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# TO ANALYSE THE FACTORS AFFECTING INK MIGRATION IN THE OFFSET LITHOGRAPHIC PRINTING PROCESS

*Madhura Mahajan, Dr. A. Arulmozhi*
*School of Engineering, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore 641108 Tamil Nadu, India*

**Abstract:** *Packaging for food is available in different forms based on product and technical requirements in the supply chain and the branding required for the product and package. Paper and board are versatile materials used to package foods. Manufacturers in the food packaging segment focus on the highest levels of manufacturing controls to protect the user and consumer. Migration from paper occurred very fast compared to migration from plastics. Printers must focus on the printing quality of that package. The offset press room manages colourful images with aesthetic outputs by ink flow. The offset process will do printing on paperboards with four process colours. Ink transferred on paperboard at the time of printing with an offset machine may affect the migration of foodstuff; therefore, using the experiment design, it is possible to evaluate migration due to paperboard and press parameters. Overall, ink migration on food simulant was measured. The simulants were selected as per regulations of U.S. FDA 176.170. The ink migration equation was used to calculate migration in mg/in$^2$. Also, an optical microscope measured the ink penetration of each process colour to know its relation with ink migration. Thus, an analysis of the migration of contaminants into food simulants was carried out to evaluate the suitability of paperboards and inks.*

**Key words:** food packaging, ink migration, Total Area Coverage (TAC), Paper board, simulant

## 1. INTRODUCTION

Paperboard is cheap and readily available, which is why food packaging has been using it for hundreds of years. To improve its functionality, certain additives are added during processing; however, if these additives are used more than safe limits, they may be harmful to human health and result in conditions like cancer or organ inflammation. Migrants are substances that can enter packaged food via a printed layer and contaminate it because of their molecular size and chemical makeup. During the printing of paper or paperboard, ink solvent migration may take place, which could contaminate food items through direct or indirect contact. There are multiple ways in which this can happen: penetration, set-off, vapor phase, and condensation. Food safety must be guaranteed by addressing essential aspects of the printing process to remedy this problem. The issue arises when raw materials used in packaging, such as paperboard and ink, are manufactured. As a result, it needs to be taken care of during raw material production and packaging manufacturing. Safeguarding end users' safety is of primary importance in this matter. The main goal of Richter, Gude and Simat's (2009) study was to calculate the amount of ink contamination that migrated into the food that was packaged using offset ink. The low-migrating patented ink was utilized. Typically, mineral and vegetable oils make offset inks; however, the new fatty acid ester (FAE) eliminates these ingredients. The migration test was conducted on food goods that came in packaging, including meat, chocolate, and sweets. These foods had contamination levels ranging from 5 to 80 µg fatty acid ester/kg. The work was reviewed after ITX levels as high as 250 ug/l were discovered in baby formula and with an emphasis on the set-off phenomenon-the migration of materials from the printed outside layer of packaging to the inner layers - Clemente et al. (2016) investigated the ink and varnish migration from packaging materials. Two different kinds of studies were designed and carried out to investigate this. Set-off effects can cause printing inks to migrate even though they are applied to the packaging's outer layer. In migration testing, 149 volatile chemicals in total were found. Usually composed of many polymeric layers or paper linked with adhesives, food packaging materials have outside coatings like varnish or inks. The study aimed to discover volatile substances that migrate because of set-off occurrences and investigate mitigation or prevention techniques. SHI et al. (2015) conducted several experiments to determine the pace at which photoinitiators transfer within paperboards. The investigation used six distinct photoinitiators and two types of paper and board. The partition coefficients (K_paper/air) between paper and air for each of the six photoinitiators were found for kraft paper and white carton board. The lowest and highest K values were found for 2-ethylhexyl-4-dimethylaminobenzoate (EHDAB) and

4-methylbenzophenone (MBP). Yang et al. (2012) emphasized the significance of using gas chromatography along with mass spectrometry (GC-MS) to identify pollutants in food packaging materials. Because GC-MS may identify pollutants by ionization, it is necessary to identify dangerous chemicals found in food packaging, as the study demonstrated. For food packaging materials, this technique is essential for quality monitoring. Plasticizers, solvents, and antioxidants with low molecular weight are added during the manufacturing and processing of paper-plastic food packaging materials. Food packaging uses more recycled paperboard. However, as Triantafyllou, Akrida-Demertzi and Demertzis (2006) pointed out, there are drawbacks. The study compared two paper samples with varying thicknesses, grammage, and percentages of recycled pulp. Depending on where they came from, recovered paper and board may include printing inks, adhesives, waxes, fluorescent whitening agents, dyes, sizing agents, organochlorine compounds, plasticizers, volatile organic compounds, aromatic hydrocarbons, curing agents, grease-proofing agents, amines, biocides, and surfactants. Ten model substances were chosen to symbolize various molecular weights, polarities, volatilities, and functions in paper production. Extraction techniques and GC-FID quantification were used in the analysis. Temperature, the properties of the paper sample (grammage, thickness, and pulp content), and the surrogate characteristics (molecular size, chemical structure, and volatility) all affected the migration kinetics. Meal's fat content, the chemical makeup of the migrants, their volatility, and the type of paper samples all significantly impacted the percentage of chemicals that migrated into meals. The substrates with the highest fat content showed the highest organic pollutant migration. It was discovered that Tenax worked well as a food simulant for dry goods with low to moderate fat content. Jung, Simat and Altkofer (2010) examined the literature showing that food can come into contact with packaging-related ink. Specifically, he emphasized that UV printing inks can enter packed foods through the set-off effect in multilayered materials such as beverage cartons. Due to its detectability, the study used the well-known migratory ITX model. Paperboard was tested to be waterproof and resistant to moisture migration by Wu et al. (2013). Diffusion of water vapor in empty spaces and condensed form via fibre cell walls are the two ways that moisture migrates. They found that corrugated paperboard's compressive strength drops by 25% as ambient humidity rises from 60% to 80%. By using sizing agents to change the paperboard surface's wettability or applying a hydrophobic coating, a waterproof or moisture-proof barrier can be produced. Tenax and food were used by Aurela, Ohra-Aho and Soderhjelm (2001) to investigate the migration of alkylbenzenes from packaging. Ten of the fifteen samples, comprising three different types of board, had alkylbenzenes in them. Migration tests at 70°C for 30 minutes revealed the migration of alkylbenzenes, a solvent used in offset printing inks, from printed hamburger collars into rolls. It was proposed that alkylbenzene migration at 40°C over 10 days might be worth investigating. A different test that used Tenax as a simulant examined the impact of a varnish coating on the food contact surface by subjecting samples to single-side contact with Tenax. A 70% reduction in migration was seen when the varnish layer was applied. Compared to experiments using rolls as a food simulant, testing using Tenax produced increased migration. The mechanisms of alkylbenzene transfer were unclear. The relationship between ink penetration and binder migration in paper coatings was examined by Li and Gu (2015). According to the study, the behavior of ink penetration is determined by the coating's surface structure as well as the characteristics of the binders and pigments. By using scanning electron microscopy (SEM) and fluorescent inks, the study demonstrated that higher drying temperatures caused a greater amount of binder migration toward the paper surface. The binder surface coverage was found to be lowest at 100°C and highest at 220°C when drying temperatures were measured using Atomic Force Microscopy (AFM). Higher temperatures led to less ink penetrating the paper layer, according to an inverse relationship between drying temperature and ink penetration depth. Our study aimed to study the impact of using a low migration facility on the migration of the components using various methods, such as penetration with Total Area Coverage.

## 2. METHODS

The experiments used different paperboards, inks, and press room chemicals. Table 1 lists the types of paperboards used in the press trials and their properties. Table 2 lists the process colour inks of a specific category for a low migration printing facility from Huber Group. Table 3 lists the various low-migration press room chemicals used before, during printing, and after the press trials, such as fountain solutions, cleaning solvents, etc.

*Table 1: Specifications of paperboards used for press trials*

| Paperboard | GSM | Coating Thickness | Coating | Porosity | Cobb in GSM |
|---|---|---|---|---|---|
| SCD | 280 | 10 gsm | 30% clay + 70% $CaCO_3$ | 60 ml/min | 35 |
| CYD | 285 | 20 gsm | 15% clay + 85% $CaCO_3$ | 10 ml/min | 35 |
| MGTH | 180 | - | - | 200 ml/min | 25-30 |

*Table 2: Specifications of inks used for press trials*

| Material Group | Material Description |
|---|---|
| MGA Process Colours | MGA NATURA YELLOW |
| MGA Process Colours | MGA NATURA MAGENTA |
| MGA Process Colours | MGA NATURA CYAN |
| MGA Process Colours | MGA NATURA BLACK |

*Table 3: Pressroom chemicals used during printing*

| Material Group | Material Description | Material Code |
|---|---|---|
| Additives 2 | MGA LIQUID DEGLAZER | HGI-20342/1F7 |
| NGA Roller Wash | MGA WASH | HGI-20096 |
| Fountain System Cleaner | MGA SYSTEM CLEANER | HGI-20340/1F7 |
| MGA Fountain Solution | MGA COMBIFIX | MGA-806009/10A1 |
| MGA Fountain Solution | MICRONOL MGA | HGI-20097/10A1 |
| Washes/Cleaners | MGA PLATE CLEANER | HGI-20341/1F7 |
| Spray Powder | MGA Anti Setoff Powder | HPC-0591 |
| MGA Acrylac | ACRYLAC MGA GLOSS S | GA 1200/25D2 |

We designed a test chart for printing on three different paperboards. It contains standard test chart images, a control strip, halftone patches, solid Cyan, Magenta, Yellow and Black patches, and a Total Area Coverage (TAC) chart. The test chart also contains a patch of varying Process colours (C 75%, M 68%, Y 67%, K 90%) used for migration testing. The test chart is seen in Figure 1. The test chart was printed using a Lithrone SIX29 offset press, details mentioned in Table 4.

*Table 4: Lithrone Komori 629*

| LITHRONE SIX29 (29-inch offset printing press) specification | | |
|---|---|---|
| MODEL | | LSX-629 |
| Number of colours | | 6 |
| Max. printing speed | sheets per hour | 16000 |
| Max. sheet size | mm | 610 X 750 |
| Min. Sheet size | mm | 297 X 420 |

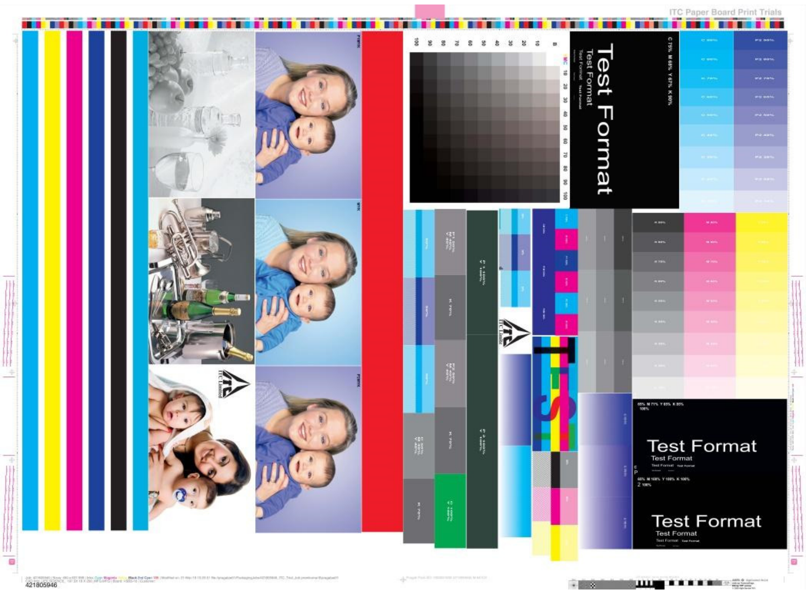


*Figure 1: Test chart comprising of various elements*

Printing was done on a six-colour offset machine, as given in Table 3, at a speed of 9600 sheets/hour. All food safety precautions were taken into consideration, and the machine was cleaned according to safety requirements. The same low migration process inks were used for each of the three paperboards. The ink densities on the press were varied so that three total area coverage values were achieved. The print sequence was black, cyan, magenta, and yellow.
Low migration products covered under the brand MGA (By Huber) were used along with offset MGA inks. While using MGA products to manufacture food-safe packaging, the pressroom followed guidelines to print without contaminating unwanted chemicals.
The SOP was followed in our presence during the run of our MGA system.

1. All the inking rollers were cleaned thoroughly by applying MGA LIQUID DEGLAZER HGI-20342 and running for 15 minutes.
2. Rollers were then cleaned with MGA WASH HG-20096
3. MGA process inks MGA 5250 (and MGA spot colours, if applicable) were applied to the rollers of respective units and run for 15 minutes.
4. The rollers were cleaned with MGA WASH HG-20096
5. Repeat steps 3&4
6. The ink ducts were filled with MGA inks, and the rollers were cleaned with MGA WASH HG-20096 after all colours were registered before commencing the production run.
7. The impression cylinders were cleaned with MGA WASH HG-20096
8. The dampening solution tank was drained completely, and the freshwater was run for 15 minutes. After draining it out, fresh water with MICRONOL MGA HG-20097 was run for 15 minutes. After draining it out, fresh water was run for 15 minutes. The dampening form rollers were cleaned with MICRONOL MGA HG-20097
9. The new dampening solution was prepared in a tank by adding 4% of MGA COMBIFIX HGI-806009 fount concentrate and 8% of MICRONOL MGA HG-20097 with fresh water.
10. The aqueous coating unit was cleaned with water and MICRONOL MGA HG-20097. The warm water was then circulated for 30 minutes. ACRYLAC MGA HIGH GLOSS 58 MGA 1200 aqueous coating was pumped directly from the can.
11. The plates, after mounting on the cylinders, were cleaned with MGA PLATE CLEANER HGI-20341

Measurement of Ink Penetration: Ink penetration of paperboards in the Z-direction was measured on a 4x optical microscope. IDS photo-capturing software was used to get pixel data. With the help of ImageJ software, Pixel data were converted into micrometres to know the penetration depth (Real Distance: Scaled pixels = 100 µm: 116). Ink penetration was measured for solid patches of process colour, as mentioned in the test chart in Figure 1. An image of the solid patches is given in Figure 2.


*Figure 2: Total Area Coverage patches*

Ink Migration: Ink migration test for the patch of varying % of Process colours (C 75%, M 68%, Y 67%, K 90%) was measured by Sec. 176.170 components of paper and paperboard in contact with aqueous and fatty foods. Overall migration testing was done for the samples. Ink migration was measured for the total area coverage (TAC) patches mentioned in the test chart in Figure 1. The patches are given in Figure 3.

*Figure 3: Solid Patches of Cyan, Yellow, Magenta and Black*

Migration testing procedure and Simulants used:

1. Distilled water,
2. n-heptane,
3. 50% ethanol,
4. Vegetable oil,
5. 3% acetic acid.

The selection of extractability conditions was done as per the 176.170 section. First, the type of food product being packed commercially in the paper or paperboard and the standard conditions of thermal treatment used in packaging the kind of food involved were ascertained. As per the 176.170 section, the food-simulating solvent or solvents and the time-temperature exaggerations of the paper or paperboard use conditions were selected. The applicable extraction procedure was followed, and the appropriate food-simulating solvent or solvents were chosen, as well as the time-temperature exaggeration over normal use. The following Reagents were used:

1. Water: All water used in extraction procedures should be freshly demineralized (deionized) distilled water.
2. n-Heptane: Reagent grade, freshly redistilled before use, using only material boiling at 208 deg. F.
3. Alcohol: 8 or 50 percent (by volume) was prepared from undenatured 95 percent ethyl alcohol diluted with demineralized (deionized) distilled water.
4. Chloroform: Reagent grade, freshly redistilled before use, or a grade having an established consistently low blank.

After selecting the Reagents, the test method was selected: Paper or paperboard ready for use in packaging was tested using the extraction cell described in the "Official Methods of Analysis of the Association of Official Analytical Chemists."

## 3. RESULTS

Ink migration is essential for food safety in the food packaging industry. It can occur due to many input parameters. In this analysis, inks and paperboards are considered influential parameters of the material manufacturing industry in ink migration. Total area coverage (TAC) is regarded as an influential parameter of the pressroom in ink migration. The results of migration using 3% Acetic acid solution migration values in (Mg/inch$^2$) are given in Table 5.

*Table 5: Ink migration reports*

| Grade | TAC Value | Marking during measurement | 3% Acetic Acid Solution Migration Value (Mg/Inch$^2$) |
|---|---|---|---|
| CYD | 370 | D | 0.18 |
| CYD | 350 | H | 0.26 |
| CYD | 330 | G | 0.27 |
| | | | |
| SCD | 390 | E | 0.23 |
| SCD | 370 | F | 0.17 |
| SCD | 350 | A | 0.33 |
| | | | |
| MGTH | 390 | B | 0.22 |
| MGTH | 370 | I | 0.18 |
| MGTH | 350 | C | 0.16 |

Ink penetration of solid patches (Process inks) was measured in pixels, and then the measurements were converted into Z-directional depth. Three samples of each paper and TAC were taken for measurements, and random measurements on solid patches were taken from every sample. Penetration data for 330 TAC are given in Table 6.

*Table 6: Penetration results at 330 TAC*

| Paper type | Penetration in Cyan ink (microns) | Penetration in Magenta ink (microns) | Penetration in Yellow ink (microns) | Penetration in Black ink (microns) |
|---|---|---|---|---|
| SCD | 141.09 | 150.96 | 176.55 | 118.78 |
| CYD | 149.71 | 137.17 | 155.55 | 129.49 |
| MGTH | 109.58 | 132.57 | 156.32 | 91.09 |

## 4. DISCUSSION

Distilled water, N-heptane, 50% ethanol, Vegetable oil and 3% acetic acid were used for migration testing. These four simulants, Distilled water, N-heptane, 50% ethanol, and Vegetable oil, did not show any migration of residues. Distilled water and N-heptane are used as a simulant for nonacid, aqueous, dairy, and bakery products; 50% ethanol is used as a simulant for beverages containing more than 8% alcohol; Vegetable oil (95% ethanol & iso-octane) is used as a simulant for fatty foodstuffs while 3% acetic acid is used as a simulant for acidic foodstuffs (watery foodstuffs pH<4.5). Ink migration by simulants distilled water, N-heptane, 50% ethanol and vegetable oil did not show migration on paperboards. At the same time, simulant 3% acetic acid detected a migration level below the compliance limit of 0.5 mg/in$^2$.

## 5. CONCLUSIONS

The main purpose of the paper coating process is to cover the paper fibres by filling a thin film layer of pigment, binder, and some additives onto the base paper or cardboard to fill in the gaps between them and to obtain a smoother surface. Fillers/Coatings can influence optical properties and sheet structure, such as formation, bulk, pore structure, and surface topography (texture). $CaCO_3$ and clay are used as a coating content for the paperboards. $CaCo_3$ is more in content, as compared to clay in those paperboards. Calcium carbonate is an alkaline material that reacts strongly to acidic conditions. Calcium carbonate may also contain trace amounts of magnesium carbonate, silicon dioxide, aluminium oxide, iron oxide, and water. The presence of calcium carbonate in papers creates difficulty in offset lithography, as the alkalinity of the paper filler or coating tends to react with the acidic dampening solution used on the press. As, the 3% acetic acid was used as a simulant for migration testing, there can be a chance of detection of $CaCO_3$ as a migrant in migration test. Solvents or inks used in printing which contain organic compounds can have a high affinity towards acetic acids, and may be detected as migrants. Ink penetration of ink pigment particles was measured by a reflection microscope. Colourless particles or solvents cannot be measured from optical microscope. So, it cannot be clearly said whether ink penetration has any relation with ink migration or not. Colourless particles from the coating can be penetrated, which may cause migration.

Yellow and black process inks were transferred to the gloves when handling a printed sheet while cutting the samples for ink migration and penetration test. This will cause ink migration due to set-off.

TAC is proved to be the most considerable factor for ink penetration and migration in this analysis. In the pressroom, Printers print their jobs at standard densities as per their machine calibration. Though, sometimes ink deposition (TAC) affects printability as well as effects on ink migration and penetration on paperboards. TAC can be a highly effective parameter for the food packaging industry, especially as safety is the main concern for end users/ consumers.

Ink migration by simulants distilled water, N-heptane, 50% ethanol and vegetable oil did not show migration on paperboards. While simulant 3% acetic acid detected a migration level below the compliance limit of 0.5 mg/in$^2$. All the mentioned paperboards taken for analysis can be used in the food packaging industry as they have migration levels below the compliance limit.

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