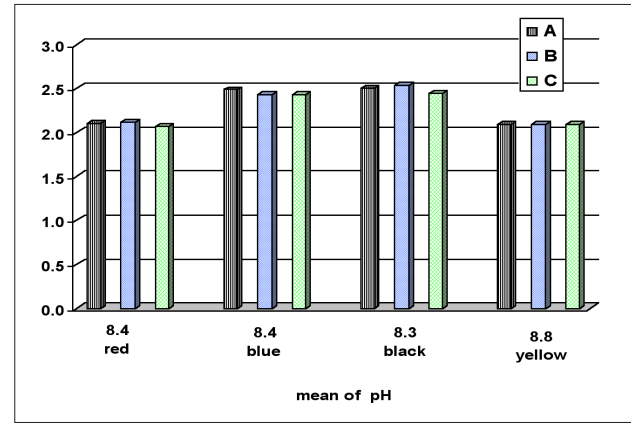
Effect of ink solids content on print density

The solids content of pigments is especially of interest because pigments are one of the largest components in ink. If the solids content is too high or too low, its effects will be seen immediately in the transferred amount (i.e., ink weight) and in press runnability. The solids content values of inks with different amounts and viscosities (i.e., 25–30 and 50–55 mPa·s) are shown in **Figs. 5** and **6**. Results indicated that the solids content of the inks affected print density. Also, the results in Tables I and II show that the difference between process ink solids content was statistically meaningful. Again, the highest print density at two viscosities occurred with black and blue inks.

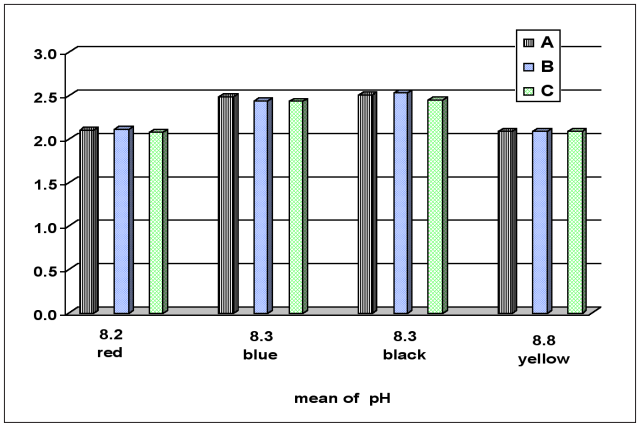
High solids content has been found to give a faster suspension immobilization [23]. High solids content and fast immo-



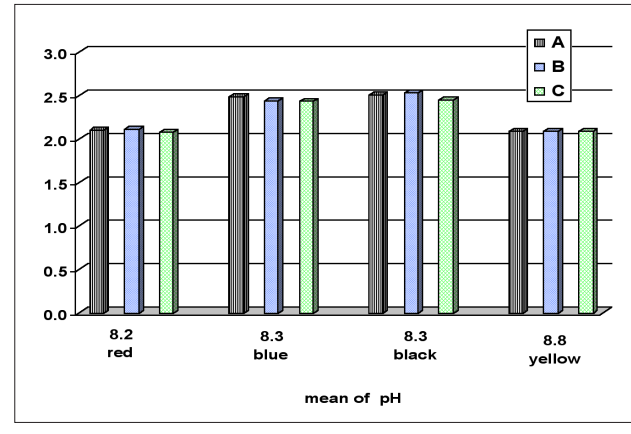
7. The effect of ink pH value on print density (ink viscosity 25–30 mPa·s).



9. The effect of ink particle diameter on print density (ink viscosity 25–30 mPa·s).



8. The effect of ink pH value on print density (ink viscosity 50–55 mPa·s).



10. The effect of ink particle diameter on print density (ink viscosity 50–55 mPa·s).

bilization reduce the possibility of the paperboard substrate absorbing liquid and expanding underneath the applied coating layer. Hagemeyer [24] showed that high dry solids content improved surface coverage and smoothness.

Effect of ink pH value on print density

Figures 7 and **8** show the effects of pH value on print density. The pH value had a statistically significant effect on print density. The results in Tables I and II show that the difference between process inks' pH values was statistically meaningful. The print density at low pH values was high, and the optimum pH value was 8.3. Käpynen and Virtanen [25] suggested that the normal pH range is 8–8.5 but higher levels are needed when using some synthetic thickeners or pH-dependent latexes. Therefore, it is essential to control pH of inks within narrow limits.

Effect of ink particle diameter on print density

The effect of ink particle diameter on print density is shown in **Figs. 9** and **10**. The particle diameter had a statistically significant influence on print density. The results in Tables I and II show that the difference between process ink particle diameters was statistically meaningful. The particle diameter of 5 µ, irrespective of viscosity, could be an acceptable size for a good print. Bulow et al. [10] investigated the penetration depth and lateral distribution of pigment related to the pigment grain size and the calendering of paperboard. They found that the pigment grain size and calendering affected print quality.

CONCLUSIONS

The effect of process ink and paperboard properties on print quality in two ink viscosity levels was investigated. Print density is one of the important factors used to quantify print quality. Our study showed that by controlling components of the printability matrix, such as the solids content, pH value, and particle diameter of the ink, it is possible to affect the quality of printed images. In contrast, the surface roughness (PPS) and water absorption of the substrate had no statistically significant influence on print density. Results showed that, under various conditions, the best print quality was achieved by black and blue colors. These conditions are as follows:

Viscosity 25-30 mPa·s

Black: pH value 8.3, solids 71.2%, particle diameter 2 µ
Blue: pH value 8.4, solids 62.1%, particle diameter 5 µ

Viscosity 50-55 mPa·s

Black: pH value 8.3, solids 70.7%, particle diameter 5 µ
Blue: pH value 8.3, solids 59.8%, particle diameter 5 µ

In addition, the two paperboards—brown kraft (A) and white kraft (B)—received the most of the coating by black and blue colors as follows:

Brown kraft: PPS roughness 8.9 µ,
water absorption 20 g/m²
White kraft: PPS roughness 6.3 µ,
water absorption 22 g/m²

Further research will be carried out to complete the results and quantify other parameters that influence flexographic print density. **TJ**

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ABOUT THE AUTHORS

Flexographic printing for packaging material is increasing, and it is the most common method for printing on corrugated board. In addition, print quality is an important factor in the quality of image printed. We chose this topic to research because we were interested in how paperboard and ink behave during printing. Although there is much literature on flexographic printing, our study was done with different conditions (paperboard and process inks). However, the results we obtained support previous work.

The most difficult aspect of our research was the lack of a flexography facility for printing samples. So, inks were transferred on prepared paperboards using a pilot scale coater fitted with a roll no.15 applicator blade metering device. The results showed that the paper properties (i.e., roughness and water absorption) had no statistically significant difference on print density. This finding was interesting to us.

The results of our study may prove beneficial to paperboard mills by helping them to improve print quality. Our results may help to optimize conditions, which can lead to cost and time reductions in paperboard mills. The next step in research is to study the effects of ink and paperboard characteristics on other printing processes.



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