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# Mechanical and Physical Properties of Recycled Carton Sheets Treated with Copolymer Latex BuA/MMA and BuA/St through Two Techniques

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**ABSTRACT**

The aim of this work is to get rid of agricultural, paper wastes which consider a big environmental problem and their utilization in the production of economic products of some special applications. The use of paper-pulp packaging has become more attractive than traditional materials. In our work the mechanical and physical properties of recycled carton treated with copolymer latex butyl acrylate – methylmethacrylate emulsified copolymer (BuA/MMA) were measured through two techniques. Dipping recycled carton in different concentrations of emulsified BuA - MMA (2-4 %) copolymer and using different concentration of BuA - MMA emulsified copolymer (1-10 %) added during sheets making. From the results, a slight increase in the breaking length, cobb by treated sheets with different concentrations of the copolymer. But the burst and tear factors were decreased through the dipping effect. The breaking length of sheets increased at 1% copolymer, and then deceased by increasing the copolymer concentration. Whereas tear, burst factors and cobb increased through the addition of copolymer during paper making. Thermal gravimetric analysis (TGA) of samples was measured. The Microstructure of untreated and treated recycled carton sheets were clarified using SEM.



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## 1. INTRODUCTION

The folding carton created the packaging industry as it is known today, beginning in the late 19th century (Hanlon et al. 1998). The folding carton is a container of varying size and shape made from bending grades of paperboard or small flute corrugated board, which is typically printed, cut and creased, folded and glued, and delivered flat to the customer, where it is filled with the product for distribution to retail outlets.

Recycled fiber is an important raw material for the forest products industry, the use which is growing rapidly. Recycled fiber include all kinds of recovered papers having natural fiber sources, such as old corrugated container (OCC) pulp, waste newspaper, magazine, and coated board. Considerable interest has been shown in recent years for the development of dry- strength additives having improved efficacy (Lorenćak et al. 2000; Kitaoka & Tanaka 2001; Claesson et al. 2003; Lindström et al 2005). There is no universal standard for the maximum percentage of virgin pulp in recycled paper (Hershkowitz 2002). 'Recycled' paper is available that includes anywhere from 10 to 100 percent "post-consumer" paper.

Some research efforts to develop polymeric alternatives to petroleum-based products focused on using agropolymers (proteins, polysaccharides, lipids, etc.) as raw materials for packaging development (Guilbert & Gontard 2005; Guilbert et al. 2002). Corrugated fiberboard containers are the most widely used packaging materials for the shipping and handling of food and nonfood materials. It has the highest volume of any single packaging material in the world and represents more than 80 % of the volume of all paper-based packaging materials (Twede & Selke 2005). Corrugated fiberboard, which is composed of the linerboard and the medium, is characterized by its cellular structure, which imparts high compressive strength at a relatively low weight. Though corrugated board is the most highly recyclable packaging material, due to its composition of cellulose, the hydrophilic nature of cellulose causes it to be less water resistant.

Paperboards are prone to absorb water vapor from the environment, especially when stored under high humidity conditions or when coming into contact with high-moisture food materials such as fresh agricultural produce. Absorption of moisture reduces physical and mechanical strength of the paperboards, causing corruption of boxes during storage and distribution. Surface treatments such as sizing and coating are usually used to improve physical strength as well as water barrier properties.

The decrease of water vapor and gas transfers through papers treated by calendering and coating was clearly observed by (Andersson et al. 2002c; Dury-Brun et al. 2006; Schuman et al. 2004 a, b). In contrast, the effects of calendering, impregnation and/or coating treatments on aroma compound transfers through paper packaging were little studied. (Chalier et al. 2007) have shown that a gluten layer was effective in decreasing the transfer of two methyl ketones through paper coated with a wheat gluten solution.

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 (bagasse and rice straw, etc…) due to low price of recycled paper, environmental benefits such as biodegradability (Sridach et al. 2006; Yajun 2004; Yajun & Xuejun 2003), and low cost of production. So, the treatment of recycled carton by using different types of polymers was used via two different techniques: either through dipping the sheets or during its making (Nada et al. 1996).

Impregnation of paper sheets in polymer solution is a common method for improving mechanical properties as well as water absorption of paper sheets (Nada et al. 2005). Coating of paper sheets with organic polymeric solutions are used to improve paper sheets properties.

## 2. EXPERIMENTAL

### 2.1. Preparations of MMA / BuA and St / BuA Copolymer Latex using the Semi Continuous Process for Treatment of Recycled Carton Sheets

The emulsion copolymerization of butyl acrylate (BuA) with styrene (St) or with methyl methacrylate (MMA) with feed monomer composition 1:20 having solid content ca. 20 % ± 2 % were prepared by semicontinous technique at 70 °C with mechanical stirring 500 rpm. The reaction was carried out in a 500 ml three necked reaction flask equipped with a reflux condenser, stirrer, and two separating funnels. The first feed was the addition of the pre-emulsion (BuA with St or MMA) with dodecyl benzene sodium sulphonate (DBSS) and octyl phenol ethoxylated). The other feed for the initiator solution. These two feeds were added dropwise through a period of time three hours to the flask which contained part of soluble co-emulsifier, soluble initiator and a small amount of the pre-emulsion. At the end, the latex is cooled down to room temperature. All the ingredients and their amounts are given in Table 1 (Badran et al. 1997).

Table 1. The recipe of preparation of BuA/MMA and BuA/St copolymer latices

| Ingredient | Amount (g) |
|---|---|
| Water | 400 |
| BuA | 5 |
| St | 95 |
| MMA | 95 |
| Dodecyl benzene sodium sulphnoate as emulsifier | 3 |
| Octylphenol ethoxylated | 0.75 |
| Potassium persulphate as initiator | 3.37 |

**2.2. Treatment of Recycled Carton with Copolymer Latex BuA/MMA and BuA/St through Two Techniques**

**2.2.1. Dipping Technique**

The sheets of the recycled carton were dipped in different concentrations of the copolymer latex BuA/MMA (2, 3 and 4%) or BuA/St (1, 3, 5, 10 and 20%) for one min then the excess of the polymer was removed by wiping with the filter papers and left to dry

The use of aqueous dispersed polymer e.g. acetate, acrylate and methyl methacrylate copolymer (Hamphry 1984) as well as polyvinyl acetate / vinyl versitate (Nada et al. 1999) is highly established for conservation as restoration of archival material. The use of wet strength polymer during the production of paper and board increases the machine runnability and retention of fillers and fines (Dav'son, 1982).

**2.2.2. During Sheets Making Technique**

The recycled carton sheets were treated with different concentrations of the copolymer latex BuA/MMA (1, 3, 5 and 10 %) and or BuA/St (1, 3, 5, 10 and 20 %) then the sheets were dried in the drum at 105 °C.

**2.2. Thermal Gravimetric Analysis (TGA)**

The thermal degradation of each sample proceeds into three stages, early dehydration stage due to the evaporation of water and easily volatile materials, fragmentation stage which is the main degradation step and proceeds in two or more steps, and finally the carbonization stage in which the evolution of gases takes place (Sefain 1975).

## 3. RESULT AND DISCUSSION

### 3.1. Mechanical and Physical Properties of Recycled Carton Sheets According to Dipping Technique

The breaking length of recycled carton dipped in different concentrations (2-4%) of (MMA-BuA) copolymer for 1 minute was shown in Figure 1. The results showed that there is an increases in the breaking length by treated sheets with different concentrations of copolymer, it may be due to the increase in the interfibre bonding and the adhesive force between the fiber of sheets and the copolymer. This increase is low due to that the copolymer dissolves in an aqueous medium which causing swelling in the fiber of recycled carton. This phenomena is very clear in case of tear, burst factors and cobb.

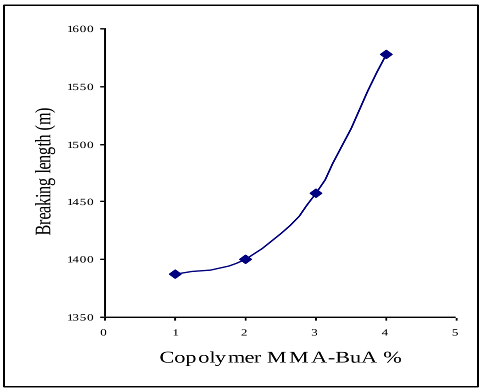


Figure 1. Breaking length of treated sheets with different concentrations (2-4%) of (MMA-BuA) copolymer

From Figure 3 and 5, it could be noticed that at the copolymer caused a slight decrease in the burst and tear factors. That may be due to the swelling of fibers of paper sheets with water which used as medium of emulsion copolymer and consequently decreases the interfiber bonding in the sheets. But increasing the emulsion concentration enhanced slightly the burst factor and tear factor.

Figure 7 shows the water absorbance (cobb) of the treated sheets, from the Figure it can be observed that, the cobb increased by increasing the concentration of the emulsified copolymer from 2 % to 4 % for all dipped sheets. That is due to the swelling of fibers of paper sheets with water which used as medium of emulsified copolymer.

### 3.2. Mechanical and Physical Properties of Recycled Carton Sheets According to Addition during Sheets Making

Another trial was used to show the effect of emulsified copolymer MMA-BuA which added during paper sheets formation at different concentrations from (1–10 %). The mechanical and physical properties are represented in Figure 2, 4, 6, 8.

The Figure 2 shows the breaking length of recycled carton which affected by different concentrations (1-10 %) of MMA-BuA copolymer added during paper sheets formation. From this figure, the addition of copolymer during paper sheets formation has a good effect than that used as a dipped medium. This can be due to that the increase in homogeneity distribution of copolymer between the sheet fibers, also during drying the sheets, the crossing and interfiber bonding between copolymer and sheets fibers increases. On the other hand, the increase in breaking length of sheets has a maximum increase in case of 1% copolymer, and then decreased by increasing the copolymer concentration but it still has a higher values than the blank.

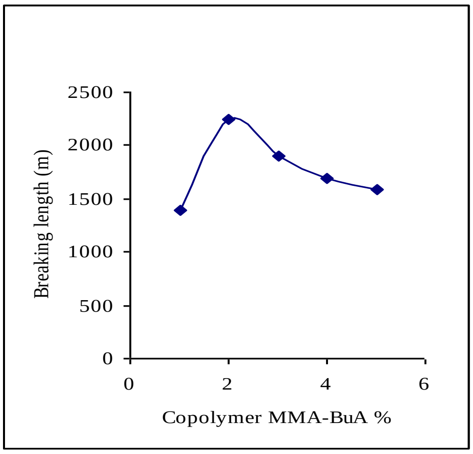


Figure 2. Breaking length of treated sheets with different concentrations (1-10 %) of MMA-BuA copolymer

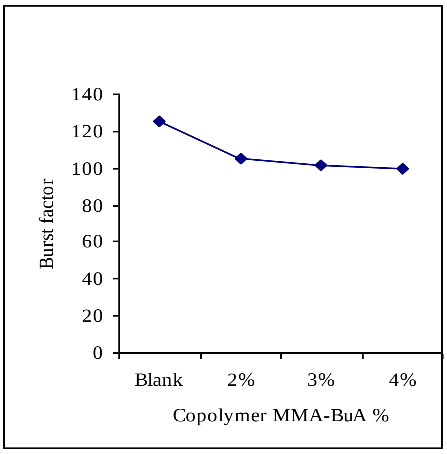


Figure 3. Burst factor of treated sheets with different concentrations (2-4%) of (MMA-BuA) copolymer

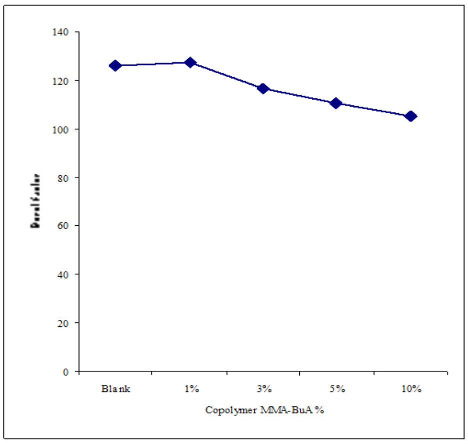


Figure 4. Burst factor of treated sheets with different concentrations (1-10 %) of MMA-BuA copolymer

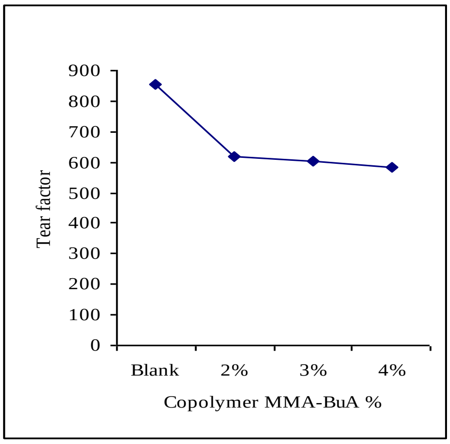


Figure 5. Tear factor of treated sheets with different concentrations (2-4%) of (MMA-BuA) copolymer

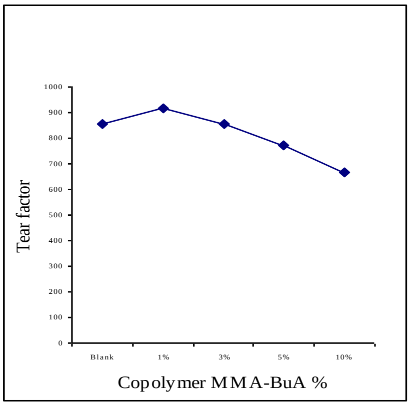


Figure 6. Tear factor of treated sheets with different concentrations (1-10 %) of MMA-BuA copolymer

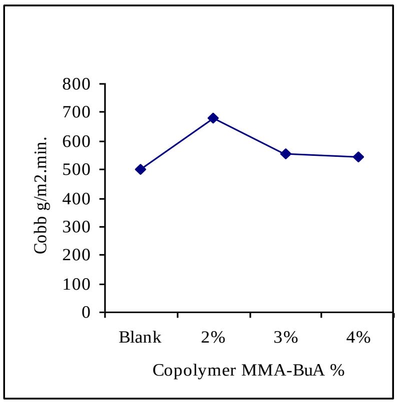


Figure 7. Cobb of treated sheets with different concentrations (2-4%) of (MMA-BuA) copolymer

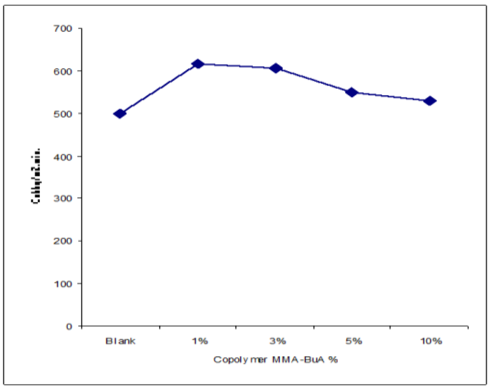


Figure 8. Cobb of treated sheets with different concentrations (1-10 %) of MMA-BuA copolymer

Figure 4-8 show burst, tear factors and cobb of recycled carton which affected by different concentrations (1-10%) of copolymer added during paper sheets formation. From the Figures it is clear that, the use of 1% copolymer added during making paper sheets improve tear factor and burst factor. This is due to the enhancing interfiber bonding but using higher concentrations of copolymer the properties decreased than the blank. It can be due to the increase in the retained copolymer which during drying the sheets cause a hardening of fibers then became brittle. For this reason the tear and burst factors decreased, but the cobb increased.

### 3.2.1. Thermal Gravimetric Analysis (TGA)

TG curves and data are illustrated in Table 2 and Figure 9-11.

Table 2. Thermal stability of treated recycled carton sheets

| Sample | Temperature °C | Weight loss % |
|---|---|---|
| Blank recycled carton sheets | Minor 310 | 11 |
| | Major 375 | 88 |
| 4% BuA-MMA copolymer (dipping) sheets | Minor 312 | 12 |
| | Major 370 | 84 |
| 1% BuA-MMA | Minor 312 | 15.5 |
| Added during sheets making | Major 370 | 88.5 |

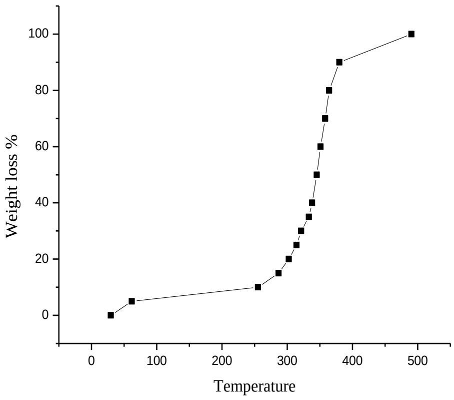


Figure 9. Thermal stability of recycled carton sheets

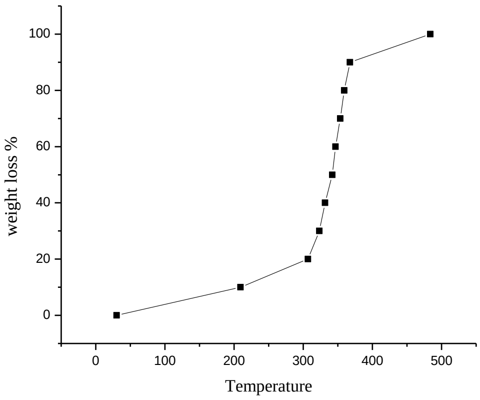


Figure 10. Thermal stability of of recycled carton sheets treated by BuA-MMA copolymer added during sheets making

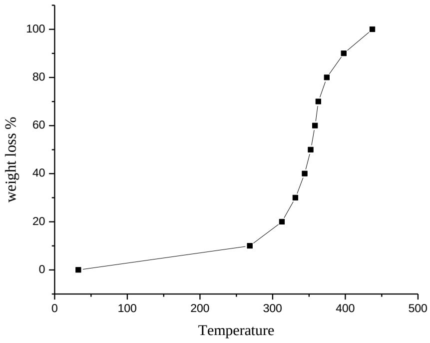


Figure 11. Thermal stability of recycled carton sheets treated by dipping in 4% BuA-MMA copolymer solution

### 3.3. Microstructure of Untreated and Treated Recycled Carton

The Microstructure of untreated and treated recycled carton sheets is very essential to confirm the physico mechanical properties of the studied samples. It will be clarified using SEM. Some selected samples were thoroughly investigated. The obtained results are given in Figure 12-14. Figure 12 shows SEM micrograph of recycled carton. From the figure there is a clear pore size between the fibers.

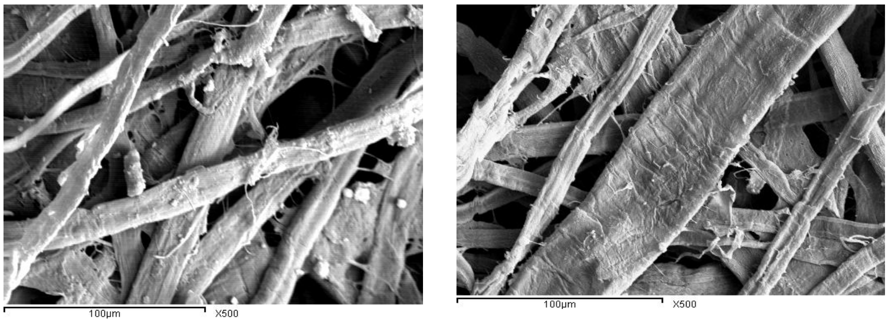


Figure 12. SEM micrograph of recycled carton sheets

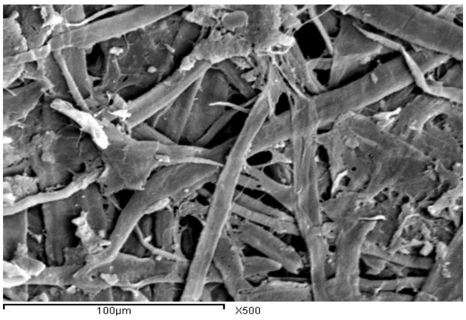


Figure 14. SEM micrograph of recycled carton sheets dipped in BuA-MMA copolymer solution

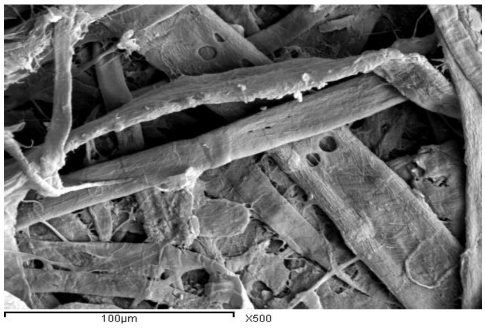


Figure 13. SEM micrograph of recycled carton sheets treated by BuA-MMA copolymer added during sheets making

Figure 13 shows SEM micrograph of recycled carton treated with BuA-MMA copolymer during sheets making. The Fig. shows a homogeneity distribution of the copolymer through the pores of the sheets, but there are some pores which unblocked with the copolymer.

Also Figure 14 shows SEM micrograph of recycled carton dipped in BuA-MMA copolymer. The figure shows that the fibers looks like uncovered by the copolymer because the low viscosity of the copolymer which did not make a good thin film on the fiber surface.

## 4. CONCLUSION

In our work the mechanical and physical properties of recycled carton treated with copolymer latex butyl acrylate – methylmethacrylate emulsified copolymer (BuA/MMA) were measured through two techniques. Dipping recycled carton in different concentrations of emulsified BuA - MMA (2-4 %) copolymer and using different concentration of BuA - MMA emulsified copolymer (1-10 %) added during sheets making. From the results, a slight increase in the breaking length, cobb by treated sheets with different concentrations of the copolymer. But the burst and tear factors were decreased through the dipping effect. The breaking length of sheets increased at 1% copolymer, and then deceased by increasing the copolymer concentration. Whereas tear, burst factors and cobb increased through the addition of copolymer during paper making. Thermal gravimetric analysis (TGA) of samples was measured. The Microstructure of untreated and treated recycled carton sheets were clarified using SEM.

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