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RESEARCH HIGHLIGHTS

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SHANGA VERLAG

"RESEARCH HIGHLIGHTS by AVINSAHILINGAM UNIVERSITY"

248 pages

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SHANGA VERLAG

174, Nethaji Road, Pappanaickenpalayam,
Coimbatore – 641 037.

Printed from camera-ready copy provided by Editors in digital printer on 75 gsm maplitho paper

ISBN 978–93–85604–02–7

Published by GANESH SHANKAR. D,
on behalf of SHANGA VERLAG
and printed at SIVASALAPATHY PRINTERS, (Unit – II)
174, Nethaji Road, Pappanaickenpalayam,
Coimbatore – 641 037.
Printed in India

A COMPARATIVE STUDY OF ECOFRIENDLY AND CONVENTIONAL SCOURING TREATMENTS

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ABSTRACT

Scouring is a cleaning process for renewing natural and acquired impurities of fibers. Common industrial practices involve use of sodium hydroxide to remove non – cellulosic materials. In this process, the individual non – cellulosic components other than natural colouring matters are converted into solute compounds are removed in subsequent washing. This traditional scouring process consumes large quantities of energy and water and is not ecofriendly. High level of pH and temperature used in this process that damages the fiber due to non – specific attack of alkali especially when performed in the presence of oxygen, it also results in loss in strength of the fiber. Hence, there was demand for scouring process carried out using mild conditions. It led to the development of substrate specific, low water consuming and environment friendly process, namely enzymatic scouring. Textile wet processing is one of the largest and oldest industries world wide, responsible for substantial resource consumption and pollution especially in terms of water.

Keywords: Sodium Hydroxide, Cellulosic, Enzymatic Scouring, Ecofriendly and Effluent

Introduction

Scouring is a cleaning process for renewing natural and acquired impurities of fibers. Common industrial practices involve use of sodium hydroxide to remove non – cellulosic materials. In this process, the individual non – cellulosic components other than natural colouring matters are converted into solute compounds are removed in subsequent washing. Enzymes are protein substance preferred due to the reasons that these replace harsh chemical create no pollution, act as a catalyst and are biological degradable. Wet processing enzymes are preferred in textiles because of accelerate the rate of reaction, specific in action, low temperature operation, easy to control and safe, replace hash chemical no pollution, and biologically degradable Prasad and Muthumanickam (2006). Enzymatic scouring has opened new ways to lower effluent generation, the water pollution and quite good soft action. The objectives of the study are to: identify the presence of cellulose enzyme in natural source, extract and optimize the enzyme for activity, optimize enzyme for scouring, soften the sisal yarns, evaluate the effluent and compare the cost effectiveness.

Methodology

The materials and methods of the study involves the following.

Selection of Source for enzyme extraction

Cellulase enzyme in textile industry, are used to improve the hand of fabric mention (Saravanan et al., 2010). Though they originate from different sources like plants, animals and microorganisms, plant source is the cheapest because of its easy availability and extraction procedure. Hence the waste of sugarcane called bagasse was selected for the study. For extraction of Cellulase, about 80 gm of bagasse was crushed in mixie by using 100 milliliter of phosphate buffer at pH 8. The extract was filtered. The filtrate was further centrifuged at 5000 rotation per minute in a refrigerated centrifuge at 4°C and the supernatant served as the enzyme source.

Determination of Cellulase Activity

For finding the Cellulase activity about 1 ml of bagasse solution was taken, from the prepared solution. The test tubes "T_1" and "C_1" were taken and 1 ml of buffer solution was added into the test tubes. About 0.5 ml of enzyme was added to test tube "T_1". The standard solutions of 0.2, 0.4, 0.6, 0.8, and 1.0 ml was taken in the standard test tubes S_1, S_2, S_3, S_4, and S_5 respectively. All the test tubes were incubated for 30 minutes at 45°C in an incubator. About 0.5 ml of enzyme was taken in test tube "C_1". The enzymatic reaction was stopped by adding 2 ml of DNS to all the test tubes. These test tubes were heated in boiling water bath for 10 minutes, one ml of sodium potassium tartarate solution was added when warm. The test tubes were cooled and water of about 7, 5.5, 5.8, 5.6, 5.2 and 5.0 ml were added to test tubes T_1, C_1, S_1, S_2, S_3, S_4 and S_5 respectively to increase the volume. The absorbency at 540 nm was recorded.

Optimization and Extraction Processes

Optimization of various parameters for the cellulase activity as well as enzyme were carried out. The cellulase activity was optimized for incubation time, pH and temperature. The enzymes were optimized for various essential physical parameters were optimized. To extract the cellulose enzyme, about 800 gm of sugarcane waste (bagasse) was weighed using Electronic weighing balance and collected in a clean vessel. The bagasse was crushed with one litre of 0.1m of phosphate buffer of pH 8.0 using mixie. The extract obtained was filtered into a beaker. The filtrate was further centrifuged at 4°C at 5000 rotation per minute using a refrigerated centrifuge and the supernatant served as the enzyme source.

Conventional Scouring of Sisal Yarn Samples

The conventional scouring was carried out with the following procedure as suggested by Sunitha and Krishnabai (2005). Twenty four gm of sodium hydroxide, 6 gm of soda ash, and 3 gm of wetting agent were mixed in 6000 ml of water and the solution was boiled for period of one hour and the temperature was adjusted to 50°–60°C in a water bath. After one hour yarn sample was removed, washed with hot and cold water and then dried.

Enzymatic Scouring of Yarn Samples

Based on the standardized procedure, 250 gm of sisal yarn was treated using the composition as Enzyme extract – 1 litre, pH – 8.0, Temperature – 50°C, Time – 60 minutes and M:L – 1:8. The yarns were pretreated in water for ½ hour at 100°C. The enzyme was taken in a clean vessel and 250 gm of sisal yarn was immersed. The vessel was placed in the water bath at 50°C for duration of 60 minutes, that enzymes are biocatalyst operate under moderate temperatures (30°C – 60°C) and pH level (3 – 8). After which the sisal yarn sample was removed, washed thoroughly with cold water and dried.

Evaluation

Evaluations of effluent samples are given as under.

Analysis of Effluent

The conventional and enzymatic scoured effluents obtained through the processes were analyzed for pH, TSS, TDS, BOD, COD, Hardness and Alkalinity. These parameters were determined as per suggestion of Kaul et al., (2003).

pH

pH is the measure of intensity of acidity (or) alkalinity and determines the concentration of hydrogen ions present in water. The pH meter was first standardized using buffer solutions of pH 7.0 and pH 9.2. The electrodes were rinsed in distilled water and immersed in the conventional and enzymatic scoured effluent samples and readings were noted in the digital display.

Total Suspended Solids (TSS)

Suspended solids of the conventional and enzymatic scoured effluent samples were estimated by centrifuged method. Fifty ml of conventional and enzymatic effluent samples was centrifuged and after centrifugation the residue was washed with distilled water, recentrifuged and the suspended solids in the centrifuge tubes were filtered through a pre-weighed What Man No.1 filter paper and then the filter paper was dried at 105°C. The increase in weight was equal to the amount of suspended solids. The suspended solids present in the sample were calculated by using the formula.

$$\text{Total suspended solids in mg/l} = \frac{\text{Initial weight of the silica dish}}{\text{Volume of the sample}} \times 1000$$

Total Dissolved Solids

Fifty ml of the conventional and enzymatic scoured effluent samples was taken in a pre-weighed silica dish and the sample was evaporated to dryness using water bath. After complete evaporation the final weight of the silica dish was taken. The total dissolved solids present in the samples were calculated by using the following formula.

$$\text{Total suspended solids in mg/l} = \frac{\text{Final weight} - \text{Intial weight of the silica dish}}{\text{Volume of the sample}} \times 1000$$

Biochemical Oxygen Demand (BOD)

Analyses of the BOD of conventional and enzymatic effluent scoured samples were carried by the procedure where the samples were collected in a BOD bottle. Two ml manganous sulfate solution was added followed by the addition of two ml alkali-iodide-oxide reagent. Stoppered the bottle without entertainment of air and mixed by inverting the bottle for ten times. Allowed the precipitate to settle completely which leave a clear supernatant liquid. Carefully removed the stopper and added two ml concentration Sulphuric acid by the sides of the bottle and mixed thoroughly Measure 203 ml of the solution from the bottle was transferred into a conical flask of 500 ml capacity. The sample was titrated immediately with 0.025N sodium thio sulfate solution by using starch as the indicator. For determination the BOD, use one set of sample dilution and dilution water found out the initial dissolved oxygen content, the other set of samples dilution water was kept in the BOD incubator at 200°C (in dark) for five days, determined the DO content of dilution water and sample dilutions, using the procedure.

$$DO5\ (mg/l) = \frac{8 \times 1000 \times N \times V}{V_1}$$

Where, N = Normality of sodium thiosulfate, V = Volume of thiosulfate, V_1 = Volume of sample, DO_5 = Dissolved Oxygen after five day, DO = Dissolved oxygen at initial, BOD (mg/l) = DO – DO_5

Chemical Oxygen Demand (COD)

Analyses of COD of the conventional and enzymatic scoured effluent samples were carried by the Procedure, where 50 ml of both effluent samples are taken in COD flask and five ml of potassium dichromate solution were added. And the solution was kept at 100°C for one hour. Five ml of potassium iodine solution and 10 ml of sulphuric acid were mixed in the samples. Then titrate the samples with sodium thiosulphate, disappeared of pale yellow colour. Then one ml of starch was added as indicator, and then the colour burns to blue. The samples are again titrated with sodium thiosulphate till blue disappears.

$$COD = \frac{8 \times C\ (B\text{-}A)}{V} \times 1000$$

Where C = Concentration of Titrant, A = Titrant of sample, B = Blank, V = Volume of sample

Total Hardness

Total hardness of the conventional and enzymatic scoured effluent samples were estimated by EDTA titrimetric method where about 50 ml of the conventional and enzymatic scoured effluent samples were taken in a conical flask and 2 ml of buffer solution and one ml of the inhibitor were added. After adding a pinch of Erichrome Black-T indicator it was titrated against standard

EDTA, till the wine red colour changed into blue. The volume of EDTA used was noted.

$$\text{Total hardness as } CaCo_3\,(mg/l) = \frac{\text{ml EDTA titrant} \times 1 \times 1000}{\text{Volume of sample in ml}}$$

Alkalinity

Phenolphthalein alkalinity and total alkalinity of the conventional and enzymatic effluent scoured samples were carried by the following procedure where about 50 ml of the conventional and enzymatic scoured effluent samples, which was diluted, was taken in a 250 ml conical flask. Added phenolphthalein indicator solution. If a pink coloration not occurred, it indicated nil phenolphthalein alkalinity. If a pink colour appeared then titrated with 0.02N sulphuric acid until the solutions becomes colourless. Add three drops of mixed indicator solution to the sample in which phenolphthalein alkalinity had been determined and titrated against 0.02N sulphuric acid to light pink.

Phenolphthalein alkalinity

$$\begin{array}{c}\text{Phenolph Thelein alkalinity} \\ \text{as } CaCo_3\,(mg/ml)\end{array} = \frac{\begin{array}{c}\text{ml of 0.02N } H_2SO_4 \text{ for} \\ \text{Phenolphthalein end point} \times 1 \times 1000\end{array}}{\text{ml sample taken for titration}}$$

Total alkanity

$$\begin{array}{c}\text{Total alkalinity} \\ \text{as } CaCo_3\,(mg/ml)\end{array} = \frac{\begin{array}{c}\text{ml of 0.02N } H_2SO_4 \text{ for} \\ \text{total alkalinity end point} \times 1 \times 1000\end{array}}{\text{ml sample taken for titration}}$$

Results and Discussion

The results of this study are presented and discussed under the following headings.

Identification of Cellulase Activity and optimization

The activity of cellulase enzyme from bagasse was noted the absorbency of 1.07 nm at 540 nm. The optimization of time, pH and temperature for effective reaction of cellulase enzyme from sugarcane waste namely bagasse is presented in Table 1

Table 1 Optimization of Time, Ph and Temperature for Cellulase Activity

S. No	Particulars	Absorbency at 540 nm
1.	**Time (minutes)**	
	15	0.46
	30	0.51
	45	0.54
	60	0.64
	75	0.54
2.	**pH**	
	5.0	0.12
	6.0	0.37
	7.5	1.22
	8.0	1.45
	9.0	0.75
3.	**Temperature (°C)**	
	20	0.20
	30	0.38
	40	0.21
	50	0.41
	60	0.22

Hence it could be concluded that the absorbency rate of cellulase was highly effective at time of 60 minutes, pH of 8 and temperature of 50°C.

Optimization of Enzyme for Scouring

Optimization of enzyme for proportion, time, pH and temperature are presented and discussed under.

Table 2 Optimization of Enzyme Proportion for Scouring

S. No	Proportion (Enzyme: water)	Weight			
		Original Yarn (grams)	scoured yarn (grams)	Loss value (grams)	Loss (%)
1.	1:0	1.00	0.841	0.16	16
2.	1:1	1.00	0.851	0.15	15
3.	1:2	1.00	0.854	0.15	16
4.	2:1	1.00	0.841	0.15	16

Optimization of Enzyme Proportion for Scouring

The effect of different proportion of enzyme to water on scouring of yarn samples is given in Table 2.

Hence the proportion of enzyme to water of 1:1 was considered for further study.

Optimization of Incubation Time for Scouring

The effect of different incubation time of scouring of yarn is given in Table 3.

Table 3 Optimization of Incubation Time for Scouring

S. No	Indication time (min)	Weight			
		Original Yarn (grams)	Scoured yarn (grams)	Loss value (grams)	Loss (%)
1.	15	1.00	0.86	0.14	14
2.	30	1.00	0.87	0.13	13
3.	45	1.00	0.86	0.14	14
4.	60	1.00	0.88	0.12	12
5.	75	1.00	0.84	0.16	16

From Table III, it seen that the time 60 minutes was considered for further study as it showed the best result.

Optimization of Temperature for Scouring

The effect of different temperature on scouring of yarn is given in Table 4.

Table 4 Optimization of Temperature for Scouring

S. No	Temperature (°C)	Weight			
		Original Yarn (grams)	Scoured yarn (grams)	Loss value (grams)	Loss (%)
1.	20	1.00	0.85	0.15	15
2.	30	1.00	0.86	0.14	14
3.	40	1.00	0.87	0.13	13
4.	50	1.00	0.89	0.11	11
5.	60	1.00	0.82	0.18	18

Table IV, it seen The maximum loss of weight was observed at temperature of 60°C. Thus the temperature of 50°C gave the best result.

Optimization of pH for Scouring

The effect of different pH on scouring of yarn is given in Table 5

Table 5 Optimization of pH for Scouring

S. No	pH	Weight			
		Original yarn (grams)	Scoured yarn (grams)	Loss value (grams)	Loss (%)
1.	5.0	1.00	0.86	0.14	14
2.	6.0	1.00	0.88	0.12	12
3.	7.5	1.00	0.89	0.11	11
4.	8.0	1.00	0.91	0.09	9
5.	9.0	1.00	0.88	0.12	12

From the V, it seen that the pH 8 gave the best result. Thus the optimized parameters for enzymatic scouring is proportion – 1:1, time – 60 minutes, temperature – 50°c and ph – 8.

Evaluation

The evaluation involves the following steps.

Analysis of Conventional and Enzymatic Scoured Effluent

Analyses of conventional and enzymatic scoured effluents for their physico-chemical parameters are given in Table 6.

From table VI, it is clear that the enzymatic effluent showed drastic difference in pH, TDS, TSS, BOD, COD, total hardness, phenolphthalein alkalinity, and total alkalinity over the conventional effluent thereby expressing the discharge of water with lesser pollutants which may be ecofriendly.

Cost Estimation

The cost was estimated for scouring of one kg of yarn for both conventional and enzymatic methods for comparison. The expenditure incurred for enzymatic scouring of one Kg of sisal yarn was only Rs. 2, whereas the conventional method showed an expense of Rs. 11.59 for the same. About 82.74 per cent difference of reduction in cost was observed in natural scouring

Table 6 Analysis of Conventional and Enzymatic Scoured Effluent

S. No	Parameters	Effluent		Difference Percentage
		Conventional	Enzymatic	
1.	pH	12.5	7.8	37.6
2.	Total suspended solids (TSS) mg/l	5600	2000	64
3.	Total dissolved solids (TDS) mg/l	4880	2200	55
4.	BOD (Biological oxygen demand) mg/l	36.4	32.4	10.9
5.	COD (Chemical oxygen demand) mg/l	12.8	2.8	78.2
6.	Total hardness mg/l	250	72	71
7.	Phenolphthalein alkalinity (as $caco_3$) mg/l	600	12	98
8.	Total alkalinity (as $caco_3$). mg/l	720	64	91

process. The use of enzymes as a biotechnological process can significantly reduce the emission of chemicals and can also reduce the process cost (Sallat et al., 2010). The water consumption for conventional scouring process was higher of about 6 litres than the enzymatic scouring process as it required only 3 litres of water. Hence it could be concluded that the enzymatic scouring process using bagasse was noted to be more economical and water saving than the conventional method of scouring.

Conclusion

The enzymatic effluent showed drastic difference in Physico chemical prperties over the conventional effluent thereby expressing the discharge of water with lesser pollutants which may be ecofriendly. The enzymatic scouring process using bagasse was noted to be more economical than the conventional method of scouring. Hence the enzymatic scouring using bagasse is ecofriendly, cost effective, water saving and highly advantageous.

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EXPLORATION OF STRENGTH PROPERTIES IN DIAGONAL FLUTE CORRUGATED BOARD

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ABSTRACT

The ultimate aim of any packaging is to deliver the product from the manufacturer to the customer in safe condition. The material used in packaging plays a major role. There are different types of materials used in packaging such as corrugation, plastics films, cans, etc,. In this work corrugation board is used as packaging materials which is of low cost when compared with other packaging materials. Corrugated boards are available in different flute profile and combinations. The Vertical flute profile corrugated board is normally used in packaging application. The good physical characteristics enable a wide range of applications due to the flute profiles and their combinations. As a result the demand for corrugated board shows an annual increase. The aim of this work is to make diagonal flute corrugated board of different gsm and the strength related properties like burst strength, edge crush test, ring crush test, grammage and cob test are tested and compared with existing vertical flute corrugated board.

Keywords: Packaging materials, corrugated board, corrugation profile, Vertical flute, Diagonal flute.

Introduction

Packaging plays a very important role in the country's economy Corrugated Board technically called Corrugated Fibre Board are the most widely used in packaging materials for the shipping and handling of food and non-food materials. It has the highest volume of any single packaging materials in the world and represents more than 80 per cent of the volume of all paper-based packaging materials. Corrugated fibreboard, 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, low cost, ease of assembly and disassembly, good sealing performance, certain cushioning and anti-vibration ability and easy recovery, though corrugated board is the most highly recyclable packaging material. The board find their number of applications in the packaging of chemicals and drugs, tobacco, engineering goods, canned & bottled goods, food products, lamps, electrical appliances, glassware etc...

In fact, today, packaging is as important as the contents. Corrugated boards were first produced in India in early fifties. Since then the production of corrugated boards has increased steadily. Corrugated boxes have replaced wooden boxes & crates in many applications. Today, about 80 per cent of all shipments in the world are being made in fibre board boxes. In India, about 60 per cent of the packaging is being done with corrugated fibre board boxes.

Corrugated material comprised of two main components: a liner and a wavy fluted material. The fluted material is inserted between two liners which gives strength to the corrugated material. The liners and fluted material are then glued, pressed, cut and scored on a corrugator. Packaging material formed by gluing one or more fluted sheets of paperboard (corrugating medium) to one or more flat sheets (called facings) of linerboard. Corrugated Boxes are popular because of their strength and can be produced in high volumes very quickly and easily.

A corrugator is a set of machines in line, designed to bring together liner and medium to form single, double or triple-wall board. This operation is achieved in a continuous process; the reels of liner and medium are fed into the corrugator. The medium is conditioned with heat and steam and fed between large corrugating rolls forming fluting. In the Single Facer, starch adhesive is applied to the tips of the flutes on one side and the inner liner is glued to the fluting. The fluting with one liner attached to it is called single-face web and travels along the machine towards the Double Backer where the single-face web is bonded to the outer liner and forms corrugated board. The corrugated board is then cut and stacked.

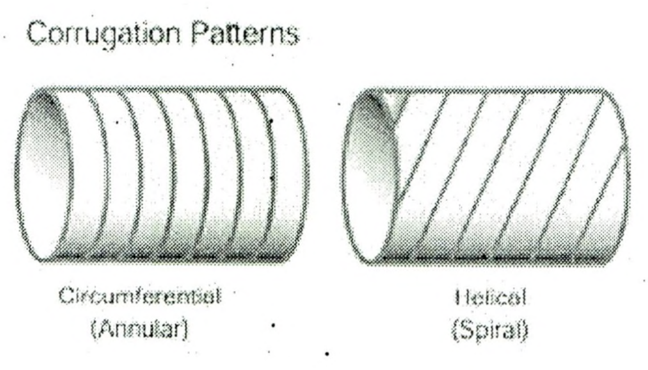
Corrugated board is mainly used in packaging and can be customized entirely for its purpose. If a moisture-repellent membrane is applied on the surface the box can contain wet products. In the fish industries this is useful, because the box is only used once and does not need to be washed or transported back after delivery. Instead, the box can be recycled immediately after it has served its purpose. An example of a new type of application is pallets, on which goods can be stapled.

Corrugated board is the preferred packaging material for many products, because it is durable, versatile, lightweight, sustainable, environmentally responsible, made from a renewable resource, customizable, protective, graphically appealing and cost-effective. It is a high-tech engineered material with ongoing R&D programs continuously improving such characteristics as strength-to-weight ratios, printability, moisture barriers and recyclability. There are thousands of possible combinations of board types, flute sizes, basis weight, adhesives, treatment and coatings, offering an infinite amount of customizability.

Experimental design and methods

To prepare the diagonal flute corrugated board with different gsm i.e., Changing the direction of flute profile (spiral) towards 45 degree right or left side to the section, by using single wall of B-flute and C-flute, Instead of existing vertical flute profile (annular). This is mainly to improve the stacking strength and in-take of air into the flute layer is gradually reduced to avoid any stretching or tearing of the fibres of the paper during the operation of diagonal corrugation. Corrugated boards are prone to absorb water vapour from the environment, especially when stored under the high humidity conditions or when coming into contact with high-moisture food materials such as fresh agriculture produce. Absorption of moisture reduces physical and mechanical strength of the corrugated board, causing corruption of boxes during storage and distribution. Surface treatment such as sizing and coating are usually used to improve physical strength as well as water barrier properties.

Figure 1 (a). Model of Vertical Flute Profile (b). Model of Diagonal Flute Profile



Virgin Paper and Recycled Paper

Virgin paper, produced from wood pulp, which is called Kraft Liner. Corrugated board component (liner and medium) can be made from virgin and recycled wood fibre, the use of the latter has increased because it is considerably cheaper, minimises wastage. Despite corrugated board having high stiffness and strength for low materials mass, its mechanical properties and structural performance tend to degrade with changes in relative humidity and temperature. Kraft liner is usually used on the outside of the corrugated for more strength and rigid.

Normal virgin pulp can contain up to 20% of pre-consumer waste, typically from the paper machine itself. Virgin paper sheet components performed better in compressive performance than recycled components in both direction and at both relative humidities.

Two generic, three-layered corrugated board referred to as "virgin board" and "recycled board" and their components paper sheet were obtained in an undamaged and uncoated condition from TGI Packaging ltd,. Virgin board components were designed "liner-virgin", "medium-mixed, or "liner-mixed" and recycled board components "liner-recycled", "medium-recycled". Specification for each board type and components are given in table 1. Starch based adhesive was used for both corrugated board.

This study has shown that the compressive strength and modulus of elasticity of commercial corrugated paperboard composed of virgin and recycled fibre were both higher in MD than in CD and decreased as relative humidity increased. These results indicate that water-absorption potential in components made of virgin fibre is greater than that of components composed of recycled fibres.

Corrugated Board with Recycled Paper

These types of failure were commonly observed at the liner-medium interface and in linerboard. In the failure zone of corrugated board containing recycled components, bulkiness and random distribution of delaminating fibre layers was attributed to weakness of the inter-fibre bond which ruptured under a low load. From the study, it can be concluded that the strength of the recycled materials is lower than that of virgin materials. Because of the following factors,

Recolouring

When ink is removed from paper during the recycling process, some may remain in its fibres and discolour the new product. Scientists can sometimes separate the ink from the paper, by adding chemicals like bleach or passing air through the pulp of the paper.

Contamination

Paper that has been contaminated by hazardous or bodily fluids cannot be used in recycling. It is critical to keep paper separated from other recyclable materials, such as cans and plastics that may contain traces of mold.

Adhesives

Some types of paper resist the recycling process, such as address labels, sticky notes and stamps. Although these formats will break down into smaller pieces, they will not completely dissolve and end up weakening the new products formed.

There are some other problems in recycled paper less strength, labels and tape not sticking, faded print, warping, complete package failure in high humid environments. Paper fibres can be reused from four to nine times depending on the paper grade and many time paper has been reused so that the recycled paper is poor in quality

Figure 2 A Sample Micro View of Recycled Paper and Virgin Paper

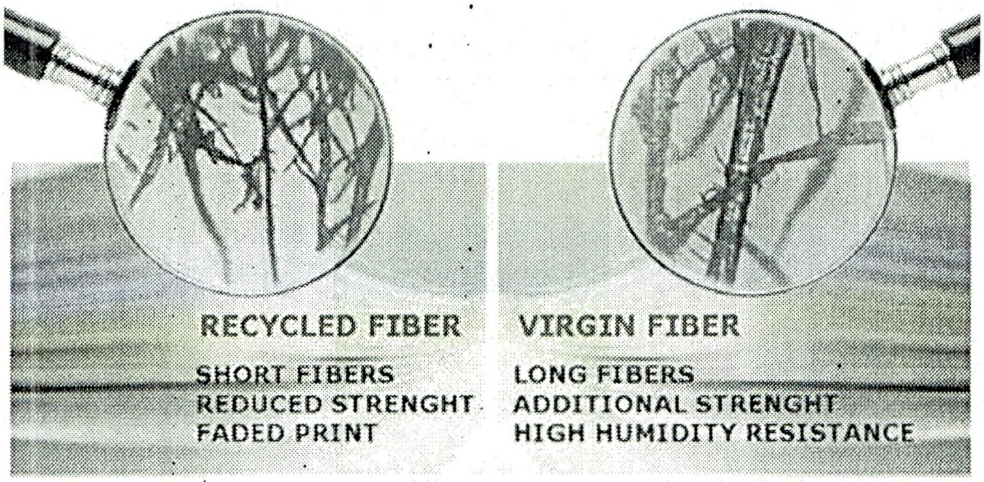


Table 1 Materials and Configuration of Virgin Board and Recycled Board

Board type	Components	Component grammage (g/m^2)	Sample designation
Virgin board c-flute	Outside liner	200	"Liner-virgin"
	medium	160	"Medium-mixed"
	Inside liner	200	"Liner-mixed"
Recycled board c-flute	Outside liner	180	"Liner-recycled"
	medium	140	"Medium-recycled"
	Inside liner	180	"Liner-recycled"

Table 2 Average Compressive Strength, Elastic Modulus of Virgin Board and Recycled Board at 50% and 90% Rh. The Error Margin is +/-5%

Board type	**Elastic modulus (mpa)**		**Compressive strength (mpa)**	
	50%	**90%**	**50%**	**90%**
Virgin board	1032(46)	616(30)	12.7(0.4)	(6.6(0.6)
Recycled board	829(10)	448(25)	8.7(0.3)	4.1(0.2)

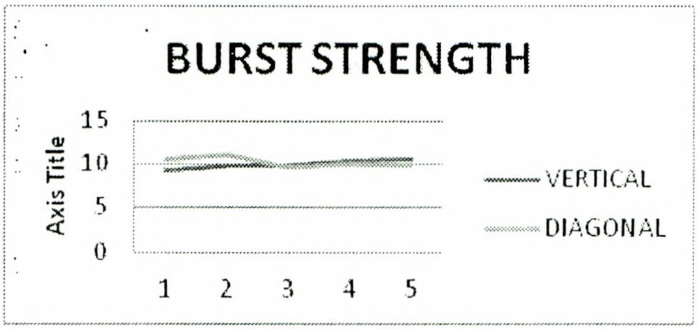
Results and discussion

Bursting strength

All the corrugated board were cut (100mm x 100mm) for proper testing and conditioned at room temperature. Test specimens are held between two annular clamps under sufficient pressure to minimize slippage. The upper clamping surface which is in contact with the test specimen has a continuous spiral grooves. A circular diaphragm of pure gum rubber is clamped between the lower clamping plate and pressure cylinder so that before the diaphragm is stretched by pressure underneath it the centre of its upper surface is below the plane of the clamping surface. The equipment is fitted with a motor driven cam mechanism, which increase fluid displacement on the lower side of the diaphragm at a specified rate. The equipment is also automatically brings down the pressure and stop the motor on completion of the test cycle. Test samples was measured using the McSparr bursting strength tester digital Eco-model in TGI Packaging Ltd, Five measurements were taken on each specimen in vertical and diagonal flute corrugated board, then mean values were reported.

Table 3 Average Material Data for Vertical and Diagonal C- Flute Corrugated Board

Grammage (g/m^2)	**Vertical C-Flute (Kn/m)**	**BS (Kn/m)**	**Diagonal C-Flute (Kn/m)**	**BS (Kn/m)**
	9.21		10.58	
	9.85		11.13	
200	9.85	9.96	9.67	10.25
	10.39		10.03	
	10.49		9.85	

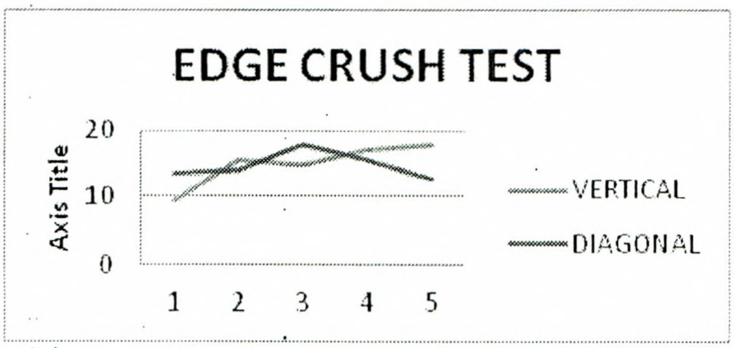


Edge crush test

All the samples were cut (380mm x 510mm) using an edge crush cutter. Samples were then divided into two groups: one of the samples was cut diagonally and the other samples in vertical. Each sample was placed in the crush tester and the edge crush strength was measured using a computer-controlled advanced testing system (model linux machine incorporation) at least five specimen for each board sample were tested, and their mean values were reported.

Table 4 Average Material Data for Vertical and Diagonal C- Flute Corrugated Board

Grammage (g/m^2)	Vertical C-Flute (Kn/m)	ECT (Kn/m)	Diagonal C-Flute (Kn/m)	ECT (Kn/m)
	9.39		13.49	
	15.41		13.95	
200	14.87	14.88	17.97	14.72
	16.96		15.50	
	17.78		12.68	

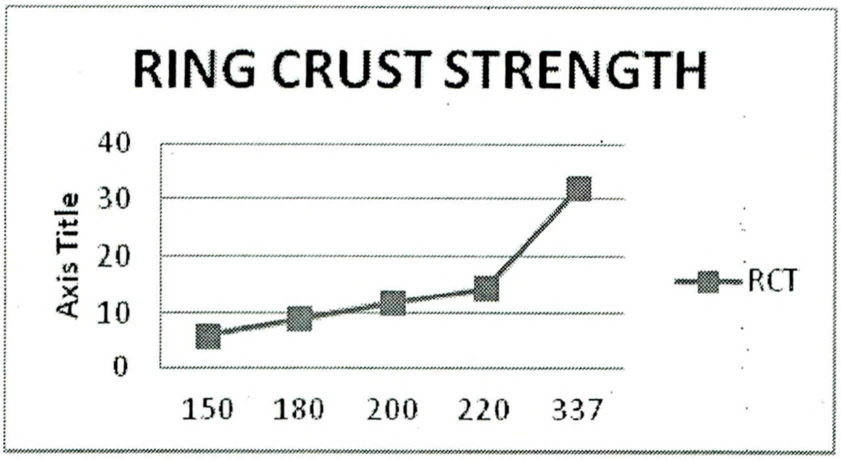


Ring crush test

All paper sample were cut into strip (12mm x 153mm) using a ring crush cutter. Each strip of samples was placed in the crush tester and the ring crush strength was measured using a computer-controlled testing system (model linux machine incorporation) at room temperature in according with TAPPI Test method T822. A 500-newton (N) load cell was used, and the cross-head speed was 50mm/min. five samples were tested, and their mean values were reported.

Table 5 Average Material Data for Vertical And Diagonal C-Flute Corrugated Board

Grammage (g/m^2)	Burst Factor	samples (Kgf)	mean (Kgf)
150	24	5.3 6.2 5.9	6
180	22	9.4 8.4 9.8	9
200	24	11.3 12.2 13.0	12
220	22	15.1 15.6 13.1	14.5
337	46	32.5 31.2 33.1	32



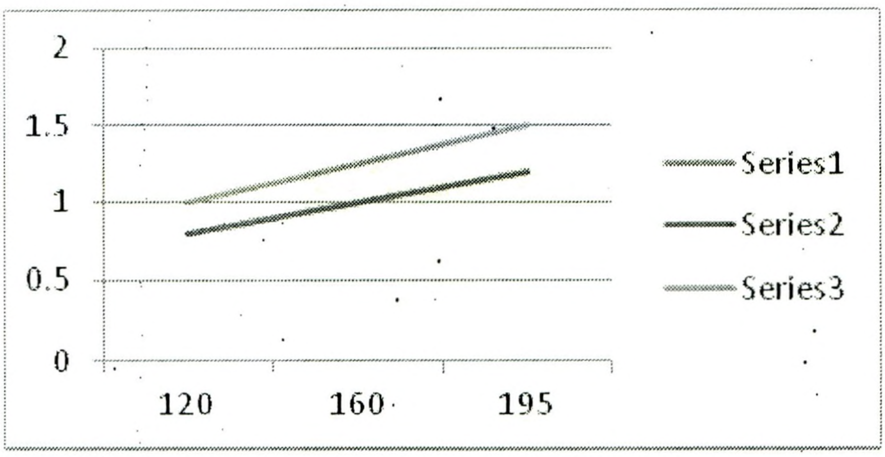
Flat crush test

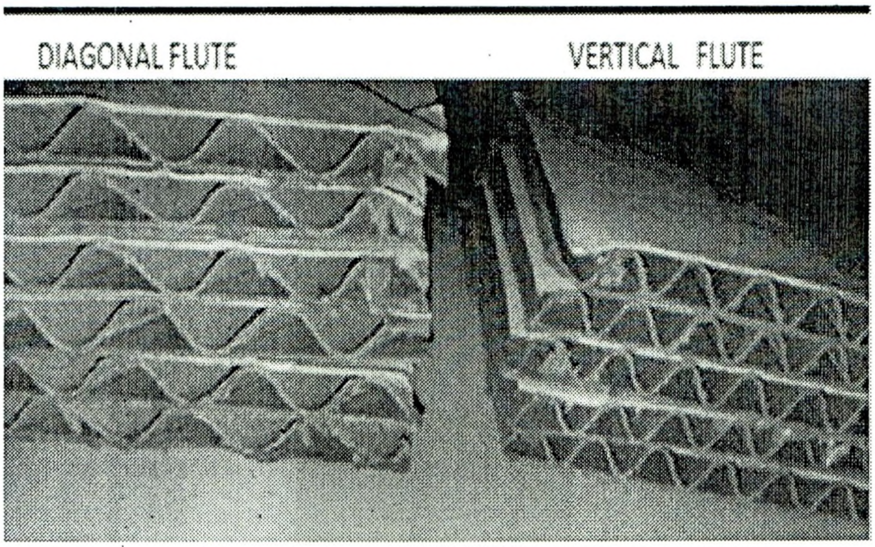
The flat crush test is a measure of the flute rigidity of the corrugated board. The test specimen were cut (350mm x 510mm) as same as edge crush test.

In flat crush test a specimen is place horizontal to its section to determine the flute strength and stiffness for both vertical flute corrugated board and diagonal flute corrugated board. This strength was measured using computer-controlled testing system (model linux machine incorporation) TGI Packaging ltd; at least three specimens for each board were tested, and then mean values were reported.

Table 6 Average Material Data for Vertical and Diagonal C- Flute Corrugated Board

Grammage (g/m²)	**Burst factor (BF)**	**Vertical C-flute**	**Diagonal C-flute**
120	14	0.80	1.00
160	20	1.00	1.25
195	24	1.20	1.50





Conclusion

The vertical flute profile corrugated board is mostly used in packaging industries because of its strength and low cost. To find an alternative to vertical flute corrugated board, diagonal flute corrugated board is made. The strength related properties such as bursting strength, edge crush test, flat crush test, ring crush test, grammage test and cob test is tested on different gsm of diagonal flute corrugated and vertical flute corrugated board and results were compared. On comparison it was concluded that 200 gsm diagonal flute profile shows the best strength and stability. Cost analysis was also made for diagonal flute with vertical flute profile. The cost analysis also shows that diagonal flute profile is economic than vertical flute profile. The strength related properties can be improved by applying coating or laminating the diagonal flute corrugated board. Further studies can also be made on five ply corrugated board which can increase the rigidity and barrier properties of the board that can find an application in bulk packaging.

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