Iraqi Journal of Industrial Research, Vol. 9, No. 2 (2022)

Iraqi Journal of Industrial Research (IJOIR)

Journal homepage: http://ijoir.gov.iq

Improving the Confining Properties against Oiling and Wetting of the Cardboard Paper Using PET Nanoparticles Coating

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Article information

Article history:
Received: August, 18, 2022
Accepted: September, 21, 2022
Available online: October, 20, 2022

Keywords:
PET nanoparticles,
Cardboard,
Confining properties,
Oil leakage

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DOI:
https://doi.org/10.53523/ijoirVol9I2ID266

Abstract

Paper or cardboard with porous surfaces have been transformed into oil- and water-resistant surfaces by coating them with nano-PET to fill the pores and increase their ability to absorb oil while keeping the fibers from swelling. Experimental results show that using PET nanoparticle solution as coating for cartoon have a strong effect on its mechanical properties especially as confining properties. Cartoon coated show high resistance against water absorption for cartoon with three layers of paint (two sides) where the ratio reach to 41.7% as compare with 16.4% for cartoon without coating also show high confining properties against two kinds of oils (cooking and machine), where the experimental result for the cartoon with two layers of paint lowest absorption for cooking oil about 0.018 g compared with carton without coating with 0.122g while for machine oil carton with three-layer paint (two side) show the difference in weight about 0.012g and without coating its about 0.026g. Furthermore, high binding energy between the PET nanoparticle solution with the cardboard molecules, which refers that the compatibility between the surface of the treated carton and the PET polymer has occurred, providing a good adhesion between carton and coating solution.

1. Introduction

Carton surface coating with nano-polymer represent the final treatment for the carton production thus decreasing the affecting the porosity, where thickness of the paper increases [1]. This process is one of the methods of providing resistance or barrier properties on a paper or cardboard against water. Density increase creates a barrier against oil, grease and gasses. However, the most efficient way of providing barrier property is through treatments applied on the surface of paper of cardboard after production. In other words, coating or gluing the paper or cardboard surface with suitable materials and methods. Generally gluing process is performed for providing barrier properties. Natural or artificial glues are used for gluing process [2].

The most important application of paper and paperboard is in corrugated paperboard packages [3, 4]. Corrugated paperboard is inexpensive and lightweight, having a high strengthtoweight and stiffnesstoweight ratios, making the material the best choice for the manufacturing of packages for the transportation of products [5]. Corrugated paperboard is an orthotropic sandwich structure consisting of the surface plies known as liners, providing bending stiffness, separated by a lightweight bending core (fluting) that provides shear stiffness.

The analysis of the structural components of the paperboard and investigation of the strength and stiffness properties are very crucial in the design of paperboard packages [5, 6]. Understanding these properties reduces the damage to the product due to lateral crushing and compression loads from stacking. Furthermore, buckling may be avoided by knowledge of these properties and understanding the response of paperboard packages is an important step in designing of packages [5, 7]. Biancolini et al. [6] identified the proper combination of paper for corrugated board as a factor that can affect package design and highlighted the uncertainties involved in the process of design due to the variation in the mechanical properties of paper.

A lot of polyesterspolymers present on the market are used in the packaging field, such as polyethylene terephthalate (PET), polyethylene naphthalate (PEN), and relative copolymer PET-PEN. These are the most common polyesters polymers used in packaging industry due to them good physical and chemical properties like heat resistance, good abrasion resistance, good thermal and mechanical behaviour. All the chemical-physical characteristics of these materials are well described in the literature [8–10]. For example, a decreasing in mechanical properties of the coated carton with polymer layer can be happened due to absorption of ambient liquid that cause an increase of polymer plasticization, [11, 12].

PET, a semicrystalline, lightweight, and water-resistant thermoplastic polymer, can be considered the largest used polymer in the production of packaging films, textiles and bottles, with a worldwide production of at least 30 million tons per year [14]. PET thermoplastic is a semicrystalline, lightweight, and water-resistantmaterial [9]. PET has been widely used for decades for food packing and beverages because of its high resistance, microorganism repulsion and corrosion resistance (FDA). PET (polyethylene terephthalate) is a thermoplastic polymer of commercial importance and has been widely used in several segments of the world industry, mainly in the production of plastics, fibres and films [15]. is versatility being due to its excellent physical and chemical properties [16]. Chitosan coating as Water- and oil-resistant materials are useful for porous cellulosic substrates such as paper, corrugated board, cardboard, and fabrics into a water- and oil-resistant materials [17]. Using polymeric coatings for cardboard, a reduction in water absorption values (up to −98%) have been obtained [18]. Our experimental results show that using PET coating for cartoon have a strong effect on its mechanical properties as confining properties such as high resistance against water, cooking oil and car machine oil absorption.

2. Experimental Procedure

2.1. Materials used

- Nanoparticles of Poly ethylene teraphela (PET)
- Dimethyl sulfoxide solvent (DMSO)
- Cooking oil (trade mark ALDAR)
- Carmachine oil (ARAL G-Oil 10W-30) brand
- Cardboard

2.2. Used Equipment

- Oil impregnation device
- Magnetic mixer

2.3. Preparation Method

0.08g weight of polyethylene terephthalate (PET) powder with natural colour from Good Fellow Cambridge Ltd, USA have been dissolved in 25 cc of DMSO solvent for (5-6) hours at (80-100 °C). Then the solvent was used to paint the external layer of (6 samples) of carton (paperboard is in corrugated paperboard packages), where 3 pieces of cardboard with dimensions of 15 × 15 cm were painted on one side using the roller, at the rate of one layer for the first sample, two layers for the second and three layers for the third, and in the same way the other 3 pieces with two side coating ,then the samples were left for about 24 hours for drying, and after making sure that the painted pieces were dry, the following checks were carried out. The test for soak is done as follows:

The international standard method issued by (fefco) organization No. (N-7) was adopted and an Australian-made water absorption measuring device (IDM-C0005) was used. This method has been used by a device contains an iron cylinder of 10 kg used to dry samples and metal ring with a cross-sectional area of (100) cm^2 and a depth of 5cm, attached to a rubber base equipped with a mechanical system that allows the cylinder to press on the base to prevent water leakage from the bottom of the cylinder. Where the examination includes weighting dry samples, then placed it in the examination device at the bottom of the cylinder and a quantity of distilled water was poured over it, provided that the height of the water was not less than 3 mm inside the cylinder and left for a quarter of an hour. Then the iron cylinder back used for draining the excess water. The sample was weighed while wet, and the weight of the water absorbed by the sample was calculated by subtracting the weight of the wet sample from the weight of the dry samples.

3. Results and Discussion

The experiential results have been obtained in Table (1) which show the soaking ratio of carton (paperboard is in corrugated paperboard packages), where the Figure (1) show with the upper row the coating with single layer while the second row show the samples coated with two faces.

Figure (1). The shape of the carton samples with and without coating.

Table (1). The soaking ratio of carton (paperboard is in corrugated paperboard packages).

sample	Weight before soak	Weight after soak	The difference in weight
Without paint	11.33	20.8	9.47
With one layer paint (one side)	11.80	23.80	12
With two-layers paint (one side)	12.25	22.7	10.45
With three layers of paint (one side)	12.29	20.3	8.01
With one layer paint (two side)	12.20	20.82	8.62
With two layers paint (two side)	12.25	21.30	10.05
With three layers of paint (two side)	12,40	19,63	7.23

It's clear that coating with three layers of nano PET solution on the surface of carton can decrease the ratio of the absorbed water of the carton layers, and as results decrease its weight and improving the confining properties of the carton. The experimental results show that the cartoon with three layers of paint (two side), and three layers of paint (one side) have the maximum confining properties as compared with others especially with one-layer paint (one side) that show the lower confining properties. Carrying out an oil impregnation test, which is done as follows: We place the carton to be examined with one or two sides on the test surface and withdraw small drops by means of a glass or plastic dropper. At a height of 1.5 cm, we drop one or two drops as needed, making sure that the tip of the dropper does not touch the carton, and when adding the drop, we start timing with a stopwatch. After 15 seconds of adding the drops, the excess of the drops on the surface of the standard carton is quickly removed by cotton or blotting paper, and after wiping, the surface of the carton is tested. The cartoon is considered a failure in the event that any dark spot appears on the carton, even if it is small, or even if a small part of the oil (machine or cooking) has run out to the second side of the carton, and Tables (2 & 3) show the results of the tests for examining the used carton before and after the nano-coating.

Table (2). Improving the confining properties of the carton against cooking oil.

sample	Weight before soak	Weight after soak	The difference in weight
Without paint	2.760	2.788	0.122
With one layer paint (one side)	2.812	2.846	0.034
With two layers of paint (one side)	2.866	2.884	0.018
With three-layer paint (one side)	2.946	2.973	0.027
With one layer paint (two side)	2.856	2.875	0.019
With two layers of paint (two side)	2.884	2.913	0.029
With three-layer paint (two side)	2.863	2.963	0.1

It is clear from Table (2) that coating carton with all types (one, two and three) layers in one and both side with nano PET solution on the surface of carton can decrease the ratio of the absorbed cooking oil of the carton layers, and as results decrease its weight and improving the confining properties of the carton.Where the carton with two layers of paint (one side) shows the maximum confining properties then the cartoon with one layer paint (two side) as compare with the carton without coating by ratio about 10 times.

Table (3). Improving the confining properties of the carton against machine oil.

sample	Weight before soak	Weight after soak	The difference in weight
Without paint	2.820	2.846	0.026
With one layer paint (one side)	2.794	2.820	0.026
With two layers of paint (one side)	2.916	2.939	0.023
With three-layer paint (one side)	2.783	2.813	0.03
With one layer paint (two side)	2.935	2.954	0.019
With two layers of paint (two side)	2.837	2.852	0.015
With three-layer paint (two side)	2.940	2.952	0.012

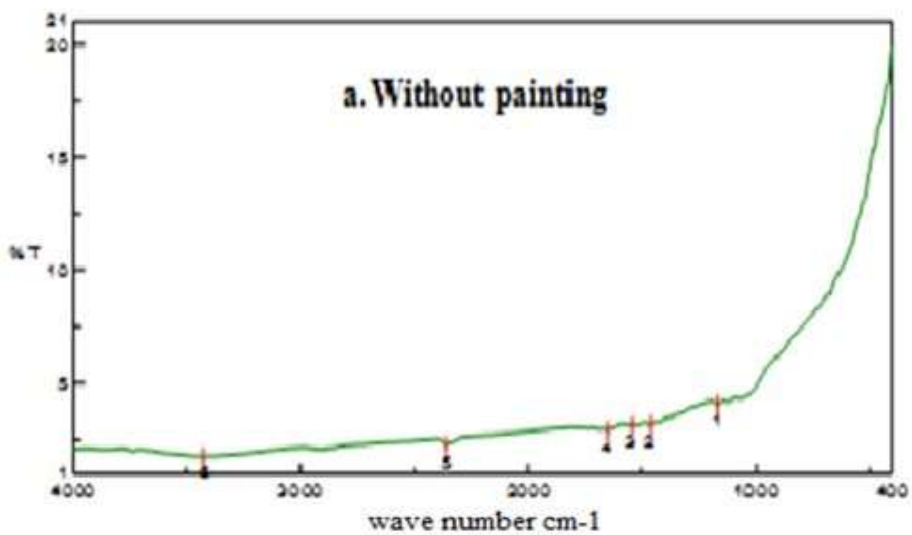
It is clear from Table (3) that coating carton with all types (one, two and three) layers of both side with nano PET solution on the surface of carton can decrease the ratio of the absorbed machine oil of the carton layers, and as results decrease its weight and improving the confining properties of the carton, where the carton with three layers of paint (two sides) show the maximum confining properties then the cartoon with two layers paint (two sides) as compare with the carton without coating.

3.1. FTIR Measurements

FTIR measurements have been obtained in the lab. of industrial research and development authority in Baghdad/Iraq by using Model FT/IR-4200 typeA with Serial Number (C092361018) and the conditions of measurements are:

Start	349.053cm^{-1}	End	7800.65cm^{-1}
Datainterval	1.92847cm^{-1}	Data points	3865
Light Source	standard	Detector	TGS
Accumulation	10	Resolution	8cm^{-1}
ZeroFilling	On	Apodization	Cosine
Gain	Auto (8)	Aperture	Auto(7.1mm)
ScanningSpeed	Auto (2 mm/sec)	Filter Auto	30000 Hz

It is clear that the intensity of the control sample in the Table (4.1) has lower intensity as compared with the samples with one-layer single or double faces, also the samples with the two- and three-layers double faces have higher intensity than in single phase and the control reference (without coating). These results can be explained as a function of the binding energy between the PET nanoparticle solution with the cardboard molecules, in other word, it refers that the compatibility between the surface of the treated carton and the PET polymer has occurred, providing a good adhesion between carton and coating solution.



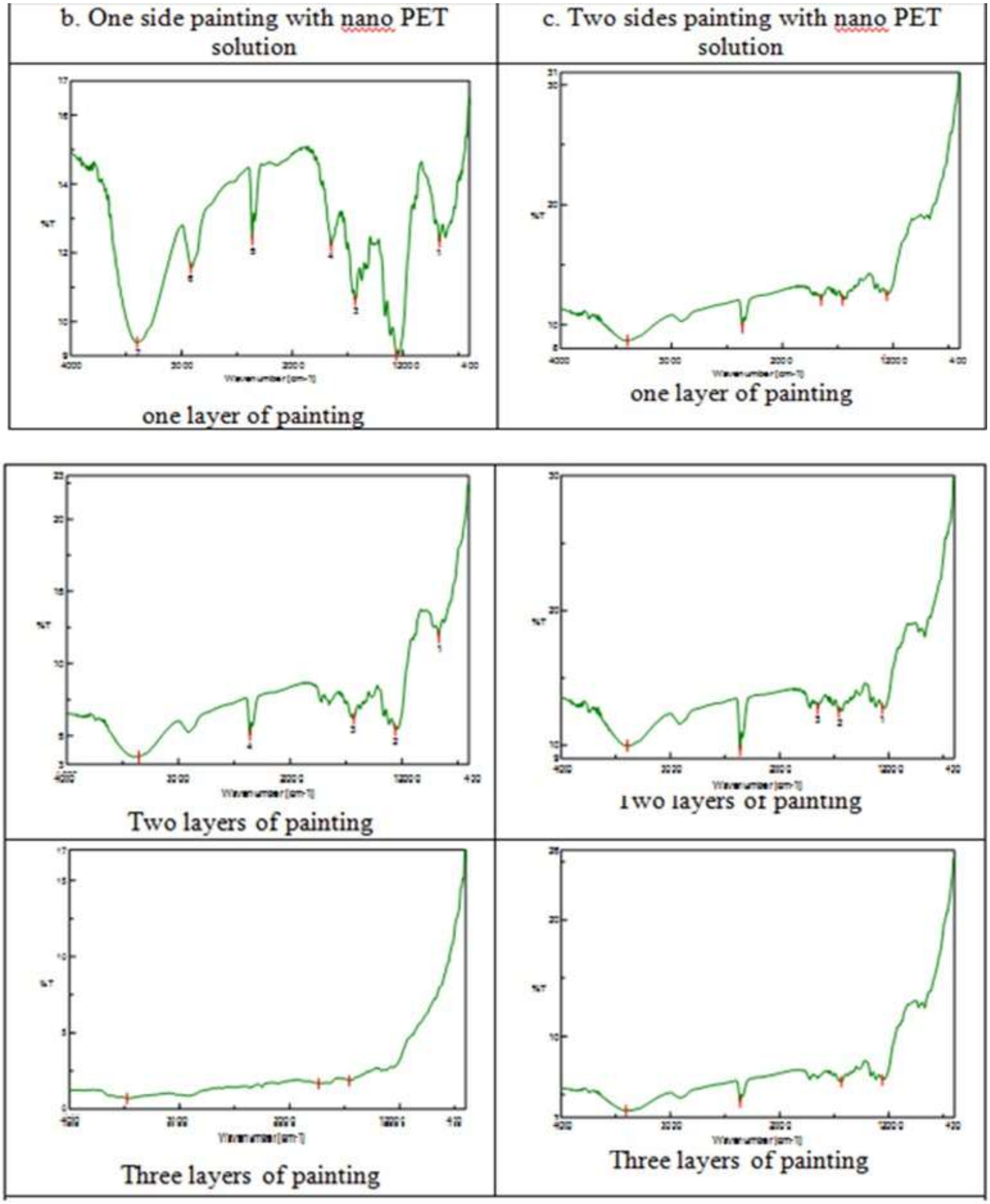


Figure (2). FTIR results for sample b. with one side painting and c. for two sides painting, where the x-axis is the wavelength and Y- axis is the intensity.

Tables (4). FTIR measurements.

Table (4.1). FTIR results for reference cardboard.

No.	Position	Intensity
1	1166.72	4.05424
2	1457.92	3.13704
3	1540.85	3.0912
4	1650.77	2.87312
5	2360.44	2.21607
6	3423.03	1.70357

Table (4.2). FTIR results for one-layer coating (single face) cardboard.

No.	Position	Intensity
1	671.106	12.3131
2	1058.73	9.02528
3	1432.85	10.6151
4	1650.77	12.1947
5	2360.44	12.3761
6	2915.84	11.5549
7	3401.82	9.39093

Table (4.3). FTIR results for two layers coating (single face) cardboard.

No.	Position	Intensity
1	1164.79	4.36457
2	1650.77	3.15993
3	2360.44	2.17922
4	3417.24	1.72647

Table (4.4). FTIR results for three layers coating (single face) cardboard.

No.	Position	Intensity
1	1457.92	1.85127
2	1735.62	1.67111
3	3475.1	0.699782

Table (4.5). FTIR results for one-layer coating (two faces) cardboard.

No.	Position	Intensity
1	1056.8	12.4483
2	1457.92	12.0574
3	1650.77	12.0487
4	2360.44	9.74904
5	3397.96	8.6649

Table (4.6). FTIR results for two layers coating (two faces) cardboard.

No.	Position	Intensity
1	1058.73	12.7028
2	1457.92	12.4445
3	1650.77	12.689
4	2360.44	9.62036
5	3394.1	9.94283

Table (4.7). FTIR results for three layers coating (two faces) cardboard.

No.	Position	Intensity
1	669.178	11.8188
2	1058.73	5.40055
3	1432.85	6.18325
4	2360.44	5.04218
5	3355.53	3.53454

4. Conclusions

Using PET nanoparticle solution as coating for cartoon have a strong effect on its mechanical properties especially as confining properties. Cartoon coated show high resistance against water absorption in one-layer single and two faces and also show high confining properties against two kinds of oils (food and machine), furthermore high binding energy between the PET nanoparticle solution with the cardboard molecules, which refers that the compatibility between the surface of the treated carton and the PET polymer has occurred, providing a good adhesion between carton and coating solution.

References

[1] MAURER, Hans W., Starch in the Paper Industry, in: Starch: Chemistry and Technology, James BeMiller, Roy L. Whistler (eds.), Chapter 18, Elsevier, USA, 2009.
[2] B. ROBERTSON, Gordon L. Paper and Paper Based Packaging Materials, in: Food Packaging: Principles and Practice, Chapter 6, CRC Press, FL, USA, 2016.
[3] L. Beldie, G. Sandberg and L. Sandberg, "Paperboard packages exposed to static loads– finite element modelling and experiments," *Packaging Technology and Science*, vol. 14, no. 4, pp. 171–178, 2001.
[4] A.C. Gilchrist, J.C. Suhling and T.J. Urbanik, "Nonlinear finite element modelling of corrugated board," *ASME Applied Mechanics Division-Publications AMD*, vol. 231, pp. 101–106, 1998.
[5] M.E. Biancolini, "Evaluation of equivalent stiffness properties of corrugated board," *Composite Structures*, vol. 69, no. 3, pp. 322–328, 2005.
[6] M.E. Biancolini, C. Brutti, E. Mottola and S. Porziani, "Numerical evaluation of buckling and post-buckling behaviour of corrugated board containers," in XXXIV Convegno Nazionale, 2005.
[7] N. Talbi, A. Batti, R. Ayad and Y.Q. Guo, "An analytical homogenization model for finite element modelling of corrugated cardboard," *Composite Structures*, vol. 88, no. 2, pp. 280–289, 2009.
[8] P. Cala and A. Sciullo, ` Materiali Destinati al Contatto con gli Alimenti, Chirotti, Pinerolo., 2006.
[9] AIM—MacromolecoleScienza e Tecnologia, vol. 1-2, 2003.
[10] D. S. Lee, K. L. Yam, and L. Piergiovanni, Food Packaging Science and Technology, CRC Press, Taylor & Francis Group, 2008.
[11] Y. Mi, S. Zhou, and S. A. Stern, "Representation of gas solubility in glassy polymers by a concentration-temperature superposition principle," *Macromolecules*, vol. 24, no. 9, pp. 2361–2367, 1991.
[12] L. E. Gerlowski, "Water transport through polymers: requirements and designs in food packaging," in American Chemical Society, Polymer Preprints, *Division of Polymer Chemistry*, vol. 30, pp. 15–16, 1989.
[14] Polyethylene Terephthalate (PET): Production, Price, Market and its Properties. Available online: https://www.plasticsinsight. com/resin-intelligence/resin-prices/polyethylene-terephthalate, 2021.
[15] Katoch, S., Sharma, V., Kundu, P. P., &Bera, M. B. Optimization of PET glycolysis process by response surface methodological approach: a two-component modelling using glycolysis time and temperature. ISRN *Polymer Science*, vol. 2012, 1-9, 2012.
[16] Pacheco-Torgal, F., Ding, Y., & Jalali, S. Properties and durability of concrete containing polymeric wastes (tyre rubber and polyethylene terephthalate bottles): An overview, *Construction and Building Materials*, vol. 30, pp. 714-724, 2012.
[17] Zhao Li, MuhammadRabnawazOil- and Water-Resistant Coatings for Porous Cellulosic Substrates, *ACS Appl. Polym. Mater.*, vol. 1, no. 1, pp. 103, 2019.
[18] Andrea Marinelli, Maria Vittoria Diamanti, Andrea Lucotti, Maria Pia Pedeferri and Barbara Del Curto Evaluation of Coatings to Improve the Durability and Water-Barrier Properties of Corrugated Cardboard Coatings, 12, 10, 2022.