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# Effect of the Printing Remedies and Lamination Techniques on Barrier Properties "WVTR and OTR Value" for Polypropylene Film

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## Abstract

**Objective:** To evaluate the main factors especially printing remedies "coating and lamination whether wet or dry technique" which affecting the strength of barrier properties of the plastic film against gasses and water vapor transmissions, that films used in the packaging of food products.

**Methods:** Six packaged samples printed and transparent polypropylene films 20 microns with metalized polypropylene for one kind of Egyptian snacks food product before packing. In addition, three samples of the same product but after packing process with different concentration of oxygen.

Regarding the gas and moisture permeability tests, all samples were analyzed by OTR permeation analyzer (Oxygen transmission rate), "from Systech Illions company- Model 8501 under ASTM D 3985 conditions". In terms of WVTR permeation analyzer (Water Vapour transmission rate), "from Systech Illinois company- Model 7001 under ASTM F-1249 Conditions". Whereas oxygen concentration tests were conducted on inside the food packaged by $O_2$ tester from WITT-GASETECHNIK company under lab conditions.

**Results:** The impact of printing materials in each of OTR and WVTR results have a positive impact where the permeability has decreased, therefore, increased the ability of plastic film to prevent the gasses and moisture from going throw the package. Results from oxygen concentration experiments have shown that there was an influenced of oxygen with this characteristic Fatly free acid and peroxide value presence inside the product with a slight change, but totally there was a change in the chemical properties of the product.

**Conclusions:** The findings from this study emphasize the importance in canteen lunches in terms of nutritional quality as well as quantity, especially in terms of fat and SFA. Even if the overall menu, considered over a week, may meet SNSSL, this study indicates that (owing to food choices made by children in the canteen) the actual lunchtime nutrient intakes of children consuming canteen lunches were often far from achieving the nutritional standards.

***Keywords:*** *Printing remedies; Barrier properties; polypropylene film; WVTR; OTR*

## Abbreviations

BOPP: Biaxially Oriented Poly Propylene; OTR: Oxygen transmission rate; WVTR: Water Vapour transmission rate

## Introduction

A wide variety of food packaging materials has many important characteristics to protect food products against moisture, oxygen, ethylene and other gasses. This material is called a barrier material which likes glass and metal and some Plastics. The barrier properties

reduce degradation of the food products and prevent odors from leaving the product which could attract animals and insects. Hermetically sealed packages prevent or reduce potential contamination by animals, insects or microorganisms.

**The Definition of Barrier in dictionary**

1.1. Something blocks or intended to block passage
1.2. Natural formation or structure that prevents or hinders movement or action

**Using Barrier in Food Packaging**

One of the core functions of plastic films is making a protection against environmental impact, so There are three basic reasons for using barrier material for food packaging products:

2.1. Keep desirable elements in (such as flavor, aroma or a controlled atmosphere).
2.2. Keep undesirable elements out (such as moisture, oxygen or other corrosive gasses).
2.3. Avoiding migration from within the film into the packaged goods

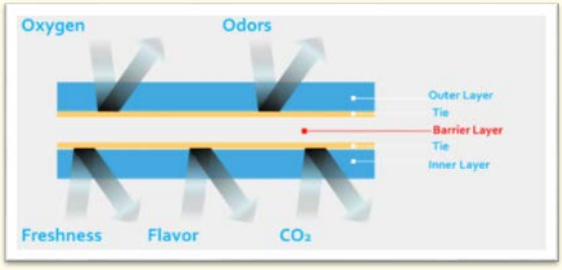



***Figure 1:*** *Functionality of Barrier Layers.*

**Moreover, permeability rates depend on three factors: -**

3.1. Nature of the polymer film
3.2. Nature of the gas
3.3. Interaction between the gas and the film

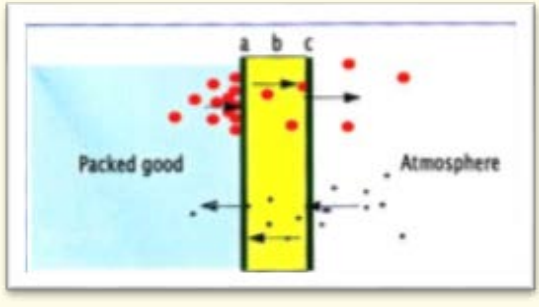



***Figure 2:*** *Figure 2: The main factors of permeability process.*

According to the plastic film, Biaxial oriented polypropylene film (BOPP) is recognized as an appropriate barrier film for most dry food after lamination with metalized film whether OPP or PET, moreover that film is considered an excellent for moisture and moderate for oxygen permeability recording around "6.0g/$m^2$/day at 38°C, 90% RH" and "1600 cc/$m^2$/day at dry conditions and 23°C" respectively regardless to pira international Ltd. But the question is if that number still remain as the same or changing up forward or down after the printing and lamination process and it has an influence on the quality of the dry food "snacks food especially" or not.

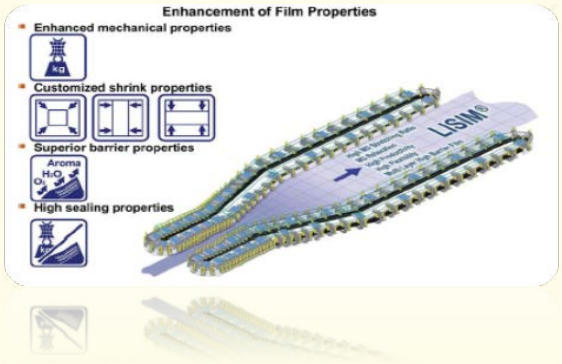



***Figure 3:*** *The benefit of using orientation process to Polypropylene film.*

There are many Advantages of use Polypropylene film as a food packaging material:

1. Excellent Tensile strength, and stiffness.
2. Good machinability properties.
3. An environmental material.
4. Good compatibility to produce metallized films.
5. Moderate cost. (lowest plastics density)
6. Relatively high melting point (150 :160°C)
7. Permanent-heat resistant
8. High chemical resistance
9. Electrically conductive
10. High corrosion resistance
11. Excellent processing capability

However, the disadvantage appears on this main characteristics:

1. Bad Gas barrier
2. Poor tear strength and Puncture resistant

3. Low wettability

4. Non- heat sealable

| OTRS of Bulk materials | | | |
|---|---|---|---|
| **Film type** | | **OTR 73°f (23°C), 0%. RH CC/100 in 2/day** | **CC/m²/day** |
| EVOH (ethylene vinyl alcohol) | Good barrier | 0.005-0.12 | 008-1.9 |
| Biax nylon-6 | | 1.2-2.5 | 18.6-39 |
| OPET (oriented polyester) | | 2-6 | 31-93 |
| BOPP | | 100-160 | 1,550-2,500 |
| Cast pp | | 150-200 | 2,300-3,100 |
| HDPE (high-density polyethylene) | | 150-200 | 2,300-3,100 |
| OPS (oriented polystyrene) | | 280-400 | 4,350-6.200 |
| IDPE (low-density polyethylene) | poor barrier | 450-550 | 7.000-8,500 |

***Table 1:*** *OTR Permeability properties of Polypropylene and other plastic films.*

| Typical WVTR barrier values | | | |
|---|---|---|---|
| **Film type** | | **WYTR.100°(30°C),), 90%. RH G/100 in 2/day** | **g/m²/day** |
| Biaxial-Oriented PP | Good WYTR | 0.25-0.40 | 3.9-6.2 |
| HDPE | | 0.3-0.5 | 4.7-7.8 |
| Cast pp | | 0.6-0.7 | 9.3-11.0 |
| Biax PET | | 1.0-1.3 | 16-23 |
| LDPE | | 1.0-1.5 | 16-23 |
| EVOH | | 1.4-8.0 | 22-124 |
| OPS | | 7-10 | 109-155 |
| Biax NYLON-6 | Poor WYTR | 10-13 | 155-202 |

***Table 2:*** *WVTR Permeability properties of Polypropylene and other plastic films.*

***Source:*** *Jonathan Flowe, Barrier films for packaging, Pira International Ltd, 2005.*

## Barrier plastic Films Classification


***Source:*** *Jonathan Flowe, Barrier films for packaging, Pira International Ltd, 2005.*

| Barrier Classification | Oxygen ASTM D3985 | Moisture ASTM F1249 |
|---|---|---|
| LOW | > 100 $cm^3/m^2$/24 hr | > 100g/$m^2$/24 hr |
| Medium | 6-100 $cm^3/m^2$/24 hr | 6-100g/$m^2$/24 hr |
| High | 1-5 $cm^3/m^2$/24 hr | 1-5g/$m^2$/24 hr |
| Very High | < 1 $cm^3/m^2$/24 hr | 1g/$m^2$/24 hr < |

***Table 3:*** *Barrier plastic Films Classification.*

***Source:*** *PCI Films Consulting Ltd.*

According to the foodstuff: Snack foods "snacks" Considered of processed food products and they are intended to does not substitute for the main meal of the day, such as potatoes and candy chips, baked goods, characterized as give the body the necessary energy between meals. Nevertheless, World consumption of Snack foods and as much as about 107 million tons in 2003, also estimated growth have increased by 3-4% per year that sales reached $ 20 billion in 2010 and then by the Organization of simther Pira, and considers these products it is very sensitive to oxygen gas products so it requires a high level of reservation.

| Item | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|
| Snack Food Packaging (mil $) | 2985 | 3628 | 4695 | 5640 | 6650 |
| % raw materials | 52.0 | 51.7 | 54.2 | 53.5 | 53.1 |
| Raw Materials Demand (mil $) | 1551 | 1876 | 2547 | 3016 | 3534 |
| $/lb | 0.41 | 0.43 | 0.58 | 0.64 | 0.69 |
| Raw Materials Demand | 3756 | 4346 | 4395 | 4740 | 5130 |
| Plastic | 1710 | 2035 | 2145 | 2435 | 2750 |
| Paper | 1430 | 1695 | 1685 | 1715 | 1760 |
| Metal | 200 | 235 | 225 | 240 | 255 |
| Other | 416 | 381 | 340 | 350 | 365 |

***Table 4:*** *Snack food market share distribution from 1995 to 2015.*

## Materials and Methods

### Materials

**Samples**

1.1. Plain Transparent BOPP 20 Micron from EGYWRAP Company

1.2. Printed BOPP film 20 Micron from Rorographia Company

1.3. Laminated BOPP Printed film 20 with 20 microns metalized BOPP film

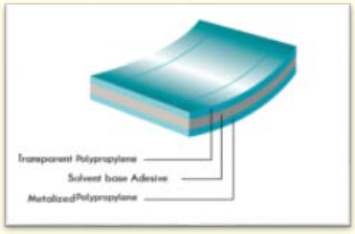



***Figure 4:*** *Structure layers of Polyprobylene film.*

**Devices**

2.1. Oxygen Transmission permeation analyzer

Test conditions

2.1.1. Temperature 23 degrees.

2.1.2. Humidity zero % “and is to be inside the machine”.

2.1.3. Standard used ASTM D 3985

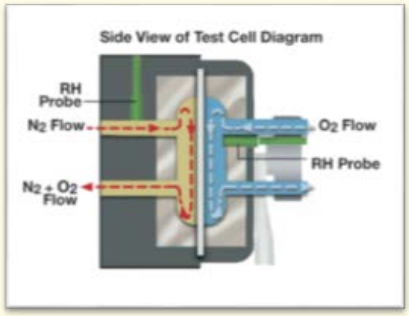



***Figure 5:*** *OTR Device.*

2.2. Water Vapour Transmission permeation analyzer

Test conditions

2.2.1. Temperature 23 degrees Celsius.

2.2.2. Humidity 80-90% “and it is to be inside the machine”.

2.2.3. Standard used ASTM F-1249

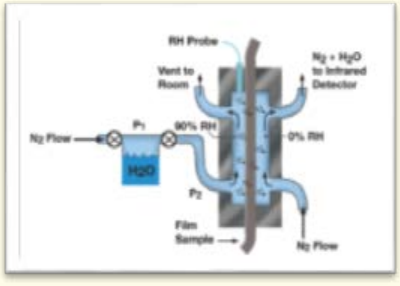



***Figure 6:*** *WVTR Device.*

2.3 Oxygen Concentration tester

Test conditions

2.3.1. Temperature 23 +/- 2 O

2.3.2. Humidity 50-60%

***Figure 7:*** *Oxygen Concentration tester.*

### 2.4. Printing machine

Plastic films are printed on Rotomec Rotogravure model machine 4003 composed of 10 units of printing, production of Bobst company.

| | **Rotomec 4003 MP** |
|---|---|
| Web widths | 850 to 1550mm (33.5 to 61 in) |
| printing cylinder repeat | 400 to 920 mm (15.8 to 36.2 in) |
| max. speed | 350 m/min {1150 ft/min) - 400 m/min* (1312 ft/min*) |
| web tension | 30 to 350 n {7 to 79 lbf) |
| standard dryer inside length | 2.2 to 4.4 m (7.2 to 14.5 ft) |
| High efficiency dryer inside length | 2.5 to 7.0 m {8.2 to 23 ft} |
| Healing system | thermal oil, gas steam electric |

***Tabel 5:*** *Technical specifications of the machine Rotomec 4003, which has been printing them.*

**Methods:** Practical program consists of two main parts, namely:

### The First part

Identify the factors that affect the Barrier Properties, including those related (oxygen permeability OTR properties - water permeability WVTR vapor) prior to printing on polypropylene films directed in two axes, both Metalized BOPP and Transparent BOPP in order to determine the effect of the change permeability of the raw material due to the lamination techniques the impact of printing variables on the permeability either positively or negatively.

1.1. The first experiment: measuring the oxygen permeability OTR before lamination after lamination "solvent base technique".
1.2. The second experiment: measuring water vapor permeability WVTR before lamination after lamination "solvent base technique".
1.3. Where the measurement of polypropylene film in three cases:
1.3.1. The first sample is transparent film only 20 microns' thickness.
1.3.2. The second sample printed film only thickness of 20 microns.
1.3.3. The third film sample printed and laminated with polypropylene mineralized film thickness of 20 microns.

### The second part

Identify the factors that affect the Barrier Properties, including those related (oxygen permeability OTR properties - water perme-

ability WVTR vapor) prior to printing on polypropylene films directed in two axes, both Metalized BOPP and Transparent BOPP in order to determine the effect of the change permeability of the raw material due to the lamination techniques the impact of printing variables on the permeability either positively or negatively.

2.1. Measuring the impact of change the concentration ratios of O2 on the biological effect on potato chips on the same production line on exact time periods "30 days" in different places of storage "wet - dry - medium": -

2.1.1. Oxygen ratio is greater than 5 % < (O2) inside the plastic bag (printed and laminated with polypropylene mineralized film thickness of 20 microns).

2.1.2. Oxygen ratio is smaller than 5 % > (O2) packaged inside the plastic bag.

2.1.3. Normal air without the injection of nitrogen (O2 = 21%) packaged inside the plastic bag.

2.2. Measuring the impact of change the concentration ratios of O2 on the biological effect on potato chips on the same production line on exact time periods "30 days" in different places of storage " wet - dry - medium ": -

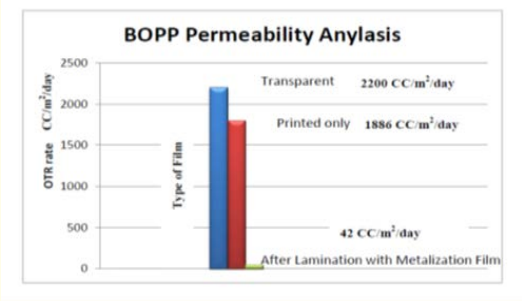
2.2.1. Oxygen ratio is greater than 5 % < (O2) inside the plastic bag (printed and laminated with polypropylene mineralized film thickness of 20 microns).

2.2.2. Oxygen ratio is smaller than 5 % > (O2) packaged inside the plastic bag.

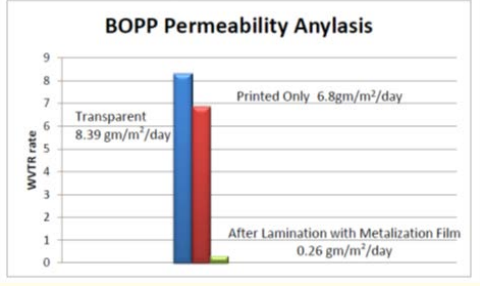
2.2.3. Normal air without the injection of nitrogen (O2 = 21%) packaged inside the plastic bag.

## Results

### First Part




***Graph 1:*** *Permeability OTR of polypropylene film after and pre-printed and lamination.*




***Graph 2:*** *Permeability WVTR of polypropylene film after and pre-printed and lamination.*

### Second Part

| Date | Location | Test Name | $0_2$- | $O_2$+ | Air |
|---|---|---|---|---|---|
| | inside lab | flavor percent | 1.40% | 1.42% | 1.38% |
| | | oil content | 31.40% | 32.30% | 31.20% |
| | | moisture percent | 1.30% | 1.10% | 1.10% |
| | | oxygen percent | 3.00% | 12.40% | 21.40% |
| | | peroxide value | 0.4 gm/km | 0.38 gm/km | 0.38 gm/km |
| | | free fatty acid (FFA) | 0.18% | 0.18% | 0.18% |
| | | air level high in product | 5.5 cm | 5.7 cm | 5.4 cm |
| **After 30 days** | outside lab | flavor percent | 1.28% | 1.30% | 1.35% |
| | | oil content | 31.80% | 33.40% | 31.50% |
| | | moisture percent | 1.20% | 1% | 1.40% |
| | | oxygen percent | 2.80% | 12.20% | 21.50% |
| | | peroxide value | %0.17 | %0.12 | %0.18 |
| | | Free fatty acid (FFA) | 0.18% | 0.18% | 0.18% |
| | | Air level high in product | 5.8 cm | 5.8 cm | 5.5 cm |

***Tabel 6:*** *The impact of an increase or decrease of oxygen on potato chips after 30 days.*

## Discussion

### First Part

Through the results of OTR became clear to us that printing materials had a positive impact where the ratio converted from 2200 to 1886 CC/ $m^2$/ 24H, while in comparison with the film after lamination has reached to 42, therefore we find that the film Aluminum and laminating adhesives have increased the final barrier capability very large margin.

Through the results of WVTR became that printing materials had a positive impact of ratio of 8.3 to 6.8g/ $m^2$/ 24H, while in comparison with the film after lamination has reached to 0.26, and therefore, they also worked to reduce the number to a premium rate recommended by the World Organization Pira, which should be in the range of 0.3-0.5.

### Second Part

It is clear from the results of the experiment influenced Free Fatly acid, as well as the presence of oxygen Peroxide Value inside the product, but was up slightly, but there are changes in these properties, but these changes still did not exceed the standard specification of the plant which is more than the one mark.

## Conclusions

1. Although the film Aluminum work to enhance the barrier to 42 in oxygen permeability of the film but the ratio recommended by the World Organization Pira when record potato chips should be from 5 to 10CC/ m2/ day, so it is necessary to access to this medium to ensure the high quality of the product by adjusting the factors that increase the quality of the film.

2. Oxygen ratio must not increase more than 5% inside the plastic bag packed with slices of potatoes in order to be affected both Peroxide Value, Free fatty acid (FFA)

3. Advised to follow up on these measurements over spaced days for a period of six months, a period of validity of this the product to make sure to ensure the stability of these properties.

4. Commitment to implementing the system BRC British Retail Consortium and HACCP System the application of nitrogen injection technology Nitrogen Injection (Flashing) and use the tracking system Traceability to the quality of the product through the various stages of his technique Modified atmosphere packaging.

## Acknowledgment

Egypt's foods company for snacks food, EGY wrap for Proplypropalyne manufacture, Rotohouse for rotogravure printing presses.

## Competing Interests

The author declares that he has no competing interests.

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