Security printing methods from a digital printing perspective

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Abstract:
The paper discussed the secured prints by digital printing method, the paper has reviewed some new programs features provided in the field. paper problem stated to study the lack of using the new anti-counterfeiting design features in addition to future using of digital printing method as a new method in preventing prints or goods anti-counterfeiting. paper methodology followed the analytical experimental approach and theoretical one' to solve paper problem. the objectives were to find the influence of those new innovations in doing the experimental, continue with the tests and its analysis to identify a fair and clear solution to the paper problem. in order to do that, the paper has to study the first part of paper research which focuses on one of security new programs, courtesy of agfa ... etc, and types of inks which is considered one of the most important elements in securing materials especially the UV inks, IR inks and taggant inks. The designs include covert elements used the invisible UV inks. semi-covert design elements include microtext, authenticate secure barcode, line in line special screen and other elements used visible Electro-inks. The overt elements include Guilloche, latent image, random pattern and other elements solution have also been used visible Electro-inks. Whereas, The second part focused on the analytical of the digital printing experimental which has been printed for the packages field, discussing the printed secured prints designs with a wide range of several substrates, the tests analysis were all about ink resistant to several agents, tests analysis has been implemented according to ISO Standards, the evaluation of the tests and the paper results showed that the prepared secured documents printed with UV inks on the selected digital printing corporation innovation machine (courtesy of Hewlett-Packard) have a very good performance in durability even with the hard tests which carried out on the printed samples. Recommendation included that the security digital printing and the new digital program features, both of them have an excellent opportunity in securing a very large sectors of low valued documents in addition to some of the valued documents except the forensic features which are not available by the digital printing yet.

Keywords:
Security Printing,
Digital Printing,
Anti-Counterfeiting,
Technology Systems,
Optical Variable Ink,
Invisible Inks

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Introduction

In security applications, it is desirable to add information into the document that prevents / hinders alterations and counterfeiting. Traditionally, security printing is associated with expensive equipment, especially designed media and/or printing material. The emerging digital printing technology is changing the dynamics of security printing. In addition to numerous newly invented digital security features, many traditional features now can be implemented with digital technology using conventional equipment and material. Furthermore, we usually got to find the main goal of security printing is protects sensitive paper documents including banknotes, passports, stock certificates and identity cards, it is often associated with expensive equipment. The previous goal is too far from securing low price packaging, tickets and so on.

The continuing advancement in digital printing technology has posted significant challenges for anti-counterfeiters, it also offers opportunities for security printing. Many new security features have been invented based on digital technologies. In addition to new methodologies and systems, many traditional features can now be implemented using commercially available equipment and material at a very low cost. This expands the range of security printing coverage to many relatively low value documents. Furthermore, the flexibility of digital technology enables cost-effective variable information embedding even at a run length of one, thus creating "individualized security printing".

In this paper, we will introduce several applied security printing technologies that have been developed in HP , the used designed program that have the ability to create new ideas of security age, one such an example JURA, arizo and Agfa which they presented recently several developed security features. Among the other advantages, these features are designed to be produced with commercially available among Hp or other digitalized machines. In addition, the features can be implemented as variable data that can be individualized for each document.

The new technologies will open the security field for even low value documents to be secured such as tickets, packaging, coupons, prescriptions are traditionally not covered by security printing

Research Problem

Lack of using new anti-counterfeiting new designs and printing methods like digital printing in securing prints or goods from fraud, and if it has use durability in future and if it will fit new market sectors of anti-counterfeiting or not?

Objectives

1. To review new designs and technologies securing data with new programs, printing methods and invisible inks
2. To evaluate and analyse a secured digital printing prints experiment followed by specific tests that effect on evaluating the new method in prevent goods or prints fraud, as well as find the immovability of the secured prints

Methodology

the paper followed an experimental approach:

First: The Theoretical Study

1. **Anti–counterfeiting technologies: principles and practical applications**

Anti-counterfeiting technologies are aimed at protecting governments' revenues, public safety, brand owners' rights, and suppliers' reputations. Technological solutions may be overt or covert. Overt technologies are elements that can be accessed using any of the human senses (vision, touch, smell, etc.) without the need to rely on a particular device or tool to perform the authentication. These applications are also easy to recognize for consumers. However, overt technology features present shortcomings that include: easier potential imitation, possible reuse, and possible false assurance. Concerning the latter element, cases have been registered where criminals affixed false security features on fake products to confuse ordinary customers. Interestingly, the original version of these products did not even have an overt security feature. When combined with other technology, overt authentication features may constitute elements of a strong and reliable anti-counterfeiting and supply chain security system. Covert technology, on the other hand, is hidden. Covert devices enable a producer or a brand owner to identify the original product against a counterfeit one. Only technology providers, brand owners or authorized stakeholders can access the components of covert technology, whereas consumers are usually neither able to detect nor verify the presence of covert devices. Both authentication and track and trace technologies assist in the fight against counterfeiting. While authentication technologies enable verification as to whether a product is genuine or fake, track and trace technologies provide for better visibility within the supply chain. When combined, they can serve as a barrier to the infiltration of fake and illegitimate products within the legal supply chain. Several types of equipment can be used to distinguish authentic goods from phony items, including holograms, colour-shifting inks, security threads, QR codes, data matrix codes, micro-printing, anti-forgery inks, bar-code technology and watermarks, to mention a few. On the other hand, tracking and tracing mainly relies on two identification methods: optical and Radio Frequency Identification (RFID), which can be applied either separately or jointly. In the case of optical technologies, a code containing information on the product is generated and then affixed on the product itself, usually via a label. The label containing the code is then read along the production (and possibly the distribution) chain. The information contained in the code is thus acquired, and will serve to authenticate the product and monitor its movements.

2. **Innovative technologies to reduce counterfeiting**

2/1: AGFA Graphics

1. Arziro Design, which is a plug-in for Adobe Illustrator for brand protection and anticounterfeiting. It enables users to create secure designs for official documents, such as tax stamps, tickets, labels and packaging (e.g., pharmaceutical and health sector packaging). According to the company, Arziro can generate ultra-complex structures, anti-copy features and relief patterns that cannot be duplicated by commonly available graphic software. It can be applied for products printed in offset, flexo, digital, with output resolutions between 1200 and 4000 dpi. The software enhances existing designs with complex elements, backgrounds or line work efforts, resulting in hard-to-copy designs.
2. Fortuna Security Design, which is a software for high security printing for ID documents and passports.100 It features different levels of verification tools and its modular structure allows users to create a wide variety of customized security designs. It is an assembly software package used for creating and protecting passports, ID cards, tax stamps,

security documents. The software consists of two parts: a core application, mainly line work-oriented, and a set of security modules integrated into the general line work core editor. The special security modules include over 30 add-on packages to the core editor. All the modules can be combined so that designs become very difficult to counterfeit. (AGFA solutions 2020)

2/2: Security inks

wide variety of security inks can be used in documents, packages, labels, and cards. In addition to security printing inks, the printer can also use overprint varnishes and laminates to help deter counterfeiting. It should be noted that many security printing inks depend upon the absorption of UV radiation and its re-emission as visible light. Therefore, to work properly, many security designs and devices must be printed on UV-dead or uncoated paper. On other media they will only work if there are no UV brighteners in the substrates (Vuarnoz et al, 2003): Fluorescent dyes; Iridescent inks; Photochromic ink; Phosphorescent inks; Thermo chromic ink; Optical variable ink; Infrared ink; Machine readable inks; fig (1) (Spiridonov 2018)

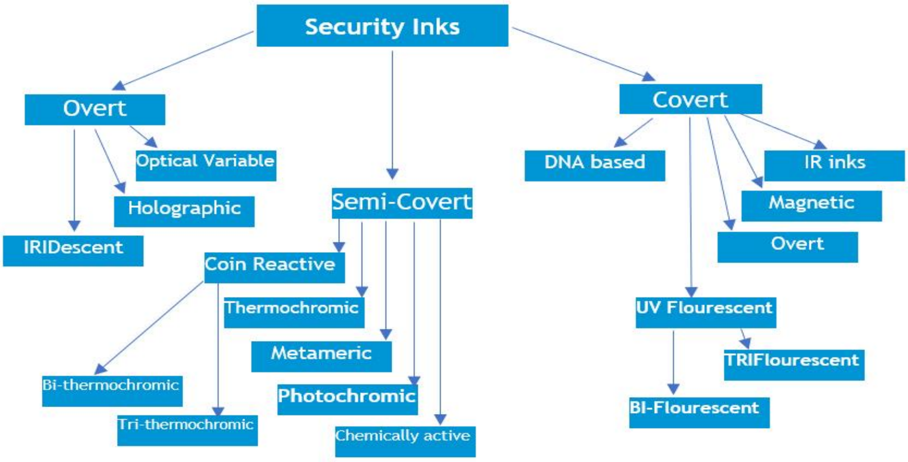


Figure (1): Security features within inks

Second: The Practical Study

3. **Digital Security Printing in Packaging Experimental**

3/1: Experimental Materials and Procedures:

3/1/1: Experiment 1: Design Preparation

A Tax Stamp Design were prepared by JURA for security printing with Corvina Security Designer Program, design includes the following security elements:

1. UV Coded information
2. Microtext as Variable design structures (size between 300 – 800 microns, very strong against reproduction)
3. Microtext (Micro text size less than 300 microns), serialized text
4. Line in line special screen
5. Latent Image (importance: Unique characteristics, Multilayer overprint with perfect registration)
6. Tactility Elements
7. Invisible Variable Information
8. IQ-R code (Multi-layered protection of 2D code. Public information for T&T, hidden & encrypted layer and layer with dynamic copy protection), fig (2)

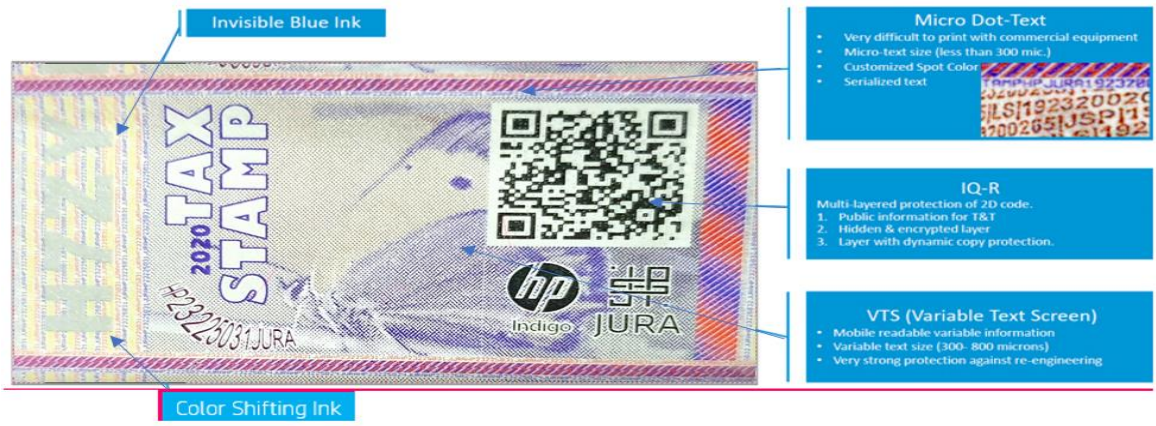


Figure (2): Tax Stamp design security elements/ designed by JURA Corvina Security Designer Program

3/1/2: Experiment 2: Design Preparation

HP/AGFA Indigo Secure Studio:

Design security studio solution for a brand protection, allow to create various elements as in fig (), powered by the Arizo design plugin in Adobe Illustrator, design includes the following elements:

1. Custom spot colors
2. Traditional guilloche
3. QR+ anti-copy Arizo Authenticate code/ multiply functional contains a QR code in addition to the covert secure graphic embedded within the QR code, the code can be scanned by Arizo Authenticate app.
4. Anti- copy random pattern
5. Micro texts

3/1/2/1: Design 2 Groups Programs:

1. Group A label design by HP Secure Studio powered by Arziro Design
2. Group B label design by SmartStream Designer HP Mosaic Program
3. Group C label design by SmartStream Designer HP

3/1/2/2: Other Prepress equipment:

1. **HP DFE Raster Image Processor (RIP)**
2. RIP's 4x data is faster than the previous version and accurate, able to create super sharp line work and micro-text at 0.8 pt. the new RIP suitable for small solid text and line work (HP RIP engine guide), examples of its work in fig (3)

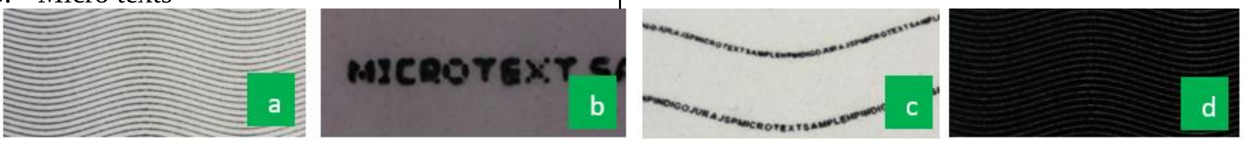


Figure (3): a) Linework, b) Microtext at 0.8 pt, c) wave-text at 1.0 and 0.8pt, d) knockouts elements (HP 6K guide)

3. New Nvidia Graphic Processing Unit: key part of modern supercomputers and continued to drive gaming and pro graphics
4. Hummingbird data transmit unit

3/2: security inks used in the experiments':

Both experiments used HP Indigo ElectroInk for Invisible Yellow for the covert design elements, in addition to optical variable inks for overt & semi-covert design elements.

3/3: Other used Materials for both Experiments:

This experimental used two types of papers:

1. Uncoated White paper weight 80 gsm (for design 1: Tax stamp)
2. Coated White sticker paper weight 90, 250 gsm (for design 2 Group B, C1,2)
3. Polymer substrate 70 gsm (for design 2 Group A)
4. Foil metallization layer

3/4: Digital Security Printing Process for both Experiments:

3/4/1: HP Indigo 6K HD security Printing upconversion nanoparticles for anti-counterfeit applications

A new courtesy of HP, able to print invisible yellow for s4 sheet fed – Q3 beta. The machine can print Covert with Taggant inks, IR invisible ink in PQ mode and UV inks. Also, it can print Semi-covert for Microtext

Authenticate secure barcode, Lenticular Image, Registration pattern / Line-in-line, in addition the ability to print Overt for Serialization, Random Pattern, Guilloche, Latent Image, Holographic

* High-Definition imaging system (HD) capability means: a 1600 dpi resolution suitable for security printing and small fonts

1. First Digital printing for Design 1: The Tax Stamp has been printed on HP Indigo

2. Second Digital printing for Design 2 labels groups:

1. Group A label designs printed on HP Indigo 6900 Digital Press
2. Group B label designs printed on HP Indigo 6900 Digital Press using HP Indigo Silver and HP Indigo ElectroInk invisible yellow
3. Group C label designs printed on HP Indigo 6900 integrated with KURZ DM- JETLINER (digital metallization foil machine on paper. also, the machine capable of produce hologram foils. But in our experiment, we used it to make a glossy look along entire line during digital printing for group C, Once the foil is applied with a UV-curing adhesive to the unprinted substrate, the PET carrier is removed, and the substrate can be overprinted within the printing machine). (HP guide)

3. Security Covert Designs Invisible Analysis:

Visibility (under visible light): Not invisible on clear substrates ("milky" look), unless using a white backing layer

When printed directly on smooth substrates, may be seen as a gloss difference

Can be eliminated by Varnishing/lamination or by printing on top of half scale areas/images

Otherwise, Nano-particle yellow Invisible inks can be visible within emitting an Ultra Violet light source under excitation 548 nm, fig (4)

3/5: Design 1 experiment Security Covert Invisible Analysis:

The author has analysis the first design by using UV lamp source and microscope, the security elements appear as below in fig (4)

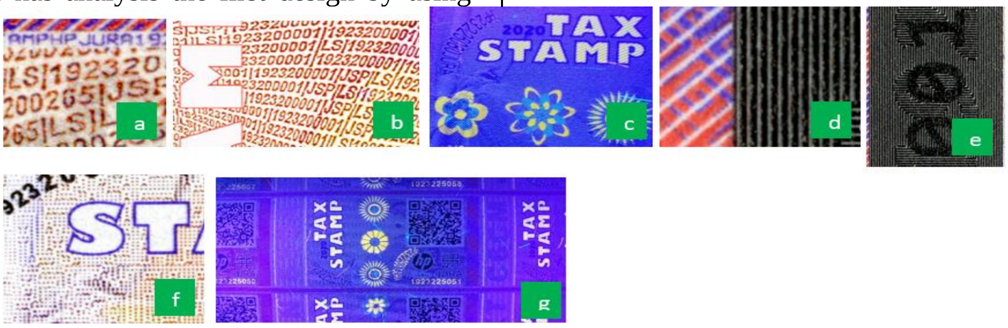


Figure (4): The printed design 1 experiment / security covert invisible design analysis by UV lamp source and Microscope: a) Microtext, b) Microtext as Variable design structures, c) Sample of UV Coded Information, d) Line in line special screen, e) Latent Image, f) Invisible Variable Information, g) The Printed Tax Stamp Sample within UV

9/6: Design 2 experiment Security Covert Invisible Analysis:

The author has analysis the second 4 label designs by using UV lamp source, the security elements appears as below in fig (5)

Group A, The Printed Designs Label 2 before UV exposure   Group A Label within UV exposure

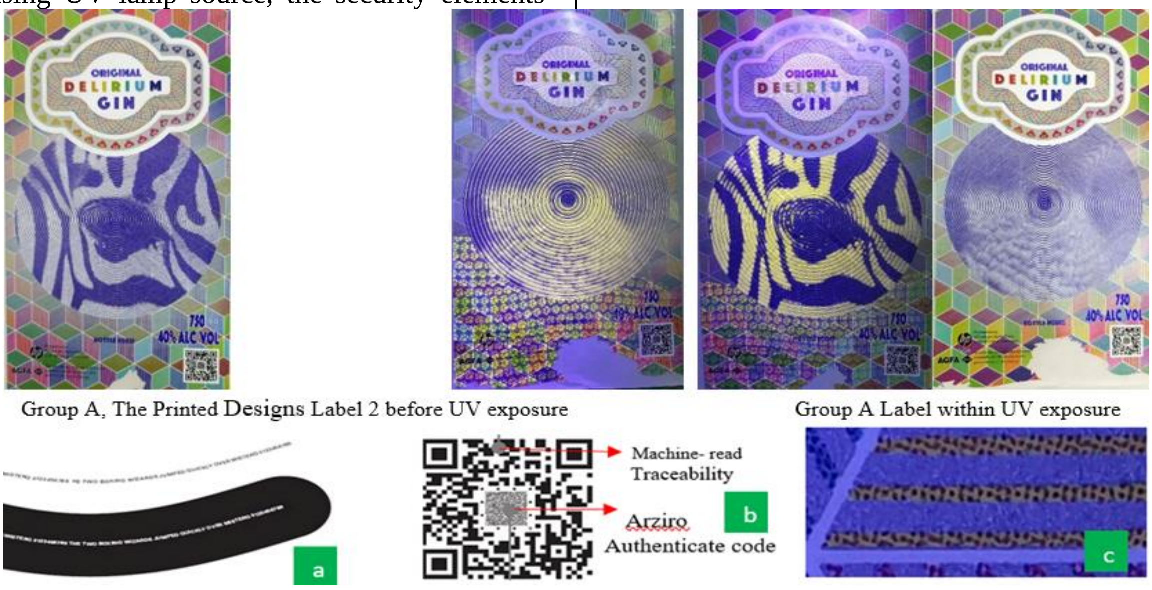
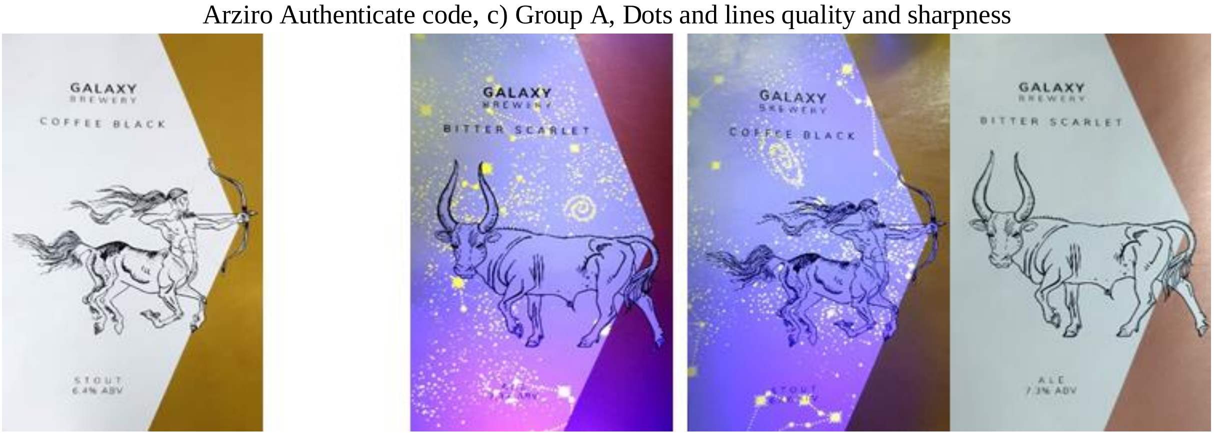


Figure (5): the printed design 2 experiments Group A / security covert invisible design analysis by UV lamp source: a) Group A, Text size on the circle lines in both label design (0.16 mm), b) The printed QR+ anti-copy Arziro Authenticate code, c) Group A, Dots and lines quality and sharpness



Group B, The Printed Design Label 2 before UV exposure   Group B within UV exposure

Figure (6): the printed design 2 experiments Group B / security covert invisible design analysis by UV lamp source

Group C, The Printed Design Label 2 before UV exposure Group C within UV exposure

Figure (7): the printed design 2 experiments Group C / security covert invisible design analysis by UV lamp source

3/7: Experiments Tests and its analysis

First test: Ink Absorption Test

Ink smears or drawdowns used to evaluate the receptivity of paper or paperboard surfaces to the used security ink. This test is intended to indicate the general level of absorbency and any variation in absorbency or mottle tendency.

1. Test Methodology:

Ink is applied to the surface and is left in contact for a measured length of time. The ink is then wiped from the surface and the brightness drop measured. A paper surface that is more receptive to ink show a larger loss in brightness.

Peak ElectroInk Invisible Yellow tested Absorption wavelength is 393nm

2. Iso Brightness of sample substrates:

Iso standard of brightness were measured to some of printed substrates:

1. Design 1 Iso Brightness = 80.36
2. Design 2 Group A Iso Brightness = 90.56
3. Design 2 Group B Iso Brightness = 85.64

Second test: Ink Rub/Abrasion Resistance

1. Purpose of test

Test is designed to evaluate scuffing or rubbing resistance of an ink film or fibre surface. The author chosen two tests: dry and wet rubbing

2. Instruments and materials

1. Ink Rub Tester (Calibrated)
2. TAPPI T830 Iso Standard
3. 12647 Iso Standard of Media prints color control and management
4. PALM datacolor check II plus Spectrophotometer (Calibrated)
5. Distilled water.
6. Un-print un-coated white paper
7. Couche un-print semi-matt coated white paper
8. Couche un-print glossy coated white paper
9. Un-printed substrate white polymer

3. The printed colors evaluation procedures before and after test:

1. According to TAPPI T830 Iso Standard, samples are usually evaluated by visually comparing them to internally maintained standards. The result is usually a pass designation. Samples also has been evaluated by using Spectrophotometer. According to the Iso, the initial reading before the rub test is designated as Zero and the change on ΔE is reported.
2. CIEL*a*b were measured by PALM in 3mm solid base colors, results recorded before and after testing. With the calculation of the difference between both of them = ΔE, all measures taken compared with the MediaStandard Print 2016 CIEL*a*b and ISO 12647 color values tolerances

4. Test Procedures

4/1: Dry Rub test

1. Select specimens of 152 * 76 mm of the Digital printed boards
2. Prepare unprinted stock from the same run in 152 * 51 mm (6*2 inch) and clip it to test block (0.9 kg and 1.8 kg)
3. Place the printed sample on the rubber pad of the base plate (print side up)
4. Place the weight over both printed and unprinted paper, both surfaces are free of dirt
5. Press machine start button to count 25 cycles, to examine the color transfer from the printed sample into the unprinted one.
6. When the strokes have been completed, examine both the inked surface and the plain surface on the test block for signs of transfer
7. Repeat the 25 stroke sequence until ink transfer occurs or a predetermined level is reached
8. Repeat steps until ink is noted or surface of board shoe abrasion (sample failure)

- **Dry rub test for Design 1 and its analysis & evaluation**

The unprinted un-coated white paper weight were 80 gm , whereas the block were 0.9 kg

Delta E has shown a little bit of color change at the same patch after 150 cycle, result as in table (1) were more than satisfied. Furthermore, the unprinted paper dirt results as in fig (8), paper has detected a little bit impression of visible inks achieved at the end of stroke sequences, while the invisible UV inks still viewed with its full appearance without any change.

As a result of this test, failure of printing Design 1 result according to Iso Standard TAPPI T830 maybe achieve after thousands of dry inks rubbing, or this is depending on people behaviour while using the packs or boards, for example they may damage it by sharp edges instruments like knifes …etc. whereas the ΔE maybe exceeds the iso standard tolerance (≤ 3) after hundreds of stroke sequence.

Table (1): Design 1 Test ΔE

 Design 1 , L*a*b	Before Test	After Test (150 cycle)
L	69.24	69.18
*a	6.75	6.46
*b	-9.27	-8.79
ΔE	0.56	

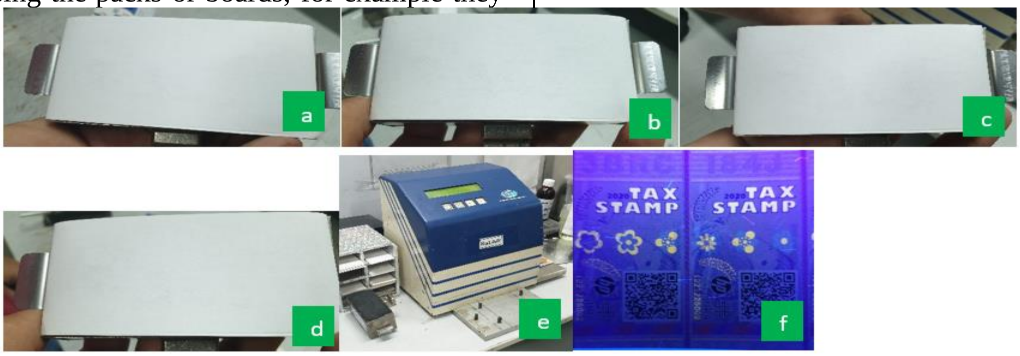


Figure (8): a) Test result after 25 stroke sequence, b) Test result after 75 stroke sequence, c) Test result after 100 stroke sequence, d) Test result after 150 stroke sequence, e) Ink rub tester, f) Design 1 under UV light source after end of dry ink rub test

- **Dry rub test for Design 2 (Group A) and its analysis & evaluation**

The unprinted glossy polymer substrate, weight was 70 gm, whereas the block was 1.8 kg.

Delta E has shown color change at the same patch after 150 cycle, result as in table (2). Still, it is in the tolerance ranges according to Iso standard of media prints. Furthermore, the unprinted dirt polymer results as in fig (9), polymer has detected a little bit impression of visible inks achieved at the end of stroke sequences, while the invisible UV inks still viewed with its full appearance without any change.

As a result of this test, failure of printing Design 2 (Group A) result according to Iso Standard TAPPI T830 maybe achieve after thousands of dry inks rubbing

Table (2): Design 2 (Group A) Test ΔE

 Design 2 (Group A) L*a*b	Before Test	After Test (150 cycle)
L	53.01	53.98
*a	18.47	18.22
*b	-35.84	-35.43
ΔE	1.09	

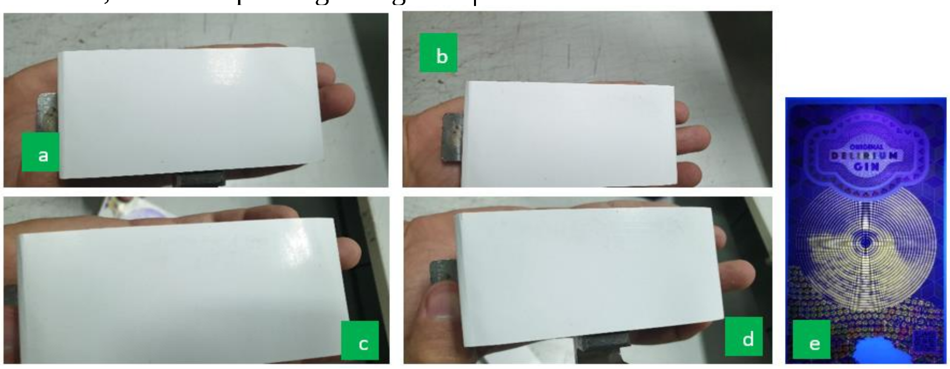


Figure (9): a) Design 2 Group A test result after 25 stroke sequence, b) Design 2 Group A test result after 75 stroke sequence, c) Design 2 Group A test result after 100 stroke sequence, d) Design 2 Group A test result after 150 stroke sequence, e) Design 2 Group A under UV light source after end of dry ink rub test

- **Dry rub test for Design 2 (Group B) and its analysis & evaluation**

The unprinted Couche glossy coated white paper, weight was 90 gm, whereas the block was 1.8 kg.

Delta E has shown color change at the same patch after 150 cycle, result as in table (3). Still, it is in the tolerance ranges according to Iso standard of media prints. Furthermore, the unprinted paper dirt results as in fig (10), paper has detected a little bit impression of visible inks achieved at the end of stroke sequences, while the invisible UV inks still viewed with its full appearance without any change.

As a result of this test, failure of printing Design 2 (Group B) result according to Iso Standard TAPPI T830 maybe achieve after thousands of dry inks rubbing

Table (3): Design 2 (Group B) Test ΔE

 Design 2 (Group B) L*a*b	Before Test	After Test (150 cycle)
L	69.03	68.37
*a	3.55	3.74
*b	45.10	45.96
ΔE	1.10	

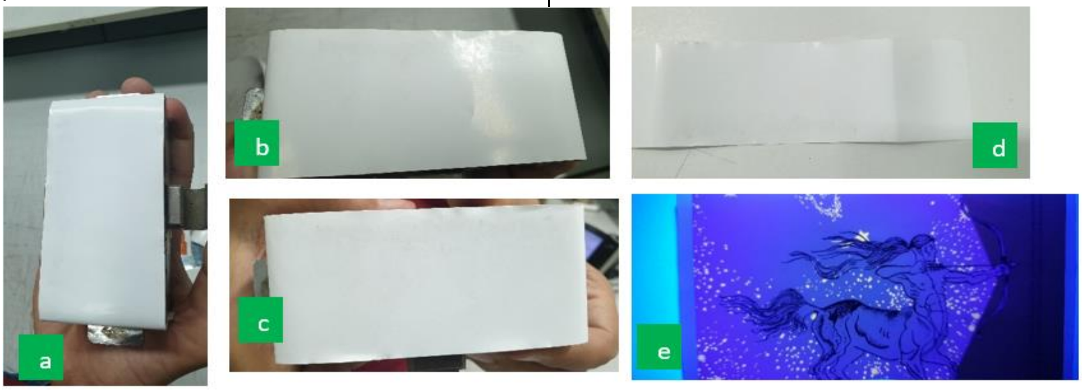


Figure (10): a) Design 2 Group B test result after 25 stroke sequence, b) Design 2 Group B test result after 75 stroke sequence, c) Design 2 Group B test result after 100 stroke sequence, d) Design 2 Group B test result after 150 stroke sequence, e) Design 2 Group B under UV light source after end of dry ink rub test

- **Dry rub test for Design 2 (Group C) and its analysis & evaluation**

(Group C1): The unprinted Couche semi- matt coated white paper, weight was 250 gm, whereas the block was 1.8 kg

Delta E has shown color change at the same patch after 150 cycle, result as in table (4). Still, it is in the tolerance ranges according to Iso standard of media prints. Furthermore, the unprinted paper dirt results as in fig (11), paper has detected impressions of visible inks noticed over the stroke sequences, while the invisible UV inks still viewed with its full appearance without any change.

As a result of this test, the sample were different from the other samples because of the ink embossed texture in the print. in spite of that, failure of printing Design 2 (Group C1) result according to Iso Standard TAPPI T830 maybe achieve after thousands of dry inks rubbing because of its high amount of inks in texture effect.

(Group C2): The unprinted Couche glossy coated white paper, weight was 90 gm, whereas the block was 1.8 kg

Delta E has shown color change at the same patch after 150 cycle, result as in table (4). Still, it is in the tolerance ranges according to Iso standard of media prints. Furthermore, the unprinted paper dirt results as in fig (12), paper has detected a little bit impression of visible inks achieved at the end of stroke sequences, while the invisible UV inks still viewed with its full appearance without any change.

- Comparing between Group C1 and C2 results: although the dirt of the unprinted paper in C1 were much more in C2, we got to find that ΔE in C1 less than in C2. That's refers to the hardness of the embossed ink texture, weight of paper and semi matt type of paper, that makes ΔE is less in C1. Whereas the C2 were glossy and this is causing an easy escaping of inks through test. And inks colour was normal in C2 and this is completely different from C1

Table (4): Design 2 (Group C) Test ΔE

 Design 2 (Group C1) L*a*b	Before Test	After Test (150 cycle)
L	88.90	88.30
*a	-3.52	-3.41
*b	56.35	55.50
ΔE	1.04	
 Design 2 (Group C2) L*a*b	Before Test	After Test (150 cycle)
L	68.95	

*a	-21.87	
*b	22.15	

ΔE	1.27

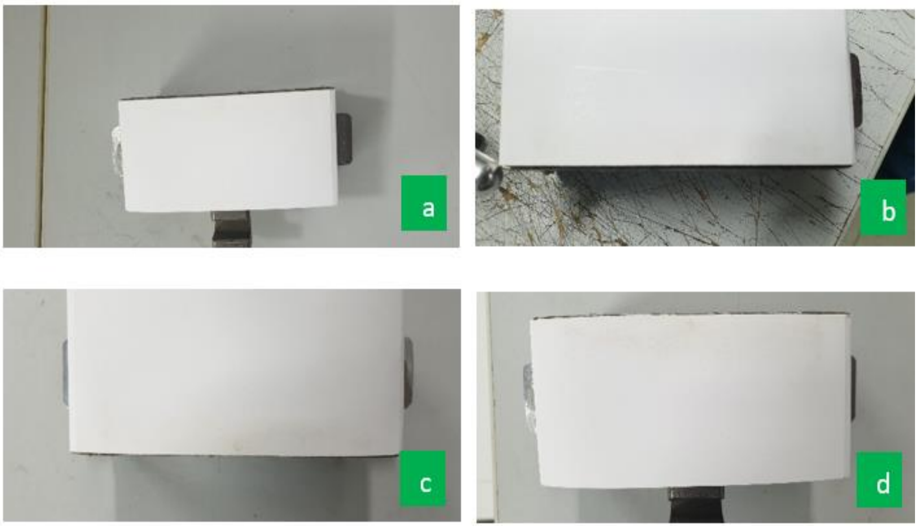


Figure (11): a) Group C1 test result after 25 stroke sequence, b) Group C1 test result after 75 stroke sequence, c) Group C1 test result after 100 stroke sequence, d) Group C1 test result after 150 stroke sequence

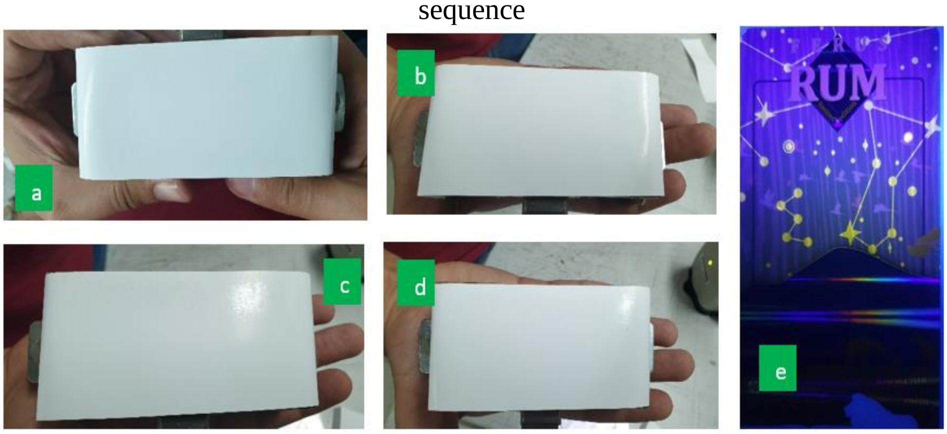


Figure (12): a) Group C2 test result after 25 stroke sequence, b) Group C2 test result after 75 stroke sequence, c) Group C2 test result after 100 stroke sequence, d) Group C2 test result after 150 stroke sequence, e) Group C2 under UV light source after end of dry ink rub test

5. Ink dry rubbing ΔE evaluation

ΔE for visible inks at all designs maybe exceeds the iso standard tolerance (≤ 3) after hundreds of stroke sequence. And this is referring that the ink durable and resistance for rubbing without losing its color quality through users handling or dropping on the floor. and so on. Whereas the invisible inks remain without any change except the damage of the printed paper/material if happened by any other factors.

4/2: Wet Rub

4/2/1: Test Procedures

1. Mount the strips in the same manner as for dry rubs, using the 0.9 kg or 1.8 kg test block.
2. Placing 3 to 5 drops of distilled water on the printed surface so that they be covered by the test block, then place the block in position and immediately press start button
3. After one stroke, observe the surface of the sample for fuzz, abrasion or color transfer. Any of these conditions indicates the end of the test, repeat single strokes until failure is noted.

- **Wet rub test for Design 1 and its analysis & evaluation**

The unprinted un-coated white paper weight was 80 gm, whereas the block was 0.9 kg

Placing 3 drops of water on the printed surface.

Delta E has shown a little bit of color change at the same patch after 3 cycle, result was more than satisfied. Furthermore, the unprinted paper dirt results as in fig (13), paper has detected a little bit impression of visible inks achieved at the end of stroke sequences, while the invisible UV inks still viewed with its full appearance without any notion. Changes only appeared in ΔE result in the same batch of the wetted area. The value of ΔE = 1.18, it seems still in the tolerance range. The printed sample weren't damaged, on the contrary of the blank paper fibres which damaged after 3 cycles only.

Figure (13): a) blank paper fibres damaged after 3 wetted stroke sequence, b) design 1 sample visible ink after wetted rub test , c) design 1 sample invisible ink after wetted rub test

- **Wet rub test for Design 2 (Group A) and its analysis & evaluation**

The unprinted Couche semi- matt coated white paper, weight was 70 gm, whereas the block was 0.9 kg

Placing 3 drops of water on the printed surface.

Delta E has shown color change at the same patch after cycle by cycle until 25 cycle, result not in its tolerances ranges according to Iso standard of media prints. Furthermore, the unprinted paper dirt results as in fig (14), paper has detected impressions of visible inks noticed over the stroke sequences, while the invisible UV inks still viewed with its appearance with a little bit of noted changes by the naked eyes, changes contain a weak of visible and invisible UV inks. Changes as measured, appeared in ΔE result in the same batch of the wetted area of the visible inks. The value of ΔE = 5.70, it exceeds the tolerance range. Neither the wetted print sample, nor the blank paper damaged after the taken cycles by the block over them.

The inks have losses a large amount because of the soft polymer substrate, which make a very easy dripping out inks after wetted by water.

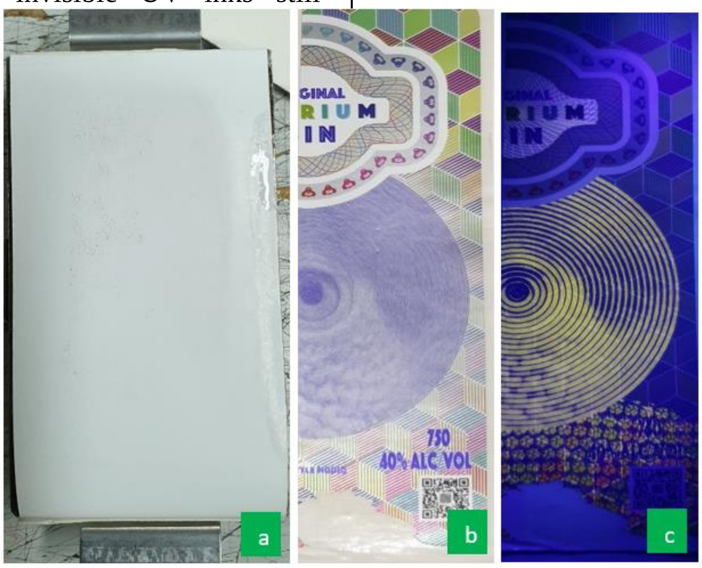


Figure (14): a) Design 2 Group A wetted test result (blank paper) after 25 stroke sequence, b) design 2 Group A sample visible ink after wetted rub test, c) design 2 Group A sample invisible ink after wetted rub test

- **Wet rub test for Design 2 (Group B) and its analysis & evaluation**

The unprinted un-coated white paper weight was 90 gm, whereas the block was 0.9 kg

Placing 4 drops of water on the printed surface.

Delta E has shown a little bit of color change at the same patch after cycle by cycle until 25 cycle, result was more than satisfied. Furthermore, the unprinted paper dirt results as in fig (15), paper has detected a little bit impression of visible inks achieved at the end of stroke sequences, while the invisible UV inks still viewed with its full appearance. Changes only appeared in ΔE result in the same batch of the wetted area. The value of ΔE = 1.99, it seems still in the tolerance range. Neither the wetted print sample, nor the blank paper damaged after the taken cycles by the block over them.

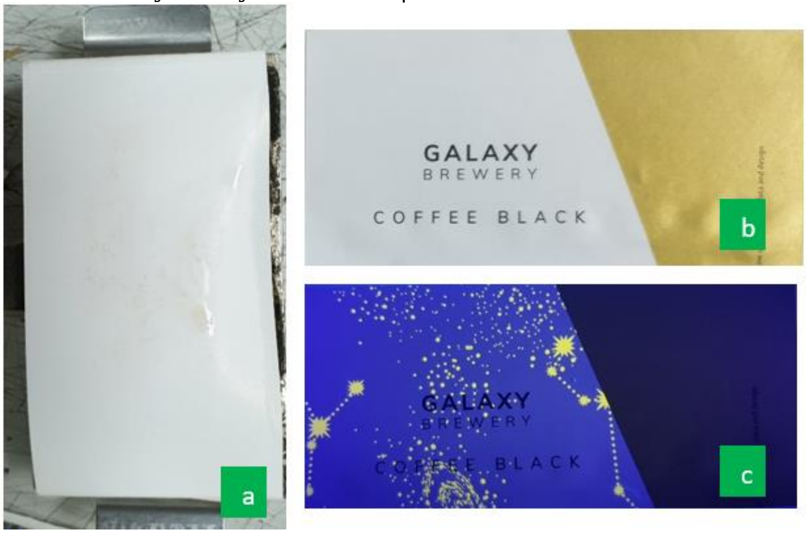


Figure (15): a) Design 2 Group B wetted test result (blank paper) after 25 stroke sequence, b) design 2 Group B sample visible ink after wetted rub test, c) design 2 Group B sample invisible ink after wetted rub test

- **Wet rub test for Design 2 (Group C) and its analysis & evaluation**

(Group C1): The unprinted Couche semi- matt coated white paper, weight was 250 gm, whereas the block was 0.9 kg

Placing 3 drops of water on the printed surface.

Delta E has shown color change at the same patch after cycle by cycle until 25 cycle, result not in its tolerances ranges according to Iso standard of media prints. Furthermore, the unprinted paper dirt results as in fig (16), paper has detected impressions of visible inks noticed over the stroke sequences, while the invisible UV inks still viewed with its appearance with a little bit of noted changes by the naked eyes, changes contain a little weak of invisible UV inks, other people doesn't feel the change by their eyes when they saw it. Changes in fact appeared in ΔE result in the same batch of the wetted area of the visible inks. The value of ΔE = 3.85, it exceeds the tolerance range. Neither the wetted print sample, nor the blank paper damaged after the taken cycles by the block over them.

By 3 drops of water Inks embossed textures losses some of its density, that's because of the large amount of inks in this sample.

(Group C2): The unprinted Couche semi- matt coated white paper, weight was 250 gm, whereas the block were 0.9 kg and 1.8 kg

Placing 5 drops of water on the printed surface.

Delta E has shown color change at the same patch after cycle by cycle until 25 cycle with 0.9 kg block then more 9 cycles with the 1.8 kg block, result still in its tolerances ranges according to Iso standard of media prints, in spite of the hard wetted test strokes on these sample. Furthermore, the unprinted paper dirt results as in fig (17), paper has detected impressions of visible inks noticed over the stroke sequences, while the invisible UV inks still viewed with its appearance without any noted changes by the naked eyes. Changes only appeared in ΔE result in the same batch of the wetted area of the visible inks. The value of ΔE = 2.44, it seems still in the tolerance range. Neither the wetted print sample, nor the blank paper damaged after the taken cycles by the block over them.

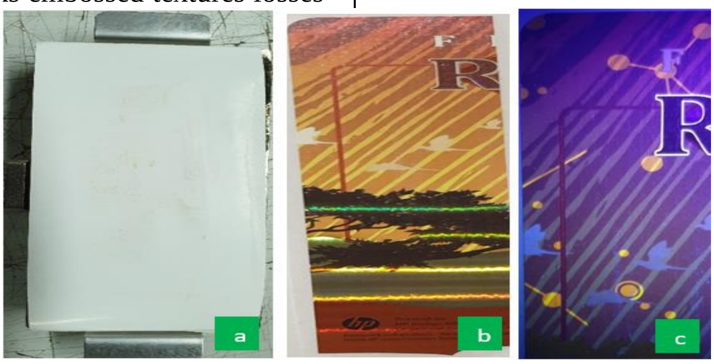


Figure (16): a) Group C1 wet rub test result (blank paper) after 25 cycles, b) design 2 Group C1 sample visible ink after wetted rub test, c) design 2 Group C1 sample invisible ink after wetted rub test

Figure (17): a) Group C2 wet rub test result (blank paper) after 34 cycles, b) design 2 Group C2 sample visible ink after wetted rub test, c) design 2 Group C2 sample invisible ink after wetted rub test

Third test: Acid Resistance of Prints Ink

1. Purpose of test

Check resistance of the digital secured prints to a particular acid as we found it in most of our food or juices and some other goods, test should be done in a particular concentration over a given period of time.

2. Instruments and materials

1. Determination of resistance of prints to acids Iso Stanadard 11628:1995(E)
2. White laboratory filter Paper, for Chemical analysis, with a very smooth and soft surface. The size of the Strips of filter Paper should be 60 mm x 90 mm.
3. Glass plates, 60 mm x 90 mm.
4. Citric acid 5% solution (looks like juice acid)
5. Grey scale for colour evaluation (according ISO 105-A03).
6. Distilled water.
7. 1 kg weight.
8. Oven, capable of being controlled

3. Test Procedures

1. Immersing two sheets of filter Paper to be used for the test totally in the acid being tested and then drain them until no free Solution drips from the filter Paper.
2. Placing one of the sheets of filter Paper on the lower glass plate.
3. Placing a 20 * 50 mm sample of the print to be evaluated on the filter Paper and cover it with the second piece of filter Paper.
4. Place the upper glass plate on top and place the whole in a moisture-tight wrapper or Container. Place a 1 kg load on the glass plates to provide pressure.
5. After exposing the print to the citric (concentration 5%) acid for 1 hour, we got to remove it and rinse it in distilled water until a neutral pH is achieved. Dry the print in the oven at 37 C for 30 min.

4. Evaluation method

The results shall be evaluated in accordance with the following:

1) the print has no changed significantly in appearing, the tested samples resistant to the selected acid.

2) the filter Paper Shows no staining, this shall be reported and evaluated as to intensity. The grey scale comparing where in the step 1 (the white colour)

- **Acid resistance of Design 1 and its analysis & evaluation**

We have no inks drain or any change in the invisible UV inks, as shown in fig (18), the filter paper doesn't show staining, the test evaluation reported as the inks were resistant to acids

- **Acid resistance of Design 2 (Group A) and its analysis & evaluation**

We have no inks drain or any change in the invisible UV inks, as shown in fig (18), the filter paper doesn't show staining, the test evaluation reported as the inks were resistant to acids

- **Acid resistance of Design 2 (Group B) and its analysis & evaluation**

We have no inks drain or any change in the invisible UV inks, as shown in fig (18), the filter paper doesn't show staining, the test evaluation reported as the inks were resistant to acids

- **Acid resistance of Design 2 (Group C) and its analysis & evaluation**

(Group C1): We have no inks drain or any change in the invisible UV inks, as shown in fig (18), the filter paper doesn't show staining, the test evaluation reported as the inks were resistant to acids

(Group C2): We have no inks drain or any change in the invisible UV inks, as shown in fig (18), the filter paper doesn't show staining, the test evaluation reported as the inks were resistant to acids

Figure (18): a) the invisible ink observation in design 1 after acid test under the UV light source, b) the invisible ink observation in design 2 Group A after acid test under the UV light source, c) the invisible ink observation in design 2 Group B after acid test under the UV light source, d) the invisible ink observation in design 2 Group C1 after acid test under the UV light source, e) the invisible ink observation in design 2 Group C2 after acid test under the UV light source, f) design 1 filter paper result, g) design 2 Group A filter paper result, h) design 2 Group B filter paper result, i) design 2 Group C1 filter paper result, J) design 2 Group C2 filter paper result

Fourth test: ink resistance to various agents according to ISO Standard 2836-1999:

1. Alkali Test

1/1. Purpose of test

Check resistance of the digital secured prints to a particular alkali as we found it in most of our food and some other goods, test should be done in a particular concentration over a given period of time.

1/2. Instruments and materials

All the previous instruments and materials of acidic test, with a change in:

1. Determination of resistance of prints to alkali Iso Standard
2. Alkali NAOH 1% solution
3. 2 glass plates, 60 mm , 90 mm , 2 mm
4. White neutral laboratory filter paper, for qualitative chemical analysis, with a very smooth and soft surface. The size of the strips of filter paper should be 60 mm * 90 mm.
5. Petri dish, diameter > 100 mm

1/3. Test Procedures

1. Immerse four sheets of filter paper to be used for the test totally in the NAOH and then drain them
until no free agent drips from the filter paper.
2. Place two saturated sheets of filter paper on the lower glass plate.
3. Place a 20 * 50 mm sample of the print to be evaluated on the filter paper and cover it with the other two sheets of saturated filter paper.
3. Cover with the other glass plate and place a 1 kg weight on top. Leave it for 10 minutes.
4. Rinse the prints being tested for alkali, then dry prints in an oven for 30 min at a temperature of about 40 °C.

- **Alkali resistance of Design 1 and its analysis & evaluation**

1. Comparing the treated design 1 piece to an untreated test piece. Observes some changes including whether the visible ink film which appears different from the untreated one. Whereas the invisible UV inks appears with some changes less than 10% in its powerful, it may be not observed by the un-specialist people or consumers, as in fig (19)
2. ink transfer has been observed on the receptor surface that has been used in the test, ink transfer about 15%, fig (19)

- **Alkali resistance of Design 2 (Group A) and its analysis & evaluation**

1. No changing between the treated piece and the untreated test piece
2. No observed ink transfer on the receptor surface, fig (19)

- **Alkali resistance of Design 2 (Group B) and its analysis & evaluation**

1. No changing between the treated piece and the untreated test piece
2. No observed ink transfer on the receptor surface, fig (19)

- **Alkali resistance of Design 2 (Group C) and its analysis & evaluation**

(Group C1): 1. Comparing the treated piece to an untreated test piece. Observes some changes including whether the visible ink film which appears different from the untreated one. Whereas the invisible UV inks appears with some changes less than 10% in its powerful, it may be not observed by the un-specialist people or consumers, as in fig (19)
2. ink transfer has been observed on the receptor surface that has been used in the test, ink transfer less than 8% fig (19)

(Group C2): 1. No changing between the treated piece and the untreated test piece

2. No observed ink transfer on the receptor surface, fig (19)

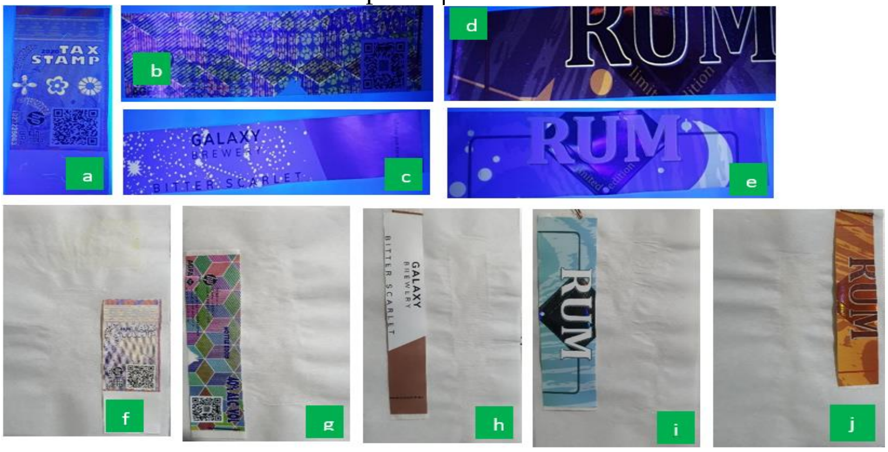


Figure (19): a) the invisible ink observation in design 1 after alkali test under the UV light source, b) the invisible ink observation in design 2 Group A after alkali test under the UV light source, c) the invisible ink observation in design 2 Group B after alkali test under the UV light source, d) the invisible ink observation in design 2 Group C1 after alkali test under the UV light source, e) the invisible ink observation in design 2 Group C2 after alkali test under the UV light source, f) design 1 filter paper result (visible ink staining) , g) design 2 Group A filter paper result, h) design 2 Group B filter paper result, i) design 2 Group C1 filter paper result (visible ink staining), J) design 2 Group C2 filter paper result

2. Meltable solid agents (Waxes) Test

2/1: Materials

1. Wax
2. Matches

2/2: Test Procedure

1. Melt 50 g of the solid wax in the Petri dish and maintain a temperature of not more than 40 °C greater than its melting point.

2. Immerse a 20 * 50 mm test piece for 5 min, leaving a small section un-immersed to facilitate handling.

3. Remove the test piece and allow to drip on a white filter paper while it is cooling.

- **Wax resistance of Design 1 and its analysis & evaluation**

1. the uncoated printed paper caused that a blur layer has been occurred on the tested piece after erasing the wax layer

2. comparing the treated sample with the un-treated one, appears a transparent layer over the tested sample and it is affected on the UV ink appearance, but still appear clearly under UV light. Fig (20)

- **Wax resistance of Design 2 (Group A) and its analysis & evaluation**

1. the printed polymer layer caused that the wax didn't sticked to it, with easily ability to remove it, no change has been observed over the tested sample

2. design appearance still very clear under UV light, Fig (20)

- **Wax resistance of Design 2 (Group C2) and its analysis & evaluation**

1. the uncoated printed paper accept a blur layer which caused some weakness of the UV inks appearance under UV light. Fig (20)

Figure (20): a) Observation result between the Design 1 reference (to the right side) and tested sample, b) Observation result between the Design 2 Group A reference (to the top) and tested sample, c) Observation result between the Design 2 Group C2 reference (to the bottom) and tested sample

3. Solid Fat (Butter) test

3/1: Material

1. Butter

3/2: Test Procedure

1. Place a 20 * 50 mm test piece with its printed side in contact with the freshly prepared smooth surface of the butter to be tested, temperature about 23° with no pressure on the sample, while the test duration were 24 hours.

3/3: Butter test Analysis & Evaluation

The all butter tested sample has the same evaluation (Design 1, Design 2 Group B, Design 2

Group C1): UV inks appearance were more saturated than the untreated sample, Fig (21)

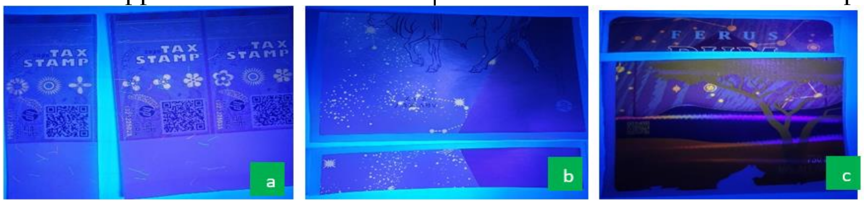


Figure (21): a) Observation result between the Design 1 reference (to the right side) and tested sample, b) Observation result between the Design 2 Group A reference (to the top) and tested sample, c) Observation result between the Design 2 Group B reference (to the bottom) and tested sample

4. Cheese (salted) test

4/1: Material

1. Fresh salted cheese in 4 C temperature and 24 hours in a water vapour saturated atmosphere

4/2: Test Procedure and conditions

1. The temperature is about 23±2 in a duration test for 72 hours with no pressure over the prints sample
2. the token sample piece is 20 * 50 mm. contact the receptor surface (cheese) with the sample for the selected duration

4/3: Cheese test Analysis & Evaluation

Changes has been observed after test ending:

1. design 1: the cheese sticked to the sample uncoated paper, it hardly has been erased, while the compare between the reference sample and the tested sample result show that there's a little bit of reduction in the invisible inks shine (about 5%), but the invisible inks appear very clearly and changes can be hardly observed. while the visible inks have not any change, also sample paper appear exhausted Fig (22)
2. design 2 Group A, B, C: the cheese has been easily erased from sample surface, whereas the comparing between the reference and the tested sample showed reduction in the invisible inks shine (about 5%), but the invisible inks appear very clearly and changes can be hardly observed. On the other hand, the visible inks don't show any change, Fig (22)

Figure (22): a) Observation result between the Design 1 reference (to the right side) and tested sample, b) Observation result between the Design 2 Group A reference (to the top) and tested sample, c) Observation result between the Design 2 Group B reference (to the bottom) and tested sample, d) Observation result between the Design 2 Group C1 reference (to the bottom) and tested sample, e) Observation result between the Design 2 Group C2 reference (to the bottom) and tested sample

10/: Conclusion and recommendations

The new features to secure documents design elements which has been implemented in the experimental design part in Design 1 and design 2 with its groups, by the following companies Agfa, HP, JURA has increased security enhancement to be trust in most printing and packaging sectors even with the complex security designs to keep it anti-counterfeiting.

Using digital printing method to print microtexts, wave-texts, linework, latent image, 2d authentication QR code were very successfully, and with the other security designed features as well as the invisible security design elements with the UV inks. a very good observed quality image has been obtained which can be noticed by naked eyes. In addition to the measures of the Iso brightness which token within the analysis part. The brightness was very high in materials used in the applied experimental.

Even the results of the experimental in the secured visible and invisible parts were very good by the HP UV and Electro-inks. The analysis of both inks types to find their resistant to dry/wet, alkali, acids, wax, cheese, butter showed the following results (with one-layer printed material):

- design 1 were printed on uncoated white paper caused that both wax and cheese sticked to it but the invisible inks still viewed by the UV light with a little bit of un-clearance, whereas it doesn't affect by the acids, while at the alkali test a little of the visible inks staining on the filter paper (magenta ink). In addition to the dry/wet ink resistant test, the uncoated paper is failed soon after 3 cycle in wet ink resistant test (according to ISO standard TAPPI T830 the failure in wet ink resistant test can be obtained after one stroke or cycle), The value of $\Delta E = 1.18$, the tolerance level still within the ISO standard, this clearly that the problem found was because of the uncoated paper not with the reason of inks bleeds, at the dry ink resistant test the uncoated paper could suffer until 150 stroke sequence without ink failure, inks was very clear under UV light, the secured printed paper appearance was very good.

- design 2 have polymer and coated paper groups: wax sticked a little bit, this is caused a minor of blur in ink observations by naked eye under UV light. cheese (salted) caused a little bit of weakness of the invisible ink but still all the designs are clear while observation. On the contrary of the other groups in design 2, At we got to find in group C1 that the UV inks appearance is become saturated (rich in colour) than before test

The cheese effect may be returns to the salt or the milk enzymes: lactoperoxidase, lysozyme, lipase,..etc. so, the author **suggest** here that the better way to analyse the real reason of ink weakness (minor) happened by cheese is to do a future experimental on the effect of each enzyme and salt chemical elements (iodin, Chlorine, sodium ,..etc) on the digital secured printed sample.

The acid test has not affect on the design 2, whereas the alkali test has some ink staining in Group C1, but still no change in UV inks preview. Also we have analyse dry/wet UV and visible ink resistant test result of design 2 groups to found that the durability were very excellent in the dry ink resistant test that may by reach to thousands of cycles without failure even with the heavy block 1.8 kg, the ΔE were very close to the reference with a minor change in it and still the result within the ISO standard tolerance levels, whereas the wet test , in spite of the value of $\Delta E = 5.70$, it exceeds the tolerance range in group A, also in group C1 the value of $\Delta E = 3.85$ but the UV inks still viewed very clearly with a minor change can be noticed to the specialized people, not to the consumers or the non-specialized ones'. Group B and C2 delta E values has in the tolerance range of the ISO standard. The UV inks appearance were very good after testing on both of them.

The all butter tested sample has the same evaluation (Design 1, Design 2 Group B, Design 2 Group C1): UV inks appearance were more saturated than the untreated sample

In general, the results of the experiments analysis tests shows us the future of the digital printed secured samples durability, the very hard bearable during packages contains use or on moving or even bad storage, as well as the durability of certifications and other secured documents handling, the digital printing integrated successfully with the new designs and program features to introduce another age of anti-counterfeiting , it is suitable and recommended for future use in both packaging and prints sector (except the banknotes secured printing method and its high level secured features).

- **Difficulties** may faces consumers in securing packaging sector: that not all the people have a UV light source to ensure that the product is original or taxed paid. In another solution the markets could buy a UV source, it only costs about 250 Egyptian pounds. Each person buys a product can make sure of it by use the UV test before s/he leaving the market.

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