Improving of Recycled Folding Carton Properties by Treatment with Styrene and its Copolymer

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ABSTRACT

Folding carton from recycled carton was prepared and evaluated. Its mechanical properties as breaking length, burst factor, tear factor as well as water absorption (Cobb factor) were investigated. The prepared folding carton was treated with the polystyrene and its copolymer solutions from toluene in the presence of different types of plasticizers. Also, emulsified antishock polystyrene wastes from the aqueous media were used for folding carton treatment using the dipping technique process.

Key words: Styrene butadiene, polystyrene, folding carton, recycled carton, paper packaging.

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INTRODUCTION

Global production of paper for wrapping, packaging, corrugated boxes and other containers increased 75 percent over just the last 5 years [1]. The rapid growing in paper packaging has the effect of exacerbating solid waste handling problems. Disposal of paper products in landfill sites can lead to emissions of the greenhouse gas methane, and incinerating chlorine-bleached paper at landfills may release dioxins into the atmosphere. As a result, the management of this waste has become one of the more pressing issues of the modern age. Emulsified styrene–butadiene (SB) copolymers were used for paperboard coating [2, 3]. It could be used for coating of recycled carton in order to improve its surface characteristics and barrier performance with regard to water vapor [3, 4]. The performance (including a reduction in water vapor and transmission rate) of the coated products was significantly enhanced by a pretreatment (precoating or high-temperature calendaring) of the board. Paper and paperboard are by far the most prevalent sources of packaging materials in the world over. Nowadays paper-pulp is practically completely recyclable and considered as an environmentally friendly material. The use of paper-pulp packaging has become more attractive, than traditional raw materials due to low price of recycled paper, environmental benefits such as biodegradability [5-7], and low cost

of production. So, the treatment of recycled carton by using different types of polymers was used [8] by dipping the sheets technique.

This work aims to, study the preparation of folding carton from the recycled cartons and evaluate its mechanical and physical properties such as breaking length, burst factor, tear factor and water absorption. The mechanical and physical properties of prepared sheets after coating with polystyrene or its copolymers were also studied.

MATERIALS AND METHODS

Sheet formation

The paper sheets were prepared according to the S.C.A standard, using the model S.C.A sheet former (AB Worentzen and Wettre). The sheets were made from different kinds of recycled carton which were collected from different sources. In the apparatus a sheet of 165 mm diameter, surface area 214 cm^2, was formed. The weight of oven dry pulp used for every sheet was about 3.2 gm. After sheet formation, the sheet was pressed for 4 minutes (at 5 kg/cm^2) using a hydraulic press. Drying of the test sheets was made with the help of a rotating cylinder or drum at 100 °C ± 5 for 2 hours. The sheets were then placed for conditioning at 65 % relative humidity and temperature ranging from 18-20°C.

Preparation of laboratory hand-made paper sheets: (Tappi T 205 sp-02).

Beating and disintegration:

All pulp samples were soaked in water for 24 hours before beating in a Jokkro mail beater. The beating process was at 2% pulp consistency at a speed of 150 rpm. At the end of the beating, the pulp was transferred to a 2 liter measuring cylinder. The stock was diluted with water to 2000 ml and processed in disintegrator for 2 minutes at 3000 rpm. Then the degree of the Shopper Regular (°SR) was determined.

Treatment of recycled carton using styrene butadiene antishock polymer:
Styrene - butadiene antishock waste treatment:

The recycled carton sheets were dipped in different concentrations of styrene – butadiene antishock waste solutions (1, 3, 5 and 10 % dissolved in toluene) for 1 min, and then the excess polymer was wiped and left to dry.

Emulsified recycled styrene – butadiene treatment:

Styrene – butadiene antishock waste solution (10 %) in toluene was prepared, from food packaging wastes, then emulsified by its addition drop by drop to water solution containing 1 or

1.5% sodium lauryl sulfate (SLS) as emulsifier and homogenized in a homogenizer for 30 min. The recycled carton sheets were dipped in the emulsified solution of styrene – butadiene antishock waste for 1 min, and then the excess polymer was wiped and left to dry.

Paper testing:

Physical properties of folding cartons:

The conditioned folding carton sheets were weighed and the thickness was measured (TAPPI T 411om10). The sheets were then subjected to the following tests.

Water absorption (Cobb TAPPI T441 om-09):

The water absorption of paper sheets was carried out as the following. The weighed paper sheet was put in Cobb apparatus, 100 ml of water was added over the paper, left for one minute, and then the water was poured. The paper sheet was dried well between two filter papers and the sheet weighed was determined and the Cobb value was calculated as the following equation.

Cobb (g /m^2 .min) = (Weight of paper after - Weight of paper before) X 100.

Basis weight:

Basis weight is measured in the metric system. It is the number of grams per square meter of paper i.e. weight in grams of one square meter of paper.

Basis Weight = Weight of paper sheet in gram/Area of the paper sheet in sq.m.

Strength properties:

Strength properties were estimated according to the TAPPI Standard Method.

Tensile strength and breaking length (TAPPI T 494 om-06):

Tensile strength of the prepared folding carton (FC) is a measure of the resistance of paper to direct tension. It is defined as the forces required to break a strip of paper of a specific length and width of 15 mm. The tensile strength is converted into breaking length which is more accurate since it takes the thickness and basis weight of paper sheet into consideration. The breaking length is the length of paper at which the strip of paper breaks under its own weight.

$$\text{Breaking length (m)} = \frac{\text{Tensile strength, (kg) X Length of strip (m)}}{\text{Weight of strip (kg)}}$$

Also, breaking can be estimated as follows:-

Breaking length (m.) = (200.000 X P / 3R (Kg).

Where: R = Basis weight in g. /m^2 (moisture free basis)

P = Tensile break load in Kg on 15 mm. strip.

Bursting strength:

Bursting strength was conducted according to Tappi standard T 403 om-97, by a Mullen tester (Perkins, Chicepee, Mass, U.S.A). It is defined as the pressure at which a sample of paper sheet bursts. Compressed air is applied to the paper sheet and the rate adjusted so that the paper bursts after 20 seconds. The bursting strength is recorded on the pressure gauge of the tester in Kilograms per square centimeter.

$$\text{Burst factor} = B\ (g / cm^2) / R\ (g / cm^2).$$

Where:

B = bursting strength in g / cm^2,

R = basis weight in g / cm^2. (moisture free basis).

Tear resistance:

The internal tearing resistance is measured by a pendulum type instrument (Elemendorf Tear Tester, Tappi *T* 414 om-12) which measures the amount of the work done in tearing the paper through a fixed distance after the tear has been started by means of a cutter attached to the instrument. The tearing resistance is the average force in gm, required to tear the sheet clamped in the tester.

$$\text{Tear factor} = \frac{\text{Force in (g) to tear a single sheet X 100}}{\text{Basis weight}}$$

Results and Discussions

2-1 **Mechanical and physical properties of recycled carton sheets dipped in different concentrations of Styrene - butadiene antishock waste solutions.**

Recycled carton sheets were treated by dipping for 1 min in different concentrations of styrene-butadiene antishock waste polymer solutions in toluene (1, 3, 5 and 10 %). The mechanical and physical properties results of treated sheets were determined and the obtained results are given in Table1.

From the table it is clear that, the mechanical properties results of treated sheets were negatively affected by dipping, but it is improved with increasing the treated solution concentration up to 10%. Water absorptions properties results markedly improved at all concentrations, the Cobb values decreased by 96-98 % for treated sheets.

Table (1): Mechanical and physical properties of recycled carton sheets dipped in different concentrations of styrene - butadiene antishock waste solutions.

styrene - butadiene antishock waste consentration %	Breaking length (m)	Tear factor	Burst factor	Cobb g/m^2.min.
Blank	1386.8	853.42	125.6	500
1	1265	208.7	42.7	21
3	1391.5	246.68	47.44	18
5	1486.4	313.0	85.18	14
10	2466.8	872.87	170.78	10

2-2. Mechanical and physical properties of recycled carton sheets dipped in 10 % emulsified recycled styrene- butadiene antishock.

Recycled carton sheets was treated by dipping the sheets for 1 min in the emulsified styrene - butadiene antishock wastes 10 % (by emulsification of the polymer solution in aqueous medium) using 1, 1.5 % SLS as emulsifying agent. The mechanical and physical properties of treated sheets were determined and the results are given in Table (2).

From Table (2), it can be seen that the treated sheets mechanical properties did not improved by treatment with 10% emulsified styrene - butadiene antishock wastes. This can be attributed to that the presence of emulsified SLS in water medium swelled the fibers sheets, and decreased the interfiber bonding. In the case of treated sheets with 10 % styrene - butadiene antishock wastes in solvent; the interfiber bonding and crossing between the fiber increases and not swelled due to the presence of solvent which has nearly no effect in the swelling of fibers. Water molecules play an integral role in the interfiber linkage. The free water causes the paper weakness, which is manifested by the reduced mechanical properties of paper as it is obvious in the table 2.

Table (2): Mechanical and physical properties of recycled carton sheets dipped in 10 % emulsified recycled styrene- butadiene antishock waste.

	Breaking length (m)	Tear factor	Burst factor	Cobb g/m^2.min.
Blank	1386.8	853.42	125.6	500
10% styrene - butadiene antishock from toluene	2466.8	872.87	170.78	10
10% styrene - butadiene antishock emulsion + 1 % SLS	1252.3	751.4	113.24	623
10% styrene - butadiene antishock emulsion + 1.5% SLS	811.2	365.01	62.66	752

2-3. Mechanical and physical properties of recycled carton sheets dipped in 10% PS solutions in toluene plasticized by styrene butadiene rubber (SBR)

Impregnation of carton sheets in polymer solution is a common method for improving mechanical properties as well as water absorption of paper sheets [9]. Coating of paper sheets with organic polymeric solutions are used to improve paper sheets properties [10, 11], but due to the rigidity of polystyrene SBR was added as plasticizer [12, 13].

Different amounts of SBR (0.5- 2g) as plasticizer dissolved in 100 ml 10 % PS solution in toluene were prepared. The mechanical and physical properties of carton sheets which dipped in these solutions for 1 minute are determined and the results are represented in Figures (1-4).

From the Figures it is clear that, the presence of SBR and PS solutions improves the mechanical properties of treated sheets. The nature of SBR (rubber properties) causes homogenous coating of polymer on the carton sheets with flexible films. Moreover the polymer solutions increase the elasticity of the paper sheets and decrease its rigidity and consequently improve the mechanical properties of the sheets. It was found that, the Cobb measurements decreases with increasing the amount of SBR in the medium due to the hydrophobic nature of polymers and its water repelling character.

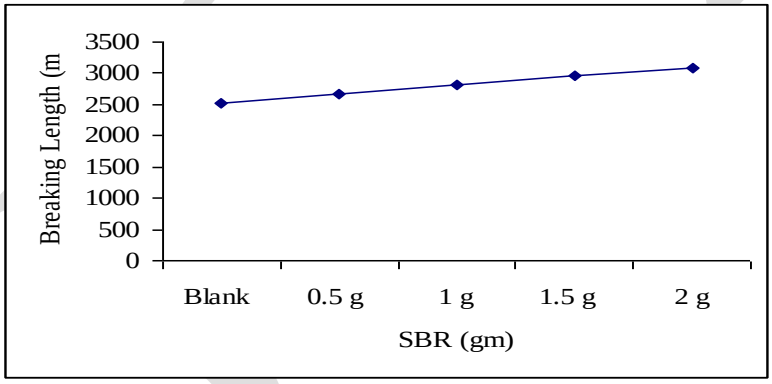

Fig (1): Breaking length of recycled carton sheets dipped in 10 % PS in (toluene) in presence of different amounts of SBR.

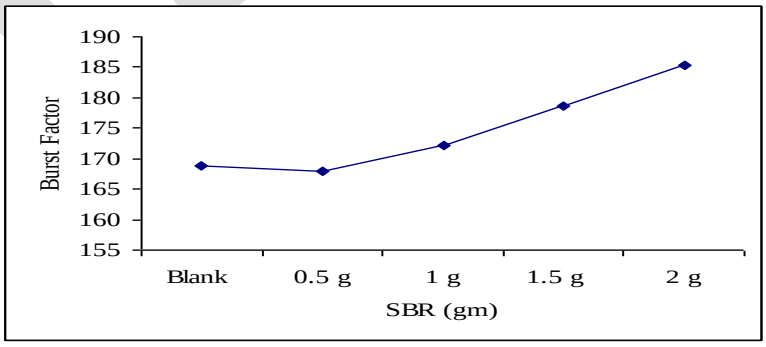

Fig (2): Burst factor of recycled carton sheets dipped in 10 % PS in (toluene) in presence of different amounts of SBR

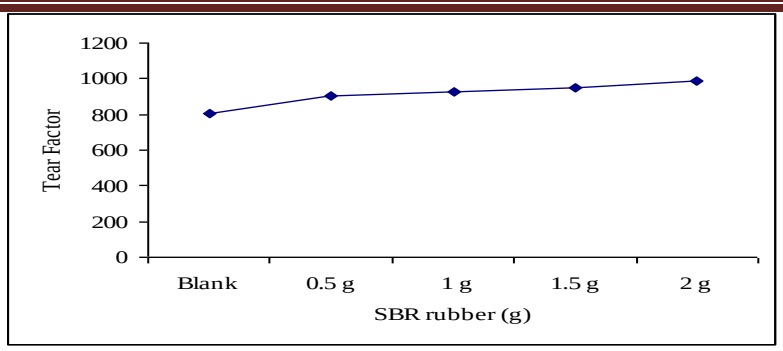

Fig (3): Tear factor of recycled carton sheets dipped in 10 % PS in (toluene) in presence of different amounts of SBR.

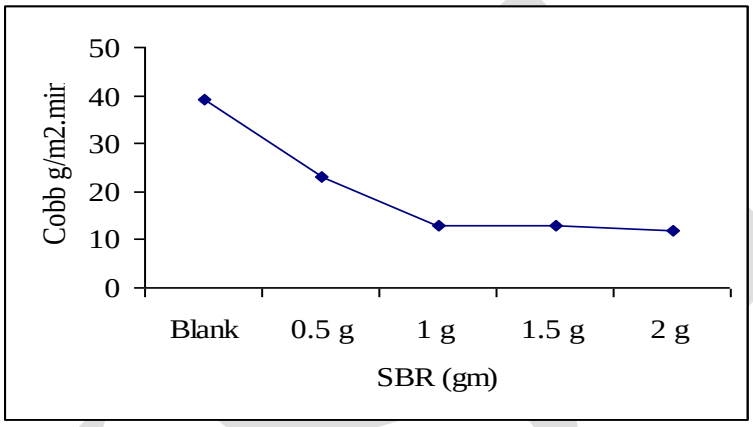

Fig (4): Cobb of recycled carton sheets dipped in 10 % PS in (toluene) in presence of different amounts of SBR.

3-5. Mechanical and physical properties of recycled carton sheets dipped in 10% PS solution in toluene in presence of dioctyl phythalate (DOP) as plasticizer.

In this study different amounts from DOP as plasticizer (0.5- 2 g) dissolved in 100 ml 10% PS solution in toluene were used in the treatments of recycled carton sheets. The mechanical and physical properties of carton sheets which dipped in the solution for 1 minute were determined and the results are given in Figures (5-8).

From the Figures it is evident that the presence of DOP in PS solution increases the mechanical properties of recycled carton sheets (breaking length burst factor and tear factor). It may be due to that the presence of DOP increases the elasticity of PS. The increase in the PS elasticity helps the homogenous distribution of PS between the fibers of sheet and causes an increase of the interfiber bonding of sheets. The improvements which caused by presence of DOP is lower than that attained with SBR. It may be due to the poor homogeneity of DOP with PS. From Figure (8) it is clear that, the presence of DOP in the polymer solution causes a higher improvement in Cobb more than in case of using SBR

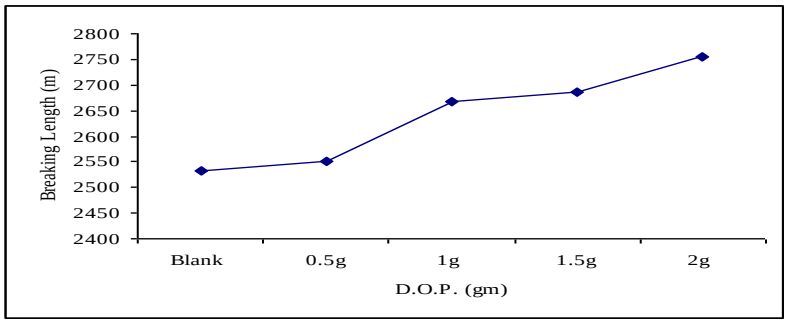

Fig. (5): Breaking length of recycled carton sheets dipped in 10% PS in toluene in presence of different amounts of DOP.

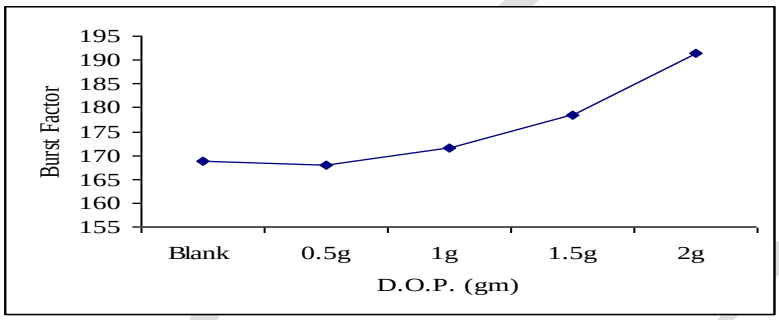

Fig. (6): Burst factor of recycled carton sheets dipped in 10% PS in toluene in presence of different amounts of DOP.

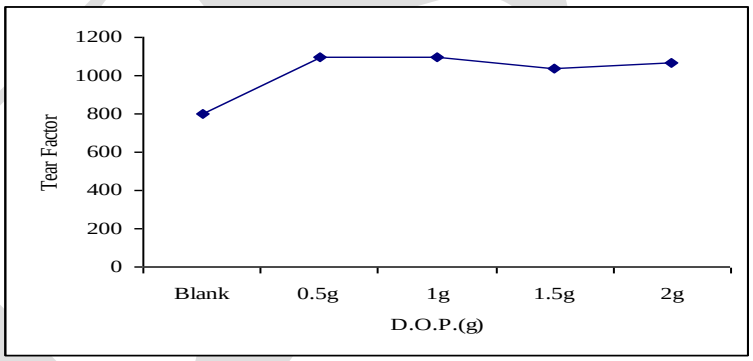

Fig. (7): Tear factor of recycled carton sheets dipped in 10 % PS in toluene in presence of different amounts of DOP.

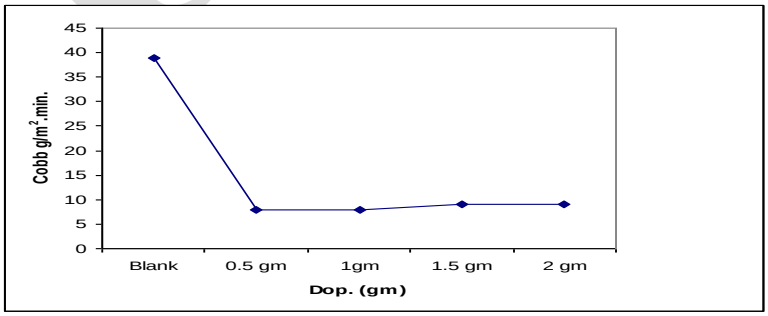

Fig (8): Cobb of recycled carton sheets dipped in 10% PS in toluene in presence of different amounts of DOP.

3-6. Mechanical and physical properties of recycled carton sheets dipped in different solid content of commercial emulsified PS-BuA copolymer.

Another trial was used to know the effect of emulsified commercial PS-BuA copolymer in which the sheets were treated by dipping for 1 min at different amounts of solid content copolymer PS-BuA (1–20 %). The mechanical and physical properties results obtained are shown in Figures (9-12).

From the figures it is clear that, the breaking length of the dipped recycled carton sheets slightly improved by increasing the solid content of the commercial copolymer with the except at lower concentration, but there is no observed change on the tear and burst factor. There is a little improving in the Cobb properties at lower solid content of emulsion.

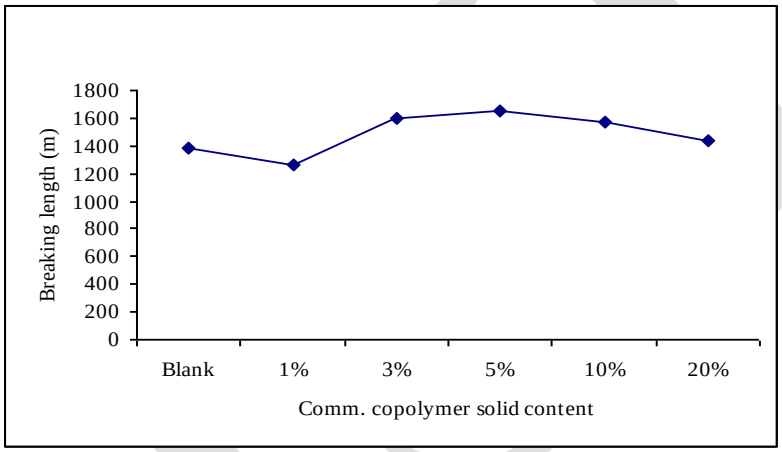

Fig. (9): Breaking length of treated recycled carton sheets with different solid content commercial copolymer PS-BuA.

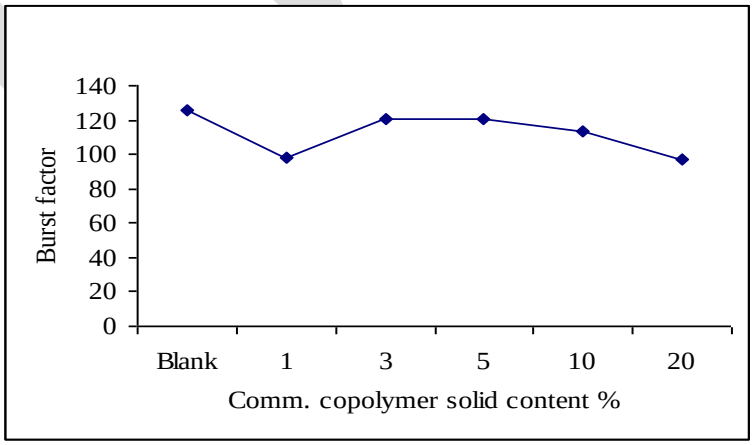

Fig.(10): Burst factor of treated recycled carton sheets with different solid content commercial copolymer PS-BuA.

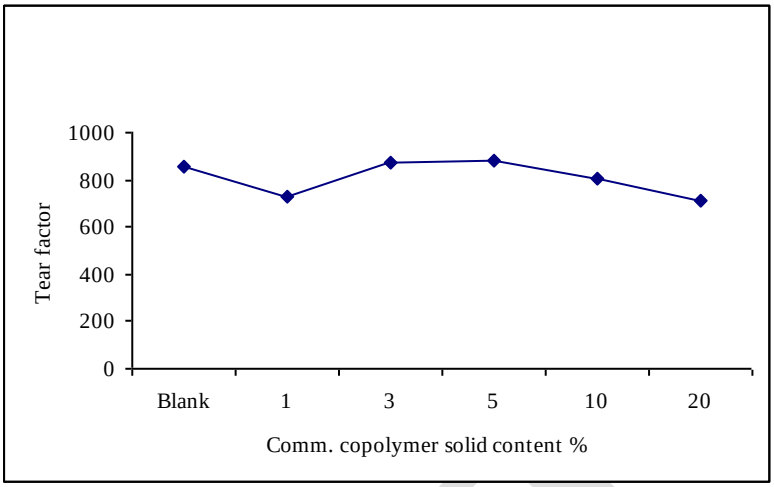

Fig. (11): Tear factor of treated recycled carton sheets with different solid content commercial copolymer PS-BuA.

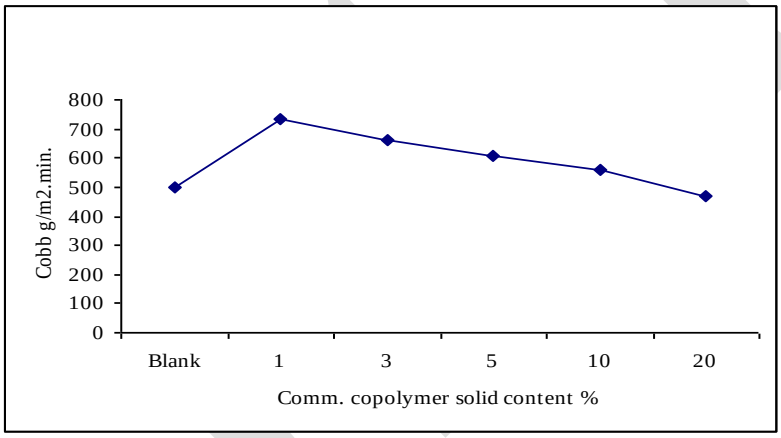

Fig. (12): Cobb of treated recycled carton sheets with different solid content commercial copolymer PS-BuA.

3-7. Mechanical and physical properties of recycled carton sheets dipped in recycled styrene - butadiene antishock solution.

Carton sheets were treated by dipping it for 1 min in different concentrations of recycled styrene-butadiene antishock (1, 3, 5 and 10 %) dissolved in toluene. The mechanical and physical properties results of treated sheets obtained are shown in Figures (13-16).

From the obtained results it is clear that, the mechanical properties results of treated sheets with different concentrations of recycled styrene - butadiene antishock solutions in toluene were improved after 5% concentration for the breaking length, but for burst factor it decreased at the lower concentration of the treatment solution followed by increasing with increasing the concentration above 3%, the same behavior was detected for tear factor. For the Cobb it decreased with increasing the treatment solutions up to 1% after which there is no change in the adsorption amounts of water with increasing the concentration.

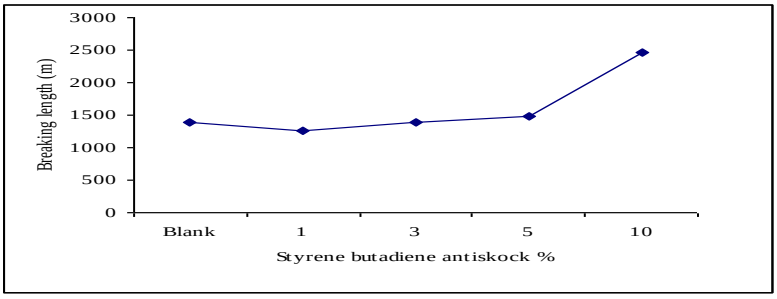

Fig. (13): Breaking length of recycled carton sheets dipped in different concentrations of recycled styrene - butadiene antishock solutions.

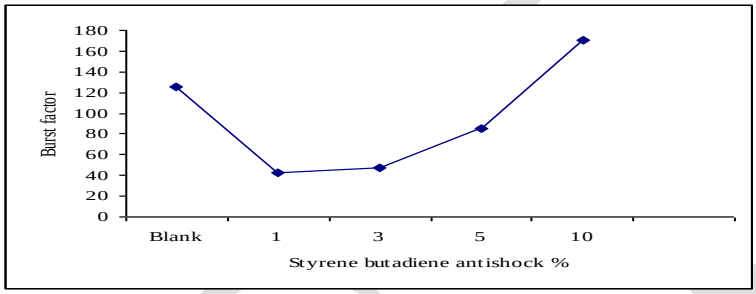

Fig. (14): Burst factor of recycled carton dipped in different concentrations of recycled styrene – butadiene antishock solutions.

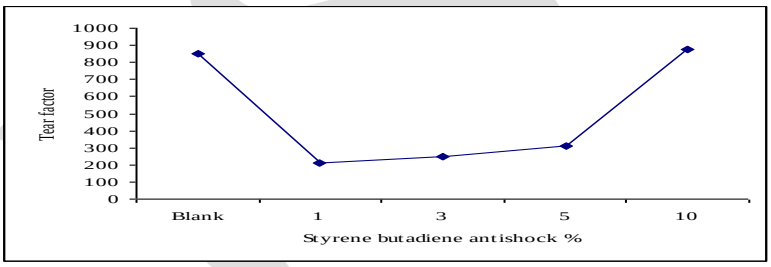

Fig. (15): Tear factor of recycled carton sheets dipped in different concentrations of recycled styrene - butadiene antishock solutions.

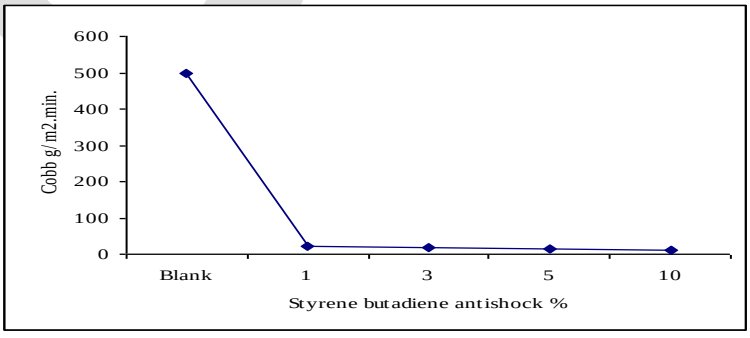

Fig. (16): Cobb of recycled carton sheets dipped in different Concentrations of recycled styrene-butadiene antishock solutions.

3-8. SEM micrograph

Fig. (17a) represents the SEM micrograph of recycled carton fibers, where it can be seen many pores between the fibers.

Fig. (17 b) shows SEM micrograph of recycled carton dipped in 10% PS. The figure demonstrated that the polymer developed well the fibers and form highly polymer layer on all fibers. Also Fig. (17 c) shows SEM micrograph of recycled carton dipped in 10 % PS-DOP solution. The Fig. shows that there is a good thin film of PS-DOP on the surface of the fibers, but there were some pores.

Fig. (17 d) explained the SEM micrograph of recycled carton dipped in 10 % PS-SBR solution. The fig illustrated that there is a good film of PS-SBR on the surface of the fibers, due to the presence of rubber which blocked the interfiber bonds between sheets.

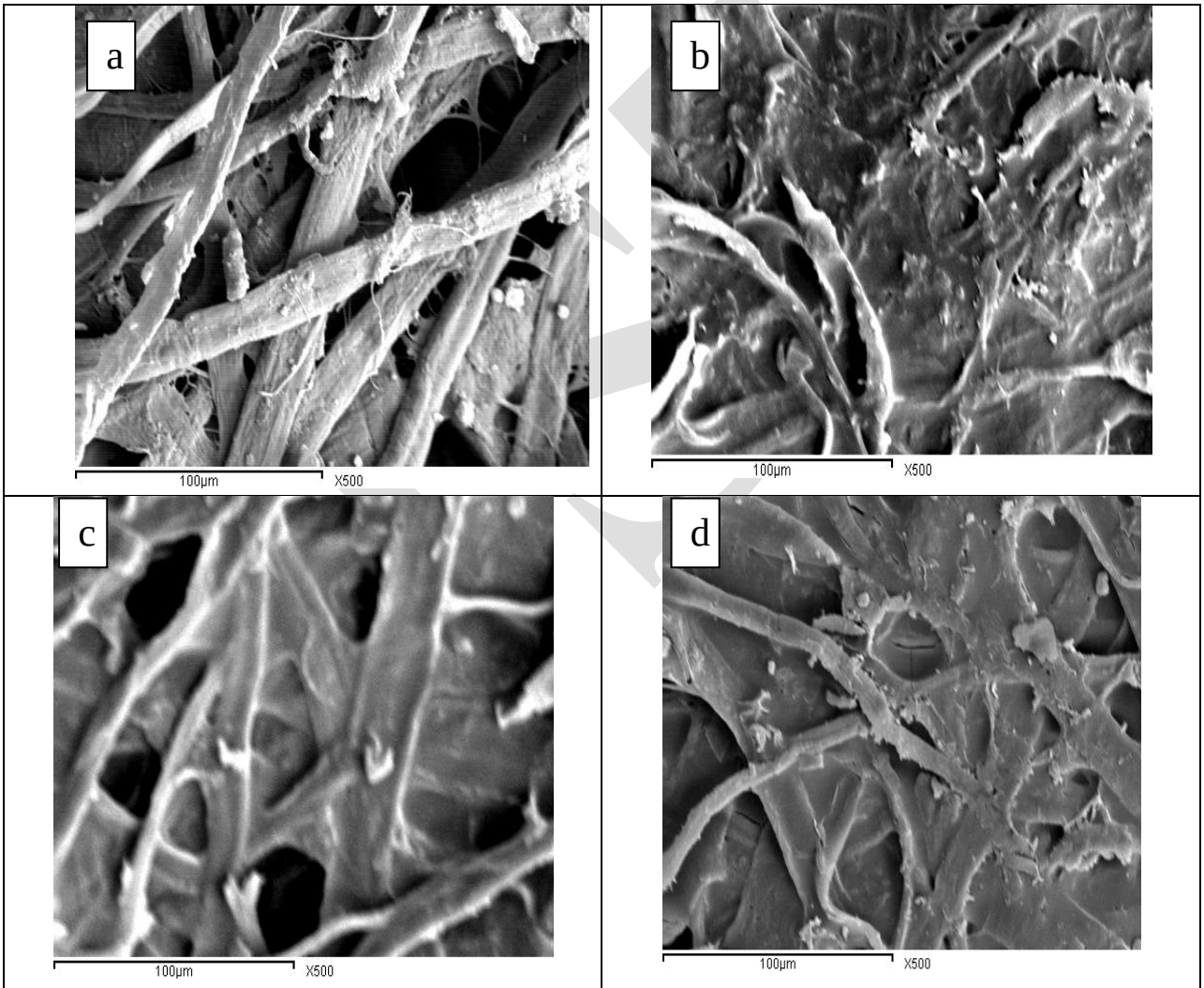

Fig (17): SEM micrograph of a) recycled carton as well as b) dipped in 10% recycled poly styrene-butadiene antishock solution, c) dipped in 10% PS-DOP solution, d) dipped in 10% PS-SBR solution.

CONCLUSION

Folding carton from recycled carton was prepared and evaluated regarding its mechanical properties such as breaking length, burst factor, tear factor as well as water absorption (Cobb factor). The prepared folding carton treated with polystyrene butadiene (antishock) and emulsified styrene butadiene using dipping process. The prepared folding carton was treated with different amounts of (0.5- 2g SBR) in presence of 10 % PS in toluene; the mechanical properties of treated sheets were improved, and the Cobb decreased with increasing the amount of SBR. Different weights of DOP (0.5- 2g) in presence of 10 % PS solution dissolved in toluene improved the mechanical properties of recycled carton sheets. The presence of DOP in the polymer solution causes a higher improvement in Cobb more than presence of SBR. The prepared folding carton was treated with emulsified commercial copolymer styrene-butadiene, where it was found that the breaking length and tear factor of the dipped recycled carton sheets improved by increasing the solid content percent of the commercial copolymer, but the burst factor and Cobb did not improved. For the carton sheets treated by dipping it for 1 min in different concentrations of recycled styrene-butadiene antishock (1, 3, 5 and 10 %) dissolved in toluene, the mechanical properties results of treated sheets were improved at 10% concentration, also the physical properties results improved at all used concentrations. By using 10 % emulsified recycled styrene-butadiene antishock in presence of SLS as emulsifier the mechanical properties of prepared sheets did not improve. The mechanical properties of the recycled carton which treated by emulsified PS-BuA copolymer at different solid content (1-20 %), did not change.

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