Evaluating the Printability Characteristics of the Paper Board by Using Nano Fibers Based Coatings

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Abstract

In this work, the nanofibers were prepared both from bagasse and wood pulp by enzymetic reaction using endoglucanase enzyme by masuko grinder in neutral medium. The prepared nanofibers were subjected for evaluation to identify the nano characteristic using practical size analyzer. The coating solutions were prepared in different weight % of nanofibers and TiO_2 nanoparticles separately with the binder carboxyl methyl cellulose. Then, it was coated on to the selected uncoated paper board of 180.0 GSM. The distribution of nanofibers and TiO2 nanoparticles coated on the paper board were evaluated using scanning electron microscope (SEM). The porosity and smoothness of the selected board before and after coating were measured using Bendtsen Automatic Densometer. The decrease in porosity values of the samples of the coated nanofiber sample is approximately 15%. The tensile strength of the coated paper board was measured using Universal Testing Machine (UTM) and a 15% increase in values compared to the selected uncoated paper board were observed. Then, the coated paper board samples were printed using IGT printability tester to evaluate the pick velocity. The pick values of the coated samples were found to be very good even at very high speed compared to the uncoated paper board sample.

1. Introduction

Paper and paperboards were coated before printing to improve the surface properties of the paper thus improves the printability characteristics. Traditionally, inorganic fillers like talc, clay etc along with binding agents of CMC, shellac were used to coat the paper and paper board to enhance the surface properties. In recent years, after the innovations of nanomaterials, the filler, nano TiO_2 finds much attention in

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paper making industries as a coating material (1-3). The research on the addition of nano TiO_2 in paper coating industries clearly indicates the improvement of surface strength and aging properties of coated paper in addition to variations of the rheological behavior of the coating components.

The development of nanocellulose fibers from natural source and from agricultural wastes are attracted most researchers in the past few years. This is due to the unique properties like high tensile strength, surface area to volume ratio and low co-efficient of thermal expansion (4-6). Based on the need for green chemistry, the bio based nano materials have wide replacement to the traditional reinforcement materials due to low cost, good mechanical properties, and also the advantages of biodegradability (7-8).

Many researchers have reported about the use of the nanocellulose fibers in the areas of polymer blending and paper coating, due to the fact of renewable source, abundant and low cost. Methods like mechanical homogenizer, cryocrushing, oxidation and enzymatic process are used for the preparation of nanocellulose fibers (9-12). Though, many methods have been followed to prepare the nanocellulose fibers, the process of mechanical grinding after pretreatment with endoglucanase produces the nanofibers with maximum uniform size without affecting the quality of the nanofibers. Many researches have been carried out on the preparation of nanocellulose fibers but only few studies have been reported on the print characteristics of the coated nanocellulose fibers on paper board. Hence, the aim of this study is to prepare the nanocellulose fibers from wood and bagasse pulp by mechanical process after enzymatic pretreatment. These nanocellulose fibers were used for the preparation of coating solutions with different weight % to be coated on the paper board. The coated paper boards were printed using IGT printability tester and the samples were examined for its print characteristics.

2. Experimental

2.1 Materials

The wood and bagasse pulp was received from Tamil Nadu Newsprint and Papers Limited (TNPL) as a mill source and it consists of cellulose 65% semi cellulose 25% and lignin 10%.The average moisture content of the wood and bagasse pulp approximately between 60-70%. The binder Carboxy Methyl Cellulose (CMC), purchased from Sigma-Aldrich Chemicals, is a white powder, odorless and hygroscopic granules. Endoglucanase, purchased from Bio Science lab, is a colorless liquid. The coating chemicals namely dispensing agent, lubricant, starch and antifoaming agents were purchased from Sigma-Aldrich. All these chemicals were used as received.
Syringe filters with the pore size of 0.45 μ and 25mm diameter purchased from RanDisc™ were used for filtration. The selected base paper was purchased from

the commercial vendor and having the properties namely GSM - 180 g/m^2, porosity 370 ml / min., tensile value 7.10MPa, opacity - 92%, and whiteness - 61%.

2.2 Preparation of nanocellulose fibers

The nanocellulose fibers were prepared by mechanical grinding process. In this process, the enzymatic pretreatment is followed to reduce the number of passes of grinding which in turn reduces the energy consumption. Moreover, this process produces fibers with more uniform structure. In the preparation, the wood and bagasse pulp were weighed 500gms each and separately mixed with 10 ml of enzyme endoglucose and then stirred for 24hrs at room temperature. The suspensions were subjected into the homogenizer for 12hrs for three times. Finally, the suspensions of each pulp were subjected for filtration using 0.45 µ filter separately. Then, the filtrate was subjected for the process of lyophilization to get the solid powder (nanofibers) for both wood and bagasse.

2.3 Preparation of coating solutions

The coating solution was prepared separately for nano TiO_2 and each nanofibers using $CaCO_3$ and CMC as binder. The different weight % (50, 60 and 70) of nano TiO_2 and nanofibers were prepared to coat the paper board .The different weight % of nanofibers and nano TiO_2 was mixed with 100ml distilled water .The solution was stirred for 30 min by magnetic stirrer .

The Table I explains the coating solutions of different weight % of TiO_2 and nanofibers.

Sample code	TiO_2 nanoparticles (%)	Nano Fiber (%)		Precipitated $CaCO_3$ (%)	Binder(CMC)
		Wood	Baggasse		
1	50	-	-	20	30
2	60	-	-	20	20
3	70	-	-	20	10
4	-	50	-	20	30
5	-	60	-	20	20
6	-	70	-	20	10
7	-	-	50	20	30
8	-	-	60	20	20
9	-	-	70	20	10

Table I Coating solutions of different weight % of nano TiO2 and nanofibers

2.4 Coating on Paper Board

The base paper was coated with the prepared coating solutions of different weight % using print coater with constant speed to obtain uniform thickness. Then, the coated papers were dried for 24hrs.

3. Characterization

The surface morphology of the coated and uncoated papers was analyzed using Scanning Electron Microscope (SEM) (S-4800, Hitachi Co. Ltd, Japan. The tensile strength of the coated samples was measured using Universal Testing Machine (UTM) (H10KS, Tinius Olsen, UK). The surface property measurements of the coated samples were measured using Bendtsen Automatic Densometer. The print characteristics of the printed samples were measured using Spectro-densitometer (X-Rite). The pick values were measured using IGT printability tester.

4. Results and Discussions

Scanning Electron Microscope (SEM)

The uncoated and coated paperboard samples were scanned to understand the surface morphology and the particle size by SEM. The Fig 1(a, b) indicates the surface morphology of the uncoated paperboard with lower and higher magnifications. The image shows the presence of voids and pores between the fiber orientations in the forming process. Fig. 1(c) indicates the presence of TiO_2 nanoparticles with an average size of 100nm at higher weight % content. Fig.1(d) shows the image of the nanofibers with an average value of 95nm. Fig (e, f, g and h) shows the uniform distribution of nano fibers at higher loading of nanoparticles with lower percentages of CMC, the binder.

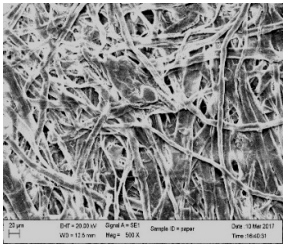

Fig 1. (a) *SEM image of uncoated paperboard sample.*

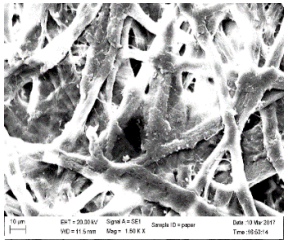

Fig 1. (b) *SEM image of uncoated paperboard sample.*

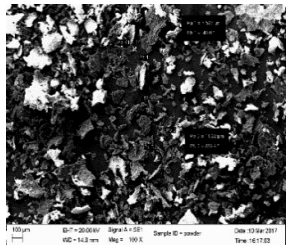

Fig 1. (c) *SEM images of nano fibers.*

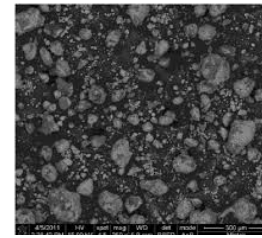

Fig 1. (d) *SEM images of TiO_2 nanoparticles.*

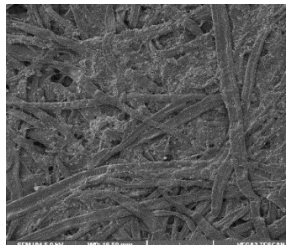

Fig 1. (e) *SEM images of 50 weight % of nanofiber coated paperboard sample.*

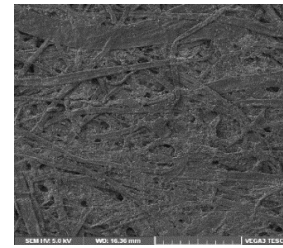

Fig 1. (f) *SEM images of 50 weight % of TiO_2 nanoparticles coated paperboard sample.*

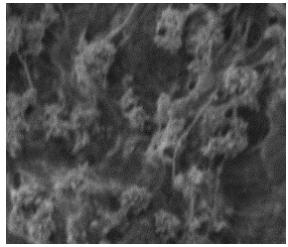

Fig 1. (g) *SEM images of 60 weight % of nanofiber coated paperboard sample.*

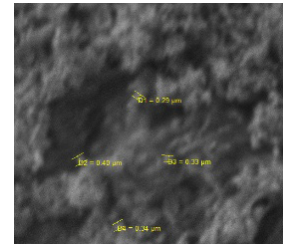

Fig 1. (h) *SEM images of 60 weight % of TiO_2 nanoparticles coated paperboard sample.*

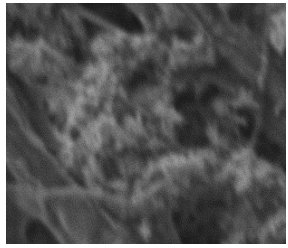

Fig 1. (i) *SEM images of 70 weight % of nanofiber coated paperboard sample.*

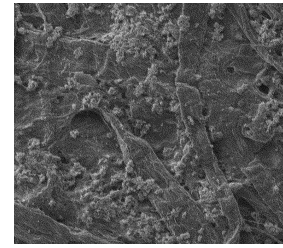

Fig 1. (j) *SEM images of 70 weight % of TiO_2 nanoparticles coated paperboard sample.*

Mechanical properties

The effect of nano TiO2 and nano fibers content on mechanical properties are presented in Fig 3. The tensile strength of paperboard is 7.10MPa. The addition of TiO_2 has improved the tensile strength of coated paperboard from 7.10MPa to 10.92MPa. The tensile strength of the coated paper board sample increased up to 70% with increase in weight % of TiO_2 nanoparticles content. The increased

tensile strength might be attributed to the well dispersion of TiO2 nanoparticles (17-18). The tensile strength of nanofiber coated paperboard sample is 9.7MPa. The increased tensile strength is due to the well dispersion and less agglomeration of nanofibers.

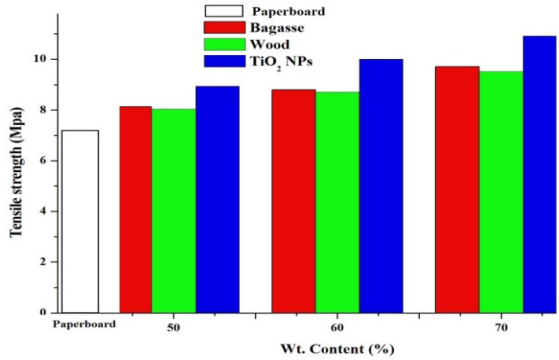

Fig. 2 *Tensile strength of coated and uncoated paperboard samples.*

Printing characteristics

The properties of the uncoated and coated paper board samples are presented in Table II. In the case of coated paper board samples of both TiO_2 and nanofiber shows 2% increase in GSM values (19). There is an increase in roughness values from 74.6 to 180 ml/min for TiO_2 nanoparticles coated samples, in comparison with the values of nanofiber coated paperboard of about 117.1 ml/min. The porosity of paperboard is important for printing because the ink absorbency and the print quality depends on the porosity values of the samples. The decrease in porosity values infers the better ink absorbency compared to uncoated paper board. The values of opacity for the nano fiber coated and nano TiO_2 coated paper board samples were less and this is due to the presence opaque nature of TiO_2 particles and reflection nature of the nano fibers. Whiteness of the coated paper board was increased due to the filler TiO_2 and fiber characteristics of the nano samples. The pick velocity of the nano fibers coated paper board samples were reduced thus improved the printability when compared to uncoated and TiO_2 nano coated. This indicates the better ink adhesion on the surface of the samples.

Properties	Uncoated Paper	Nano Fiber Coated Paper Board (Weight %)						TiO_2 Nano Particles Coated Paper Board (Weight %)		
		Wood			Bagasse					
		50	60	70	50	60	70	50	60	70
GSM (s/m^2)	180.0	180.5	181.7	182.0	180.7	181.6	182.1	182.0	182.5	180.3
Roughness (ml/min)	74.6	103.2	109.0	116.5	103.9	110.6	117.1	169.4	173.2	180.1
Porosity (ml/min)	180.0	97.9	108.6	114.4	98.2	108.9	114.8	179.4	176.9	175.3
Opacity	1.74	1.70	1.65	1.61	1.68	1.62	1.50	1.54	1.55	1.56
Whiteness (%)	60.56	60.65	60.83	61.20	60.69	60.93	61.79	60.77	60.83	60.90
Pick velocity (m/sec)	3.78	3.73	3.71	3.68	3.71	3.70	3.69	3.77	3.76	3.74

Table 2. *Properties of the uncoated and nano coated samples*

Conclusion

In this research, the SEM images of coated samples clearly indicates the uniform distribution of nano TiO_2 and nanofibers without much agglomerations. The tensile strength of the nano coated samples were increased (TiO_2 – 10.92MPa and nanofiber – 9.7MPa) compared to uncoated samples (7.1MPa). The porosity value was decreased nearly 50% (from 180ml/min to 98.2ml/min) when compared to uncoated paper board sample. The decrease in pick velocity of the nanocoated samples from IGT test infers better print characteristics .

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Reference

1. B. Li, Y. Li and Y. Tang. *Chine Pulp & Paper*, 27, 56 (2008).
2. J. Shen, Z. Song, Qian and Y. Ni. *Ind & Engg. Chem. Res*, 50, 661 (2011).
3. N.M. Julkapli andS. Bagheri. *J. Wood Sci*, 62, 117 (2016).
4. B. Li, Y. Li and R. Lu. *CIESC Journal*,61, 228 (2010).
5. J. Shen, Z.Q.Song, X.R.Qian, Y.H. Ni, *Ind. Eng. Chem. Res.*50, 661 (2011)
6. Y.J.Tang,J.A.Mosseler,Z.B.He,Y.H.Ni,*Ind.Eng.Chem.Res.*53, 10119 (2014).
7. V.K. Thakur and M.K. Thakur. *Advan. Stru. Mate.*75, DOI 10.1007/978-81-322-2470-9_2.
8. S. Lili, C. Zhaofeng, C. Zhou, Z. Aili and Y. Zhaogang. *Int. J. Polym. Sci.* 6869154, (2016).
9. Y.F.Du, Y.H. Zong and J.Du. *Ind.Eng.Chem.Res.* 50,9781 (2011).
10. B.Li, Y.M.Li, R.J.Lu, J.Chem. *Ind.Eng.Soc.China*. 61,228 (2010).
11. A. Stanislawska and P. Lepoutre, *TAPPI*. 79,117 (1996).
12. W.A. Daoud, J.H. Xin and X. Tao. *J.Am.Ceram.Soc.* 87,1782 (2004).
13. A. Dufresne. *Mater Today*, 16,227 (2013).
14. M.D. Sanchez-Garcia and J.M. Lagaron. *J.Appl.Polym. Sci.* 118, 188 (2010).
15. D.S. Cha and M.S. Chinnan. *Crit. Rev.Food Sci.Nutr.*44,223 (2004).
16. D.D. Liana, B. Raguse and J.J. Gooding. *Sensors*, 12,11505 (2012).
17. Z. Jianguo and M. Zhu. *Theo & Appli.Mech. Lett*, 4, 21008 (2014).
18. W. Xi-Shu, T. Hua-Ping L. Xu-Dong and X. Hua. *Int. J. Mol. Sci.* 10, 5257 (2009).
19. J. Vyorykka, K. Zuercher and D. Malotky. *Paper Con-TAPPI.* 1051 (2011).